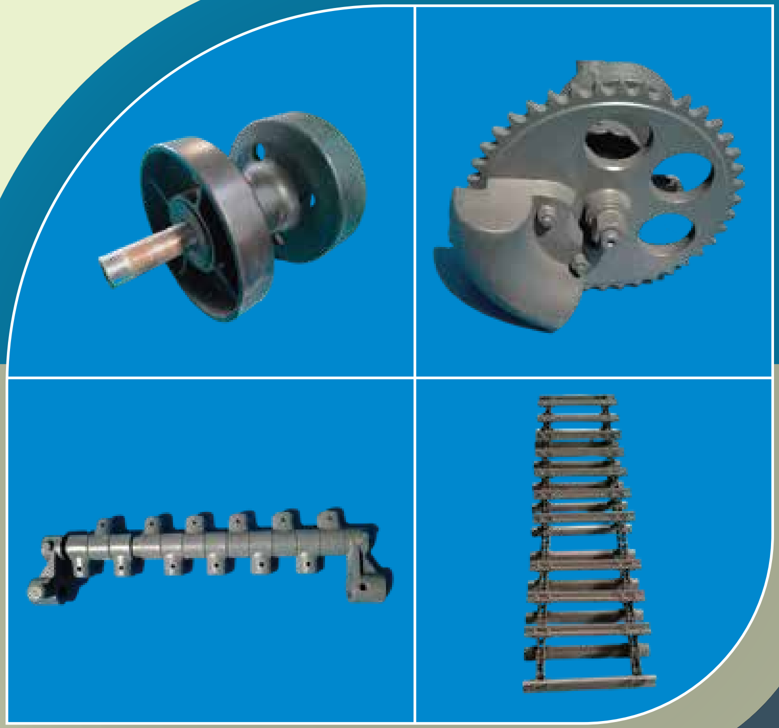
MANUFACTURING SPARE PARTS OF COMBINE HARVESTER



AKM Saiful Islam
Md. Rizwanur Rahman

Bangladesh Rice Research Institute

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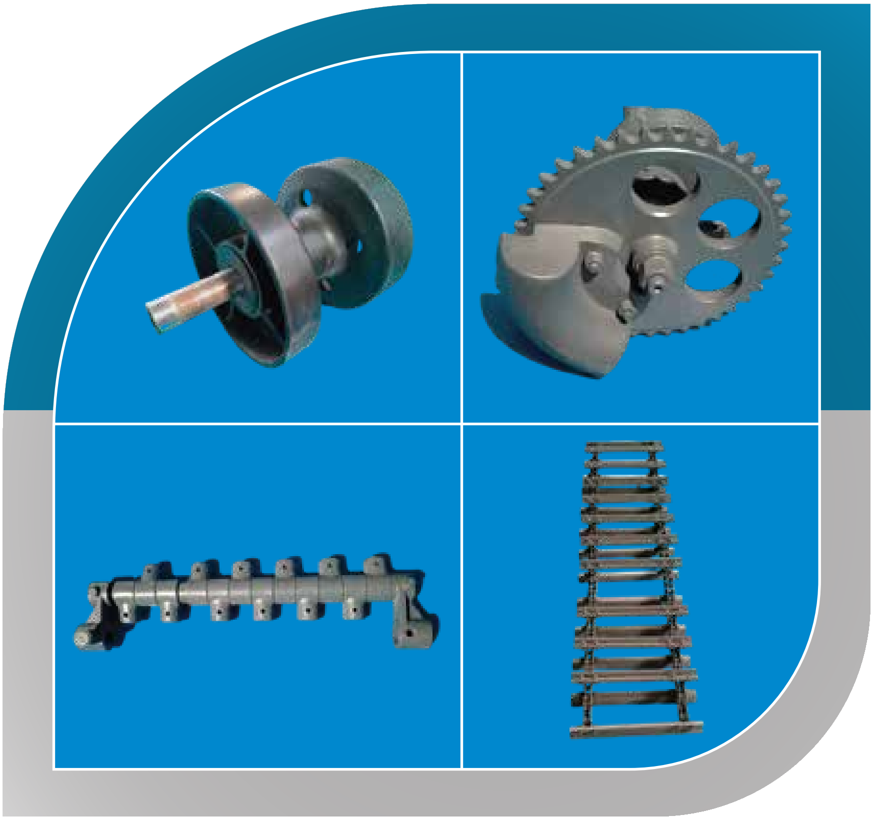

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Preface

The performance and reliability of harvester spare parts are crucial for ensuring smooth farming operations. This book delves into the manufacturing processes of fast-moving spare parts for combine harvesters, addressing the challenges and solutions necessary for high-quality production. A quantitative analysis examines the replacement times of these spare parts in combine harvesters across Bangladesh. A cross-sectional study was conducted, gathering data from 51 combine harvesters of 9 different brands across various districts. Each production stage, from raw material selection to precision machining and quality control, is meticulously reviewed. Key challenges identified include the availability of skilled machine operators, maintaining consistent material quality, and achieving precise dimensions. Structured into sections on fast-moving spare parts, manufacturing strategy, manufacturing models, manufacturing processes, manufacturing spare parts, quality control, and manufacturing challenges, the book begins with a historical overview of parts manufacturing. It then explores the essential processes and technologies for achieving precision and reliability in spare parts production. Additionally, the book discusses the benefits and complexities of prototyping, with a focus on testing and validation processes. The book also addresses ongoing manufacturing challenges, offering strategies and best practices derived from real-world experiences and expert insights. This guide is an invaluable resource for manufacturers, engineers, and quality control professionals seeking to enhance production standards for harvester spare parts and advance agricultural machinery and global farming efficiency. The book may have some linguistic inconsistencies and unintentional spelling errors. We appreciate reader's understanding in this matter. Given the current demands, it is crucial to implement necessary changes, revisions, and improvements. We welcome constructive feedback and reasonable suggestions from all stakeholders.

Director General
Bangladesh Rice Research Institute

Foreword

The reliability and performance of spare parts of combine harvester are fundamental to ensuring the efficiency of farming operations. "Manufacturing spare parts of combine harvester" authored by Dr. AKM Saiful Islam and Md. Rizwanur Rahman, emerges as a crucial resource in this domain, providing an in-depth examination of the manufacturing processes associated with these vital components. Dr. Islam and Md. Rahman address the complexities involved in the manufacturing fast-moving spare parts of combine harvester, offering practical solutions to the challenges faced by manufacturers. The authors present a comprehensive study, beginning with an exploration of the historical evolution of parts manufacturing and progressing through the intricate details of manufacturing strategy, models, and processes. Their approach includes a quantitative analysis of spare parts replacement times in Bangladesh, gathered from 51 combine harvesters of nine different brands. The book is structured to guide readers through each stage of the manufacturing process, from initial design and prototyping to final assembly and quality assurance. Manufacturing spare parts of combine harvester is an essential guide for the manufacturers, engineers, and quality control professionals involved in agricultural machinery production. Dr. Islam and Md. Rahman have provided a resource that not only enhances understanding but also contributes to the advancement of manufacturing standards and the improvement of global farming efficiency. I wish the authors continued success in writing this valuable book.

(Dr. Mohammad Khalequzzaman)

About the author

Dr. AKM Saiful Islam graduated from the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh and received chancellor award for achieving first position in graduate course. Dr. Islam obtained MS degree from the same university in 1996. He completed a postgraduate diploma course from Silsoe College, UK in 1997. DR Islam obtained PhD in Agricultural Engineering from the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh in 2012. He started his career as a Scientific Officer in Farm Machinery and Postharvest Technology Division of Bangladesh Rice Research Institute in 1998. Dr. Islam developed training manual for seedling raising techniques, BRRI weeder, rice-wheat reaper, BRRI open drum thresher, BRRI rice-wheat thresher, BRRI panicle thresher, BRRI whole feed combine harvester. He is involved in the invention and development of mechanized seedling raising techniques, BRRI seed sower, BRRI auto seed sower, BRRI rice transplanter, BRRI semi automatic rice transplanter, BRRI solar light trap, BRRI urea super granular fertilizer, Straw chapper, BRRI power weeder, BRRI rice-wheat reaper, BRRI rice-wheat thresher, BRRI panicle thresher, BRRI whole feed combine harvester, BRRI head feed combine harvester, BRRI straw rope maker, BRRI air blow rice mill, BRRI compact rice mill, BRRI mini rice huller and BRRI applicator. At present, he is working as a Chief Scientific Officer and project director of the project "Strengthening Farm Machinery Research Activity for Mechanized Rice Cultivation (SFMRA)”.

About the author

Md. Rizwanur Rahman brings over nine years of experience in the agricultural machinery business development sector, specializing in sales and marketing within leading corporate houses in Bangladesh. With a background in agricultural engineering, Rahman has developed expertise in machinery, business models, market research, team management, project collaborations, sales lead generation, corporate communications, and stakeholder management. Rahman began his career as a Business Development Executive at ACI Motors Limited, where he contributed to developing business models and sourcing new products. He then served as Assistant Manager - Escorts at IFAD Autos Limited, managing sales and marketing campaigns and monitoring market trends. Currently, as Deputy Manager at Abedin Equipment Limited, Rahman oversees sales and marketing strategies, customer engagement, and product feasibility tests. Rahman holds a Master's degree in Disaster Management from the University of Dhaka and a Bachelor of Science in Agricultural Engineering from Hajee Mohammad Danesh Science and Technology University, Dinajpur with sound academic records. His research includes a notable study on the entrepreneurial opportunities of mechanical rice transplanting services for smallholder farmers in Bangladesh. Rahman's dedication and expertise make him a significant contributor to the field of agricultural mechanization.

About the project

The project "Strengthening Farm Machinery Research Activity for Mechanized Rice Cultivation" was approved for implementation from July 2019 to June 2025 at an estimated cost of Tk 4400 Lakhs. The project is being implemented by the Farm Machinery and Postharvest Technology Division of Bangladesh Rice Research Institute under the Ministry of Agriculture in 12 upazilas of 12 districts of seven divisions of the country. One of the main objectives of the project is to strengthen farm machinery research activities for sustainable rice cultivation. The specific objectives of the project are (a) Developing nine agricultural machinery and technologies suitable to the socio-economic condition of the farmers: i.e. rice transplanter, mini combine harvester, power weeder, reaper binder, compact rice mills, rice transplanter-cum-fertilizer, straw rope maker, seed sower machines, post-harvest management and renewable energy (solar and briquette machines); (b) Further development of the machinery by collecting feedback from the stake shoulder through 324 adaptive trials; (c) Providing hands-on training to 6480 machine operators, farmers, mechanics and service providers and 200 local agricultural machinery manufacturers and extension officers/workers to increase their skills on modern agricultural machinery; (d) Capacity building of 20 scientists and 20 workshop workers for the research on modern agricultural machinery through higher education and training; and (e) Modernization of exisiting farm machinery research lab-cum-workshop. The project activities are a) Developing nine agricultural machinery and post-harvest technologies suitable for sustainable rice production i.e. rice transplanter, combine harvester, power weeder, reaper binder, compact rice mill, rice transplanter-cum-fertilizer, straw rope maker, seed sower machine, post-harvest management and renewable energy (solar and briquette machines); b) To procure prototypes from abroad and preparing indigenously adapted machines through reverse engineering and applied research; c) To develop machine according to the feedback obtained through practical field tests; d) To conduct 324 two-day residential hands-on training on seedling raising techniques, operation, repair and maintenance of rice transplanters for mechanized rice transplanting; e) To sensitize 6480 farmers, machine operators, mechanics, farmer groups/farmers associations, service providers about utility of agricultural machinery, operating techniques, repair and maintenance through 324 practical field tests of BRRI developed modern machinery; f) To publish the training schedule and names of the trainees in the form of a database on the BRRI web site to maintain transparency and accountability in the training program and to avoid duplicity in the selection of trainees; g) Developing 10 skilled scientific manpower through three months of overseas training; h) To organize short term (7-10 days) training of 10 scientists in agricultural machinery manufacturing countries; j) Conducting 10 trainings of three days duration on transfer of machinery technology to the farm machinery manufacturers/extension officers/workers; j) To enhance quality research skills by establishing machine testing lab (375 square meters) with modern equipment for machinery quality control; k) Develop a commercial approach to agriculture through limited long-term use of farm machinery and rental machinery service providers in the project area; l) Building co-operation between researchers, extension workers, manufacturers and farmers; d) Development of 2,500 cubic meter research field/plot for head office research; d) Vertical extension (450 square meters) of farm machinery lab cum office building at head office; n) Construction of machinery display cum ware house (150 sq m to 750 sq m in 5 Regional stations) for display room at BRRI Regional stations; (v) Skilling of 20 workshop workers through training in machine prototyping, repair and maintenance; d) To provide necessary technical assistance to the entrepreneurs and machinery manufacturing institutions/factories serving through the Department of Agriculture Extension for ensuring the use of sustainable agricultural machinery at the field level. Recruiting 11 persons (one office assistant cum computer programmer, two bench mechanics, two lathe-operators, two tin smiths, two hammer men and two drivers) through outsourcing to support the project director in project execution. Scientists of FMPHT division, research assistants, Accountant of Accounts division and staff of Planning and Evaluation Division are working on the project as additional responsibilities.

Content

Acronyms and Abbreviations

AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials
BAU	Bangladesh Agricultural University
BCC	Body Centered Cubic
BRRI	Bangladesh Rice Research Institute
C	Carbon
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CBN	Cubic Boron Nitride
CI	Cast Iron
CMM	Coordinate Measuring Machine
CNC	Computer Numerical Control
Cr	Chromium
DAE	Department of Agricultural Extension
EDM	Electrical Discharge Machine
FCC	Face Centered Cubic
GMAW	Gas Metal Arc Welding
HCP	Hexagonal close Packed
HIP	Hot Isostatic Pressing
HSLA	High Strength Low Alloy
HST	Hydrostatic Transmission
HST	Hydrostatic Transmission
MIG	Metal Inert Gas
Mn	Manganese
Mo	Molybdenum
MoA	Ministry of Agriculture
MS	Mild Steel
NDT	Non-Destructive Test
OBM	Original Brand Manufacturer
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
OH	Operating Hours
PVD	Physical Vapor Deposition
RH	Replacement Hours
SAE	Society of Automotive Engineers
SFMRA	Strengthening Farm Machinery Research Activity for Mechanized Rice Cultivation
SS	Stainless Steel
TIG	Tungsten Inert Gas
US	United States
V	Vanadium
XRF	X-ray Fluorescence

Chapter One

Introduction

Combine harvesters are vital agricultural machines that revolutionized the harvesting process by automating the tasks of reaping, threshing, and winnowing crops in a single operation. These complex machines consist of numerous components and parts, and like any mechanical equipment, they may require maintenance and replacement of spare parts over time. The manufacturing of spare parts for combine harvesters plays a crucial role in ensuring the longevity, efficiency, and productivity of these essential agricultural tools. A combine harvester comprises various components such as the cutting platform, header, threshing mechanism, grain tank, and other mechanical and hydraulic systems. Each of these components consists of numerous parts, ranging from gears and bearings to belts and blades. Continuous usage and exposure to harsh agricultural environments subject combine harvester parts to wear and tear. The need for replacement parts arises due to factors like friction, corrosion, and stress, leading to a decline in performance and potential breakdowns. The manufacturing of spare parts for combine harvesters involves a series of steps. Design engineers use advanced CAD software to create precise blueprints, ensuring compatibility and adherence to specifications. Materials are then carefully selected based on durability, strength, and resistance to environmental factors. Machining and fabrication processes include CNC machining, casting, forging, and welding, depending on the type of part being produced. Quality control measures are integrated at every stage to ensure that the spare parts meet industry standards and specifications. Some spare parts may require customization to suit specific combine harvester models or address unique agricultural challenges. Manufacturers often invest in research and development to introduce innovative solutions that enhance the performance and efficiency of combine harvesters. The manufacturing process is closely tied to an efficient supply chain to ensure the availability of spare parts when needed. Manufacturers often work closely with dealerships and distributors to streamline the distribution process, providing farmers with easy access to replacement parts. The manufacturing of spare parts for combine harvesters contributes significantly to the economy. It supports a network of suppliers, manufacturers, and distributors, creating jobs and fostering economic growth in both local and global markets. Sustainable manufacturing practices, including the use of recyclable materials and energy-efficient processes, are increasingly important in the production of combine harvester spare parts. Manufacturers are exploring eco-friendly alternatives to reduce the environmental impact of their operations.

Bangladesh, recognized as the third-largest rice-producing country globally, heavily relies on combine harvesters to efficiently harvest its vast rice fields. With approximately 10000 combine harvesters in operation, the demand for these agricultural machines and their spare parts is significant. The country's reliance on imports for both complete harvesters and spare parts has posed challenges, particularly exacerbated by the 2023 US dollar crisis, which strained import capacities. In response to these challenges, ministry of agriculture initiated the Strengthening Farm Machinery Research Activity for Mechanized Rice Cultivation (SFMRA) project through the Bangladesh Rice Research Institute. This project aims to manufacture head feed (Fig. 1) and full feed (Fig. 2) combine harvesters domestically to address the import cost reduction. SFMRA represents a strategic shift towards achieving greater autonomy and sustainability in the agricultural machinery sector. The local manufacturing of harvester and its parts is integral to the SFMRA project's objectives. By producing essential parts domestically, Bangladesh seeks to mitigate the risks associated with international currency fluctuations and supply chain disruptions. Localized production offers the potential for cost savings and enhanced accessibility to spare parts for farmers across the country. The project aligns with broader national objectives of promoting industrialization, fostering technological advancement, and ensuring food security. It not only stimulates economic growth through the creation of employment opportunities but also contributes to the development of a robust ecosystem for agricultural machinery production and innovation within the country.

In conjunction with the SFMRA project, Bangladesh emphasizes the importance of local manufacturing for spare parts to elevate the resilience of the agricultural sector. The initiative signifies a proactive approach to address challenges posed by external economic factors and import dependencies. It represents a crucial step towards building a more resilient and self-sufficient agricultural machinery sector, ultimately supporting the sustainable development of Bangladesh's agricultural economy.

Fig. 1: BRRI whole feed combine harvester

Fig. 2: BRRI head feed combine harvester

Importers of combine harvester

Bangladesh's rice harvester market size reflects a substantial reliance on imported machinery, as evidenced by the importers. As of 2023, a total of 11 major companies were identified as importers of combine harvesters in Bangladesh (Table 1). The overall import volume amounted to 9,704 units, consisting of 5,600 head feed and 4,104 full feed harvesters (Field survey, 2023). Among these, there are 11 distinct head feed models from brands such as KUBOTA, YANMAR, FM

World and others with horsepower ranging from 47 to 81 HP (Table 2). For full feed harvesters, 16 different models are available from brands including FM World, LOVOL, Marksan KBOSS, and ZOOMLION, with horsepower spanning from 68 to 120 HP (Table 3). The different models and horsepower highlight the diverse requirements and preferences within the agricultural sector, reflecting the need for equipment that can meet varying operational demands and farming conditions.

Table 1: Importers of combine harvester

Sl no.	Importer
1	Abedin Equipment Ltd.
2	ACI Motors Ltd.
3	Metal Agritech Limited
4	Aadi Enterprise Ltd.
5	Alim Industries Ltd.
6	Bangla mark Corporation
7	SQ Trading & Engineering
8	Uttaron Engg Ltd.
9	McDonald Crop Care Limited
10	Global Marketing Services
11	Chittagong Builders and Machinery

Source: Field survey, 2023

Table 2: Brand and model of head feed combine harvester

Sl no.	Importer	Brand	Model	HP
1	ACI Motors Ltd	YANMAR	AG600ADX	68.3
2	Abedin Equipment Ltd	KUBOTA	PRO588i-G-BD	66
		KUBOTA	PRO488	47
3	Metal Agritech Limited	FM World	DR150A	77
		FM World	WM150AA	77
4	Alim Industries Ltd	Lucky Star	4LBZ-145	75
5	SQ Trading & Engineering	DAEDONG	DXM73GF SA	73
		DAEDONG	DXM73GF	73
6	Bangla mark Corporation	MARKSAN	BM608	72
7	Aadi Enterprise Ltd.	DF ISEKI	ENF808G	81
		CHANGFA	CF608	72

Source: Field survey, 2023

Table 3: Brand and model of full feed combine harvester

Sl no.	Importer	Brand	Model	HP
1	ACI Motors Ltd	YANMAR	YH700DX	69
		LOVOL	RG108plus	98
2	Abedin Equipment Ltd	KUBOTA	DC-70G	68
3	Metal Agritech Limited	FM World	4LZ-4.0E	88
		FM World	4LZ-4.0EA	88
		FM World	WM150AA	77
4	Alim Industries Ltd	DAEDONG	DSF75GT	73
		THINKER	4LZ-6.0Z	100
5	SQ Trading & Engineering	FIELDKING	FKCH-2100	85
		ZOOMLION	FH100	100
6	Bangla mark Corporation	MASSEY FERGUSON	MF2168	88
		MARKSAN K-BOS	MS-700	70
		MARKSAN K-BOS	MS-1200	120
7	McDonald Crop Care Limited	WISHOPE	4LZ-4.5L	88
8	Uttaron Engg Ltd	OSAKA	UH-100	100
		K-BOS	4LZ-5.0Z	100

Source: Field survey, 2023

Market demand and projections for farm machinery spare parts

The methodology for this study comprised several steps aimed at analyzing the market size for farm machinery spare parts in Bangladesh. Initially, baseline data for 2021 and future demand projections for 2025, 2030, and 2041 were obtained from Bangladesh's mechanization roadmap (Table 4). This table outlines the anticipated growth in demand for key machinery, including diesel engines, power tillers, tractors, and combine harvesters, over the next two decades. These projections offer crucial insights into the manufacturing opportunities and market potential within Bangladesh's agricultural machinery sector in the coming years. Field survey was conducted with a diverse group of machine users, spare parts dealers, and importers to gather information on yearly spare parts requirements. Local manufacturers, spare parts engineers, and mechanics were surveyed to estimate the annual demand of manufacturable parts. The collected data was analyzed to calculate both the parts market size and the manufacturable market size. The findings were reviewed and validated by industry experts, ensuring accuracy and reliability. This comprehensive approach provided valuable insights into the market growth potential for agricultural spare parts in Bangladesh.

Table 4: Mechanization roadmap

Sl no.	Name of Machinery	Base Line (in thousand unit)	Projection (in thousand unit)		
		2021	2025	2030	2041
1	Diesel engine	2800	2850	2900	3000
2	Power tiller	750	800	830	900
3	Tractor	60	70	100	150
4	Rice transplanter	1.12	2	10	40
5	Seeder	10	12	16	25
6	Bed planter	4	5	8	10
7	Prilled urea applicator	1.8	2.5	4	10
8	Guti urea applicator	18	20	25	30
9	Sprayer	1500	1550	1600	1700
10	Deep tube well	36.5	37.5	38	39
11	Shallow tube well	1550	1580	1600	1700
12	Power pump	167	180	200	220
13	Solar pump	3.2	10	50	100
14	Combine harvester	6	15	30	50
15	Weeder	250	280	350	400
16	Reaper	8	12	15	25
17	Jute ribboner	40	50	75	100
18	Open drum thresher	150	200	250	300
19	Close drum thresher	220	275	300	350
20	Maize sheller	48.5	50	60	75
21	Sugarcane crasher	50	55	60	70
22	Winnower	2	3	4.5	6
23	Dryer	0.5	5	30	50
24	Crusher machine (rice, wheat)	30	32	35	40
25	Straw chopper	150	200	350	500

Source: Mechanization roadmap, 2016

Table 5 provides an overview of the agricultural spare parts market, outlining the yearly parts requirement per unit (in Tk/unit) and the annual demand for manufacturable parts. Notably, the market for combine harvester parts is expected to experience substantial growth, with the market size projected to reach 300 crore Taka by 2025. Of this, the manufacturable market size is anticipated to be 150 crore Taka.

Table 5: Market size of farm machinery spare parts

Sl no.	Name of Machinery	Yearly spare parts requirement	Manufacturable spare parts req. /year	Projected market size in 2025	
				Total	Manufacturable
		Tk unit-1	Tk unit-1	Cr tk	Cr tk
1	Diesel engine	2500	1800	712.5	513
2	Power tiller	15000	12300	1200	984
3	Tractor	15000	4000	105	105
4	Rice trans planter	4000	2000	0.8	0.4
5	Seeder	2800	2000	3.36	2.4
6	Bed planter	2800	2000	1.4	1
7	Prilled urea applicator	500	500	0.125	0.125
8	Guti urea applicator	500	500	1	1
9	Sprayer	0	0	0	0
10	Deep tube well	3000	1000	11.25	3.75
11	Shallow tube well	1000	500	158	79
12	Power pump	0	0	0	0
13	Solar pump	0	0	0	0
14	Combine harvester	200000	100000	300	150
15	Weeder	800	500	22.4	14
16	Reaper	4000	1000	4.8	1.2
17	Jute ribboner	1000	1000	5	5
18	Open drum thresher	1500	500	30	10
19	Close drum thresher	3000	1000	82.5	27.5
20	Maize sheller	2000	1000	10	5
21	Sugarcane crasher	0	0	0	0
22	Winnower	0	0	0	0
23	Dryer	4000	500	2	0.25
24	Crusher machine (rice, wheat)	6000	2500	19.2	8
25	Straw chopper	1500	500	30	10
	Total			**2699.3**	**1920.6**

Source: Field survey, 2024

Combine harvesters play a vital role in automating the harvesting process. In Bangladesh, initiatives like the SFMRA project aim to strengthen local manufacturing capabilities, promoting economic growth, technological advancement, and job creation. Market projections indicate significant growth in the demand for agricultural spare parts, offering opportunities for local manufacturers. Producing these parts locally helps stabilize costs, enhances access for farmers, and supports broader national goals of industrialization and food security. By focusing on local production, Bangladesh can build a resilient agricultural machinery sector that supports the country's economic and agricultural development.

Chapter Two

Fast Moving Spare Parts

Farmers in Bangladesh are gradually adopting combine harvesters for harvesting crops. Mechanized harvesting is becoming an indispensable part of farming practices. However, parts failure is a common issue that frequently occurs during the harvesting season. To address this, it is crucial to identify and maintain an inventory of "fast moving spare parts" before the start of the harvesting season. The term "fast moving spare parts" in the context of a combine harvester refers to the spare parts that are most frequently subject to wear and tear and, therefore, require regular replacement. These parts are critical to the operation of the harvester and experience the highest levels of mechanical stress during use. By identifying and stocking these parts before the harvesting season, farmers can ensure that their combine harvesters function efficiently. Timely replacement of these parts is essential to minimize downtime and maintain the machine's performance during harvesting operations. This proactive approach not only helps in reducing operational disruptions but also enhances the overall productivity and reliability of the harvesting process.

Methodology

This research adopts a quantitative approach to analyze the replacement time of spare parts in combine harvesters operating across different locations in Bangladesh. A study was designed by gathering data from a diverse sample of 51 combine harvesters representing 9 different brands and operating in various districts of Bangladesh, including Patuakhali, Borguna, Dinajpur, Rangpur, Sirajgonj, Sunamgonj, Tangail, and Hobigonj (Fig. 1). The sample consists of 51 combine harvesters randomly selected from the population of harvesters operating in these districts. The data collection process involved administering a questionnaire designed to track the operating hours, annual use, and reasons for breakdown of specific spare parts. The questionnaire was distributed among combine harvester operators and owners in the selected districts, ensuring comprehensive coverage of various operational contexts. This diverse representation of harvester types allows for the capture of variations in spare parts replacement patterns across different operational modes. By including harvesters from 9 different brands, the study ensures representation across the industry, enhancing the generalizability and robustness of the findings. Data collection for this research involves administering a questionnaire to collect comprehensive information on spare parts. Additionally, contact information, brand, model, type, and geographic location of the combine harvesters are recorded to provide contextual insights into the data. The data collection process is conducted systematically to ensure accuracy and reliability, with an attention to detail. Following the data collection phase, quantitative data analysis is performed using statistical software such as Microsoft excel.

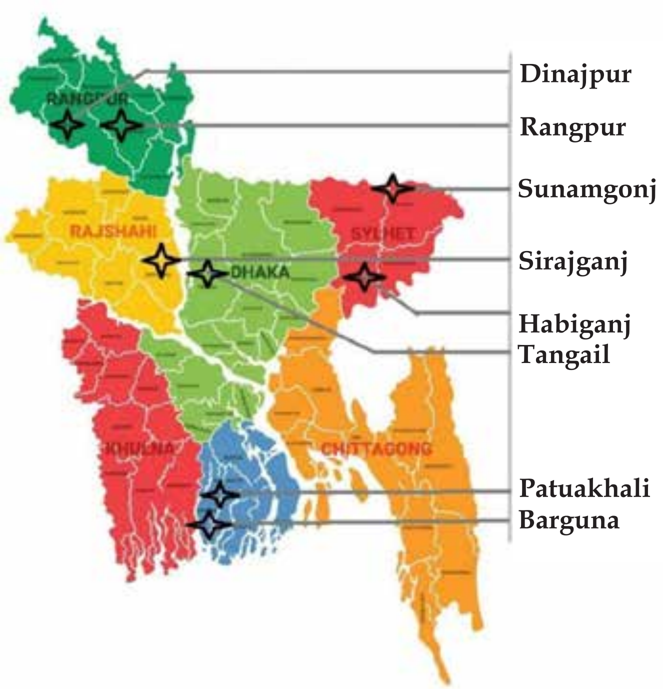


Fig. 1: Study location

Fast moving spare parts of full feed combine harvester

The parts that commonly require replacement during the operational period of a whole feed combine harvester span various sections. In the header or reaper section, components such as the cutter bar assembly blade, blade guide, belt pulley, tension pulley, chain wheel, belt, and spring frequently need replacement. The chassis or traveling unit often requires replacements of the shaft, tension or rear wheel, sprocket, rail guide, adjusting or tension nut-bolt, crawler, support roller, and tension shaft. The thresher section includes parts like the belt pulley, auger, tension pulley, thresher teeth, vibrating sieve belt pulley, grain auger pulley, fan belt pulley, chain wheel, and belt, which are frequently replaced. In the grain tank section, common replacements include the belt pulley, gear shaft, bevel gear, tension wheel, 1st auger, and 2nd auger. Table 1 provides a summary of the fast moving spare parts for a full-feed combine harvester.

Table 1: List of fast moving spare parts of full feed combine harvester

Sl no.	Section	Parts name
1	Header or Reaper	Blade (Blade set)
2		Blade guide
3		Belt pulley, upper shaft
4		Tension pulley
5		Chain wheel
6		Belt
7		Spring
1	Chassis or Traveling Unit	Shaft
2		Tension or rear wheel
3		Sprocket or driving chain wheel
4		Rail guide (front & Rear)
5		Adjusting or tension nut bolt
6		Crawler
7		Support roller
8		Tension shaft
1	Thresher	Belt pulley
2		Auger
3		Tension pulley
4		Thresher teeth or rack weld
5		Belt pulley, vibrating sieve
6		Grain auger pulley
7		Fan belt pulley
8		Chain wheel
9		Belt
1	Grain Tank	Belt pulley
2		Gear shaft
3		Bevel gear
4		Tension wheel
5		1st Auger
6		2nd Auger

Source: Field survey, 2023

Filters and belts are also commonly replaced components in full feed combine harvesters. Table 2 provides a detailed list of these parts, which include various filters such as air filters, HST filters, oil filters, diesel filters, and diesel oil pre-filters, as well as various belts like the conveyor belt for the header section, reel belt, joint belt, grain tank belt, fan belt, reverse SB belt, gearbox upper shaft belt, active transmission fan belt, and fan auger transition drive belt.

Table 2: List of fast moving filter and belts for full feed combine harvester

Sl no.	Section	Parts Name
1	Filter	Air filter
2		HST filter
3		Oil filter
4		Diesel filter
5		Diesel oil pre filter
1	Belts	Conveyor belt, header section
2		Reel belt, header section
3		Joint Belt, travelling section
4		Belt, grain tank section
5		Fan belt, threshing unit
6		Reverse SB belt, threshing unit
7		Gearbox upper shaft belt, threshing unit
8		Active transmission fan belt, threshing unit
9		Fan auger transition drive belt, threshing unit

Source: Field survey, 2023

During this study, issues with the engine, HST, and gearbox were observed and are detailed in Table 3, which lists spare parts such as bearings, gears, piston components, connecting rods, and fuel filter assemblies. Issues with the engine, gearbox, and hydrostatic transmission (HST) in full feed combine harvesters are not widespread problems; rather, they tend to arise in specific models. While these components are critical to the overall performance of the machine, their reliability varies depending on the make and model of the harvester.

Table 3: List of spare parts of engine, HST and gearbox for full feed combine harvester

Sl no.	Section	Parts Name
1	Gear Box	Bearing
2		Gear
1	HST	Bearing
2		HST input shaft
3		HST output shaft
1	Engine	Piston
2		Piston pin
3		Piston ring
4		Connecting rod
5		Fuel filter assembly

Source: Field survey, 2023

Fast moving spare parts of head feed combine harvester

The parts that commonly require replacement during the operational period of a head feed combine harvester span various sections. In the header or reaper section, components such as the chain, belt, finger, finger chain assembly, blade set, single blade, blade rivet, packer, packer shaft, bevel gear, and blade movement bush frequently need replacement. The chassis or travel unit often requires replacements of the shaft, tension or rear wheel, sprocket or driving chain wheel, rail guide, adjusting or tension nut-bolt, crawler, support roller, tension shaft, and all roller seals. The thresher section includes parts like the threshing tooth, V-pulley, thresher blade, concave, and belt, which are frequently replaced. In the grain tank section, common replacements include the belt pulley, tension pulley, auger, bevel gear, shaft, and bearing, as summarized in Table 4.

Table 4: List of fast moving spare parts of head feed combine harvester

Sl no.	Section	Parts name
1	Header or Reaper	Chain
2		Belt
3		Finger
4		Finger chain Assembly
5		Blade set
6		Single blade
7		Blade rivet
8		Packer
9		Packer shaft
10		Bevel gear
11		Blade movement bush
1	Chassis or Travel Unit	Shaft
2		Tension or rear wheel
3		Sprocket or driving chain wheel
4		Rail guide (front & rear)
5		Adjusting or tension nut bolt
6		Crawler
7		Support roller
8		Tension shaft
9		All roller seal
1	Thresher	Threshing tooth
2		V pulley
3		Thresher blade

Sl no.	Section	Parts name
4		Concave
5		Belt
1	Grain Tank	Belt pulley
2		Tension pulley
3		Auger
4		Bevel gear
5		Shaft
6		Bearing

Source: Field survey, 2023

Filters and belts that frequently require replacement in head-feed combine harvesters are crucial for maintaining the machine's efficiency and performance. Table 5 lists these essential filters, including air filters, HST filters, diesel filters, engine filters, and diesel water separators. The commonly replaced belts include the engine belt, threshing belt, thresher drum drive belt, auger drive belts, fan belt, sieve case moving belt, cutter drive belt, reaper drive belt, unloading belt, and all belt tension pulleys. Additionally, the engine-to-gear box main belt pulley and grain cleaning fan are critical components that often need replacement.

Table 5: List of fast moving filter and belts of head feed combine harvester

Sl no.	Section	Parts Name
1	Filter	Air filter
2		HST filter
3		Diesel filter
4		Engine filter
5		Diesel water separator
1	Belts	Engine belt
2		Threshing belt
3		Thresher drum drive belt
4		1st auger drive belt
5		2nd auger drive belt
6		Fan belt
7		Sieve case moving belt
8		Cutter drive belt
9		Reaper drive belt
10		Unloading belt
11		All belt tension pulley
12		Engine to gear box main belt pulley
13		Grain cleaning fan

Source: Field survey, 2023

Issues with the engine, HST, and gearbox are observed on a limited basis, specifically in certain models. These issues are detailed in Table 6, which lists the relevant spare parts that are often required for these repairs. The listed parts include friction plates, disc plates, pinions, bearings, HST shafts, plungers, balance plates, springs, pistons, fuel filters, oil filters, diesel filters, diesel oil pre-filters, and engine belt pulleys. While these problems are not widespread, they are significant in the specific models where they occur, necessitating the availability and awareness of these particular spare parts for effective repair and maintenance.

Table 6: List of spare parts of engine, HST and gearbox for head feed combine harvester

Sl no.	Section	Parts name
1	Gear Box	Friction plate
2		Disc plate
3		Pinion
4		Bearing
1	HST	Bearing
2		HST shaft (input/output)
3		Plunger
4		Balance plate
5		Spring
1	Engine	Piston
2		Fuel filter
3		Oil filter
4		Diesel filter
5		Diesel oil pre filter
6		Engine belt pulley

Bangladesh has relied extensively on imported rice harvesters, with significant volumes brought into the country up to 2023. A thorough discussion is provided on the commonly replaced spare parts in both full-feed and head-feed combine harvesters. By identifying fast-moving spare parts, this information aids in making informed inventory decisions before the harvest season, ensuring that essential components are readily available when needed.

Chapter Three

Manufacturing Strategy

Manufacturing strategy encompasses the planning and decision-making processes involved in producing spare parts specifically for combine harvesters. It defines how manufacturers and companies can produce goods efficiently and competitively, thereby impacting overall business success. Understanding this strategy is crucial for optimizing production processes, managing costs, and ensuring product quality in the context of spare parts manufacturing. It involves careful planning of resources, technology, and labor to meet market demands. Key elements of this strategy include manufacturing and capital investment. Capital investment decisions significantly impact the production setup's capabilities and cost-effectiveness. Different manufacturing approaches, such as those employed in Japanese and Chinese practices, demonstrate the various paths companies can take to achieve market leadership. Understanding these components helps stakeholders navigate the complex landscape of agricultural machinery production. It supports informed decision-making, better resource allocation, and improved product competitiveness. The integration of manufacturing and capital investment is essential for designing a strategy that aligns with both market needs and business objectives.

Manufacturing

The manufacturing of agricultural machinery spare parts involves the production of replacement components that are used to repair or maintain various types of agricultural machinery, such as tractors, harvesters, transplanter and others. The process of manufacturing agricultural spare parts involves several steps, including design, prototyping, testing, and production. The design process involves creating a detailed drawing or model of the part that is to be manufactured. The prototype is then produced to ensure that the design meets the required specifications. Testing is carried out to ensure that the part is durable and can absorbed stresses and strains when using in the field. After the part has been designed, prototyped, and tested, it can be manufactured using a variety of techniques, such as casting, forging, machining, or injection molding. The choice of manufacturing method will depend on the material and complexity of the part.

Capital investment

Producing all the spare parts for combine harvesters within a single manufacturing unit would indeed result in substantial costs due to a variety of factors. First, there is the need for significant capital investment to set up the facility, which must accommodate diverse processes such as CAD/CAM, casting, machining, deburring, grinding, coating, welding, and heat treatment. Each of these processes requires specialized equipment and infrastructure, leading to a considerable initial expenditure. Operational costs further add to the financial burden. These include utilities, equipment maintenance, raw material procurement, and rigorous quality control measures across multiple production stages. Employing skilled labor for each specific manufacturing process—ranging from machinists and welders to engineers and quality control inspectors—demands competitive salaries and training programs, increasing the overall labor costs. Research and development is another critical area that necessitates continuous investment. Keeping up with technological advancements and improving manufacturing processes are essential for maintaining competitiveness, which involves substantial R&D expenses. Furthermore, compliance with environmental and safety regulations introduces additional costs, as regular inspections, certifications, and safety implementations are necessary to meet legal standards. Effective supply chain management also poses a logistical and financial challenge. Managing the procurement, inventory, and logistics for a wide range of materials and components is complex and costly, requiring efficient systems to ensure smooth operations. While consolidating all manufacturing processes under one roof can provide benefits such as enhanced quality control and reduced lead times, the comprehensive financial outlay required for such an endeavor is significant. For the result, many companies choose to specialize in certain areas of production and outsource other processes to specialized suppliers, thereby balancing cost and efficiency.

Manufacturing approach

The comparison of Japanese and Chinese approaches to harvester manufacturing is essential due to the significant impact these two countries have on the global agricultural machinery market (Table 1). Understanding their distinct manufacturing philosophies and practices can provide valuable insights into their competitive advantages and market strategies. This analysis helps stakeholders, including farmers, investors, and policymakers, make informed decisions by highlighting the strengths and weaknesses of each approach in terms of quality, innovation, efficiency, and cost-effectiveness.

Table 1: Comparative analysis of Japanese and Chinese approaches to harvester manufacturing

Distinction	Japan	China
Manufacturing philosophy	**Quality and precision** Japanese manufacturing is renowned for its emphasis on quality, precision engineering and attention to detail. The domestic market in Japan is much smaller compared to China, but more competitive and sophisticated (Yang, 2007). There is a strong focus on continuous improvement (kaizen) and lean manufacturing principles. **Innovation** Japanese companies prioritize innovation in technology and design, often leading to advancements in efficiency, reliability, and environmental sustainability. **Customer centric** Japanese consumers demand high quality products (Yang 2007). Japanese manufacturers typically prioritize customer satisfaction, offering high quality products with comprehensive aftersales support. **Specialization in precision Components** Japanese manufacturers excel in producing high	**Scale and efficiency** Chinese manufacturing is characterized by its ability to scale production rapidly and achieve cost efficiency through economies of scale and labor. **Adaptability and flexibility** Chinese manufacturers are known for their ability to quickly adapt to market demands, offering a wide range of products at competitive prices. China receive contracts from MNCs in developed countries to assemble or manufacture products for them (Wei *et al.*, 2016) **Integration of OEM, ODM, OBM** Chinese manufacturers often integrate vertically across OEM, ODM, and OBM roles to control costs, innovation, and market presence. **Mass production capability** Chinese manufacturers are adept at mass producing standardized components and parts for harvester machinery,

Distinction	Japan	China
	precision components and subsystems such as engines, transmissions, and electronics for harvester machinery. **Engineering excellence** There is a strong emphasis on advanced engineering solutions that enhance performance, reduce environmental impact, and improve overall efficiency. Medium and large-scale enterprises in Japan, with their high technological sophistication, developed small-scale tractors tailored to the specific ecological and socio-economic conditions of Japanese agriculture. This was achieved through adaptive research and development, exemplifying the engineering excellence of Japanese manufacturing (Kako, 1987).	leveraging large scale production capabilities. **Customization and innovation** While traditionally focused on OEM roles, Chinese manufacturers increasingly engage in ODM activities, offering customization and innovation to meet diverse market demands.
Market approach	**Premium branding** Japanese manufacturers often position themselves as premium brands, emphasizing reliability, advanced technology, and superior quality. **Global reputation** Japanese brands have a global reputation for technological leadership and durability, appealing to customers seeking long-term investment value.	**Cost competitiveness** Chinese manufacturers leverage cost advantages to offer competitive pricing in global markets, appealing to cost conscious buyers. **Market expansion** Chinese brands rapidly expand their market presence through aggressive marketing, strategic partnerships, and broad product offerings.

Manufacturing strategy integrates key concepts like manufacturing and capital investment to optimize production, manage costs, and meet market demands. Capital investment influences production capabilities and cost efficiency, which directly affect business success. Japan's and China’s differing approaches which is precision versus scale, highlight diverse paths to market leadership. Understanding these approaches facilitates better decision-making, resource allocation, and strategic planning. A strong manufacturing strategy boosts efficiency, competitiveness, and customer satisfaction, aligning operations with market demands.

Chapter Four

Manufacturing Models

Manufacturing model is a structured approach or framework that a company uses to produce goods, covering the methods, processes, and systems used to transform raw materials into finished products. It defines how a company organizes its production activities to achieve business goals like efficiency, cost-effectiveness, quality, and scalability. The manufacturing model serves as a guide to optimize production processes, aiming for outcomes such as reduced costs, faster production times, high-quality products, and the ability to meet customer demands effectively. Manufacturing models represent the various ways manufacturers create and deliver products to customers. These models play a critical role by defining a business's functions, from product design and part fabrication to the assembly of final goods. The importance of manufacturing models lies in their ability to streamline the production process, making it more efficient and organized. They allow businesses to focus on their core strengths, such as innovative design, quality parts manufacturing, or effective product marketing. This clear division of tasks helps reduce costs, accelerate production, and bring new and improved products to market more quickly. Manufacturing models foster collaboration between different companies and enhancing the overall quality of products. In sectors like agricultural machinery, these models ensure that equipment is tailored to meet specific user needs, resulting in more reliable and easier-to-maintain products.

Types of manufacturing model

There are three models of manufacturing worldwide. These are described below:

1. OEM (Original equipment manufacturer): Manufacturer for others.
2. ODM (Original design manufacturer): Designs for others' manufacturing.
3. OBM (Original brand manufacturer): Own brand manufacturing.

In the manufacturing process of harvesters and their spare parts, OEMs, ODMs, and OBMs have distinct roles and specific positions within the supply chain. Below is an overview of their roles and positioning.

Original equipment manufacturer (OEM)

OEMs in harvester spare parts manufacturing specialize in producing components and parts that are specifically designed for use in harvester equipment. OEM is defined as a company that produces goods in accordance with orders from other companies in accordance with the specifications given (Sari *et al*., 2019). OEMs focus on creating parts that match the exact specifications and performance standards required by the original harvester models. OEMs are positioned as suppliers to harvester manufacturers. They produce parts based on the specifications provided by harvester manufacturers, ensuring that the parts meet the required quality and performance standards. They maintain a business to business (B2B) relationship with harvester manufacturers, supplying them with the necessary spare parts to incorporate into their harvester manufacturing.

Original design manufacturer (ODM)

ODMs in harvester spare parts manufacturing not only produce spare parts but also provide design and engineering services for those parts. ODM focuses on "design and manufacture, technology innovation, and product design; marketing of brand card sticking on goods," positioning themselves as partners with their clients by providing superior, market-oriented products and design services (Zhang and Zhang, 2015). ODMs position themselves as partners with harvester manufacturers. They work closely with manufacturers to design and develop customized spare parts that meet specific performance, quality, or functionality requirements. ODMs engage in a collaborative and often long-term partnership with harvester manufacturers to create tailored spare parts for their machinery.

Original brand manufacturer (OBM)

OBM focuses on "self-owned brand on sale; internal marketing ability improvement," enhancing their competitiveness through robust research and development capabilities, product innovation, and self-owned brand marketing. They aim to improve internal marketing strategies and develop a distinct brand identity in the market (Zhang and Zhang, 2015). OBM focus on branding, marketing, and selling product under their own brand name. OBMs position themselves as consumer facing companies that offer complete harvester to end users, distributors, or repair shops. OBMs may source spare parts from OEMs or ODMs but maintain the direct relationship with the end users or distributors. They are responsible for marketing the product and providing customer support.

To understand in short, OEMs primarily supply standardized spare parts to harvester manufacturers, ODMs offer a more collaborative approach by designing and producing custom parts for manufacturers, and OBMs focus on branding and marketing their own product to end users. Table 1 highlights the roles of OEM, ODM, and OBM within the agricultural machinery manufacturing sector in Bangladesh. It presents specific companies and the products they are involved with under each category. OEM companies such as Faisal Engineering Workshop and Alam Engineering Workshop focus on producing standardized components like rollers, shafts, and seed sower wheels. ODMs, including the Bangladesh Rice Research Institute (BRRI) and Agromech development initiatives (ADI), provide specialized design and engineering services, developing innovative products like seed sower designs and IoT-based irrigation systems. OBM companies like Alim Industries and Jamil Engineers Ltd. brand, market, and sell complete farm machinery products directly to consumers, such as threshers and seeders, ensuring end-to-end customer service and product quality.

Table 1: Model of farm machinery manufacturing in Bangladesh

Sl. no.	OEM		ODM		OBM	
	Company	Product	Company	Product	Company	Product
1	Faisal Engg. Workshop	Roller, Shaft	Bangladesh Rice Research Institute (BRRI)	Seed sower design	Alim Industries	Alim Thresher
2	Alam Engg. Workshop	Seed sower wheel, Seed plate	AgroMech Developmen t Initiatives (ADI)	IoT based irrigation system, Smart AWD	Jamil Engineers Ltd	Seeder, Bed planter, Agricultur al tipping trailer
3	Mohammad Agricultural Machineries	Drive wheel, Idler, Tension nut and bolt,	Bangladesh Agricultural Research Institute (BARI)	BARI Maize Sheller	Janata Engineeri ng	Janata Oil Expeller, Janata Winnower

Case study 1: BRRI whole feed combine harvester

In the development and production of the BRRI whole feed combine harvester, the collaborative efforts of various entities through their roles as OEM, ODM, and OBM can be illustrated as follows (Fig. 1): Alam Engineering Workshop, Ekota Iron Works, Janata Engineering, Monno Agro and General Machinery, and Babul Enterprise

Chuadanga, along with overseas partners, serve as OEMs in this project. Alam Engineering Workshop fabricates the fuel tank, all pulleys, sprockets, and bevel gears. Ekota Iron Works performs all types of bending and cutting operations for the chassis frame. Janata Engineering manufactures components such as the recycle threshing auger, straw conveying box, threshing drum, and threshing sieve. Monno Agro and General Machinery manufactures and tempers all shafts and gears, while Babul Enterprise Chuadanga handles the painting works using Berger paints. Overseas OEMs contribute essential components: Zhongce Rubber Group Company Limited supplies the crawler, Jiangsu World Agriculture Machinery Co. Ltd. provides the belt, Shanghai Xin Equation Bearing Company Limited manufactures the bearings, Suzhou Fubang Machinery Chain Transmission Manufacturer Company Limited supplies the chain and Zhejiang Xinchai Company Limited manufacture the engine. These OEM suppliers ensure the production of high-quality, standardized components that are crucial for the reliable performance and assembly of the BRRI whole feed combine harvester.

BRRI plays the role of ODM, providing specialized design and engineering expertise. BRRI collaborates closely with the various engineering workshops and Alim Industries Limited, ensuring that the machine meets the specific needs and requirements of the agricultural sector. This collaboration allows for the incorporation of advanced technologies and innovative features into the harvester, enhancing its efficiency and performance. Alim Industries Limited operates as the OBM, taking responsibility for the final manufacturing, assembly, branding, and marketing of the BRRI Whole Feed Combine Harvester. Alim Industries manufactures critical components such as the gearbox, all types of wheels, threshing auger, grain discharge auger, grain tank, reel, and stock separator. They oversee the complete assembly of the harvester and ensure that it meets the high standards associated with the 'BRRI WCH2021' brand. By marketing and selling the harvester directly to consumers, dealerships, and service providers, Alim Industries maintains a direct relationship with customers, ensuring comprehensive after-sales support and upholding the brand's reputation for quality and reliability.

BRRI whole feed combine harvester

OEM	ODM	OBM
Alam Engineering workshop Ekota Iron Works Janata Engineering Monno Agro and General Machinery Babul Enterprise, Chuadanga Shanghai Xin Equation Bearing, China Suzhou Fubang M.C.T.M, China Jiangsu World Agricultural Mach., china Zhongce Rubber Group, China Zhejiang Xinchai, China	Bangladesh Rice Research Institute (BRRI) BRRI	Alim Industries Limited

Fig. 1: Manufacturing functionality of BRRI whole feed combine harvester

In this way, the development and production of the BRRI whole-feed combine harvester are accomplished by effectively utilizing OEM suppliers for standardized parts, collaborating with BRRI as the ODM for custom-designed components, and leveraging Alim Industries as the OBM responsible for branding, marketing, and customer support.

Case study 2: BRRI auto seed sower machine

In the context of the BRRI auto seed sower manufacturing, the operation can be understood through the roles of OEM, ODM, and OBM as follows:

The BRRI auto seed sower project involves multiple original equipment manufacturers (OEMs) to ensure high-quality, specialized components. Alam Engineering Workshop plays a role by manufacturing the metering device and pulley assemblies, ensuring they meet precise specifications for durability and performance. New MM Steel in Gazipur fabricates all the sheet boxes and shafts, ensuring the structural integrity and durability of the machine. Zahangir Spring Store in Wari, Dhaka, produces all types of springs required for the seed sower. Faisal engineering workshop contributes by producing the sprocket and pulley, focusing on precise engineering to facilitate smooth operations. Each OEM ensures that their parts meet stringent quality standards, contributing to the overall reliability and functionality of the seed sower (Fig. 2).

BRRI functions as the original design manufacturer (ODM) for the auto seed sower. BRRI brings its extensive research and development expertise to the project, designing innovative components tailored to the specific needs of the agricultural sector. Their involvement ensures that the seed sower incorporates the latest advancements in agricultural technology, offering enhanced efficiency and performance. By working closely with the OEMs and OBMs, BRRI ensures that each component integrates seamlessly into the final product, enabling the creation of a machine that meets the unique requirements of local farmers. GSM engineering operates prominently as the original brand manufacturer (OBM) for the BRRI auto seed sower. They are responsible for the assembly, branding, marketing, and sales of the finished product. Under the GSM engineering brand, the auto seed sower is marketed directly to consumers, dealerships, and agricultural equipment suppliers. GSM engineering manages the entire customer experience, from initial marketing efforts to after-sales support, ensuring that the product upholds the high standards associated with their brand. This direct relationship with customers allows GSM engineering to maintain a strong market presence and reputation for quality and innovation in agricultural machinery.

BRRI auto seed sower machine

Fig. 2: Manufacturing functionality of BRRI auto seed sower machine

The collaboration among OEMs, ODMs, and OBMs in the BRRI auto seed sower project exemplifies a successful integration of specialized manufacturing, innovative design, and effective branding and sales strategies. This holistic approach ensures the delivery of a reliable and advanced agricultural machine to the farmers.

Case Study 3: Janata power thresher

Janata Engineering sources key components from a network of OEM suppliers to ensure the quality and performance of their threshers. For instance, they procure V-belts from Dongil, bearings from PRS, diesel engines from SIFANG, tires from Gazi Tire, tire ring hubs from JnJ Enterprise, and pulleys from Kamal Machine Tools and Al-Madina Metal Works. These suppliers produce components according to Janata's specifications, ensuring they meet the required quality standards essential for reliable operation. By relying on these OEM suppliers, Janata maintains consistency and reliability in their products.

For models requiring customized components, Janata collaborates with ODMs such as the BRRI and the Bangladesh Agricultural Research Institute (BARI). These partnerships enable Janata to incorporate innovative features and advanced technology into their threshers, enhancing their competitive edge in the agricultural machinery market. Janata Engineering also operates prominently as an OBM by branding, marketing, and selling their threshers directly to consumers, dealerships, and repair shops under the Janata brand name (Fig. 3). The body and final assembly of the threshers are completed in-house by Janata, ensuring that the products uphold the high standards associated with their brand. By maintaining a direct relationship with their customers, Janata ensures a seamless end-to-end experience, reinforcing their reputation for quality, reliability and innovation.

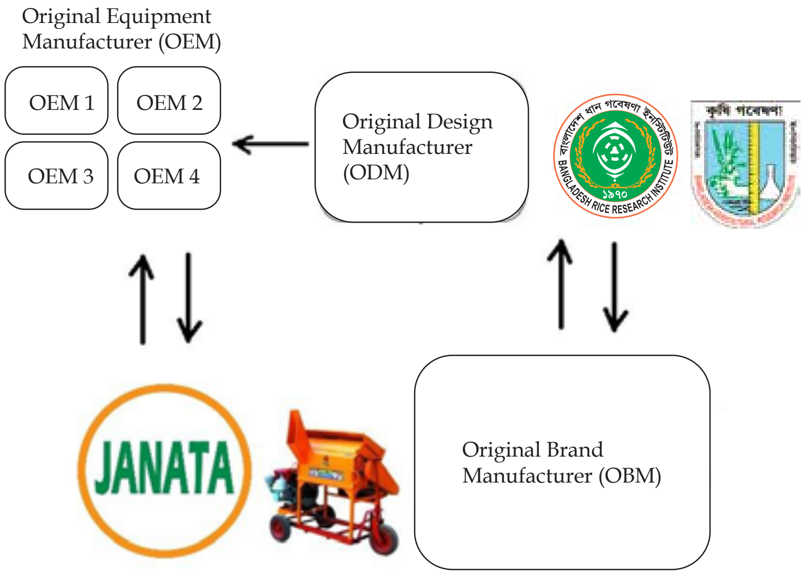


Fig. 3: Manufacturing functionality of Janata power thresher

Shifting manufacturing models

The evolution from Original Equipment Manufacturer (OEM) to Original Brand Manufacturer (OBM) represents a significant transformation. OEMs are typically positioned in the middle of the value chain, where their role focuses on manufacturing low-margin, high-volume products for external brands. As competition intensifies and profit margins shrink, many OEMs seek to upgrade their capabilities and move toward Original Design Manufacturer (ODM) models. This shift allows them to engage in higher-value activities, such as product development and design, thereby enhancing their contribution beyond mere production (Mudambi, 2008). For many firms, the ultimate goal is to evolve into OBMs, where they not only design and manufacture but also build their own brand and market products directly. This strategic transition is seen as a path to escape the "OEM trap," where firms are confined to low-value, low-margin activities (Temporal, 2005). The transition to OBM requires substantial investment in R&D and marketing capabilities, as firms need to innovate, develop unique products, and create strong brand equity to compete globally (Wang, 2010). Success in this journey demands not only technical capabilities but also a deep understanding of market dynamics and consumer preferences, as these firms shift focus to both upstream activities like R&D and downstream activities such as branding and after-sales services (Mudambi, 2008). The transition from OEM to ODM and eventually OBM is a complex and challenging process, but it offers firms the opportunity to move up the value chain and capture higher profit margins. By focusing on branding and innovation, these firms can differentiate themselves in the global market, secure greater control over the value chain, and improve their long-term competitiveness.

Manufacturing value chain map

Manufacturing value chain map outlines the series of interconnected activities involved in transforming raw materials into finished products, emphasizing the roles of various stakeholders throughout the process (Fig. 4). This value chain encompasses all the steps and processes required to design, manufacture, assemble, and distribute farm machinery. This value chain starts with raw material suppliers and importers who provide essential inputs, such as metals and chemicals, to engineering shops. Scrap collectors gather recyclable materials, supplying them to foundries that consist of three key segments: melting, casting, and finishing. Chemical importers and suppliers provide necessary chemicals to the melting and treatment units. In the engineering shops, the finished parts from foundries undergo further refinement through cutting, shaping, and machining. Some components are then treated through processes like heat treatment, plating, and coating, which are facilitated by additional chemical inputs from suppliers. However, not all parts require treatment; some are sent directly to the assembly section. Imported spare parts also play a crucial role, especially in manufacturing complex machinery like harvesters, where not all components can be produced locally. The assembly segment integrates various parts into a cohesive final product. If assembly is unnecessary, parts move directly to the branding or packaging section. Once branded and packed, the products are sold to end-users, typically farmers. Post-sale, the value chain encompasses a reuse and recycling phase, where products may either be disposed of or redirected to scrap collectors, closing the loop. Furthermore, any components failing quality control during machining are also sent for reuse.

Understanding the entire value chain helps manufacturers optimize each step, ensuring efficiency, cost reduction, and improved product quality. By managing resources effectively and streamlining operations, manufacturers can better adapt to market demands, enhancing competitiveness and sustainability in the industry.

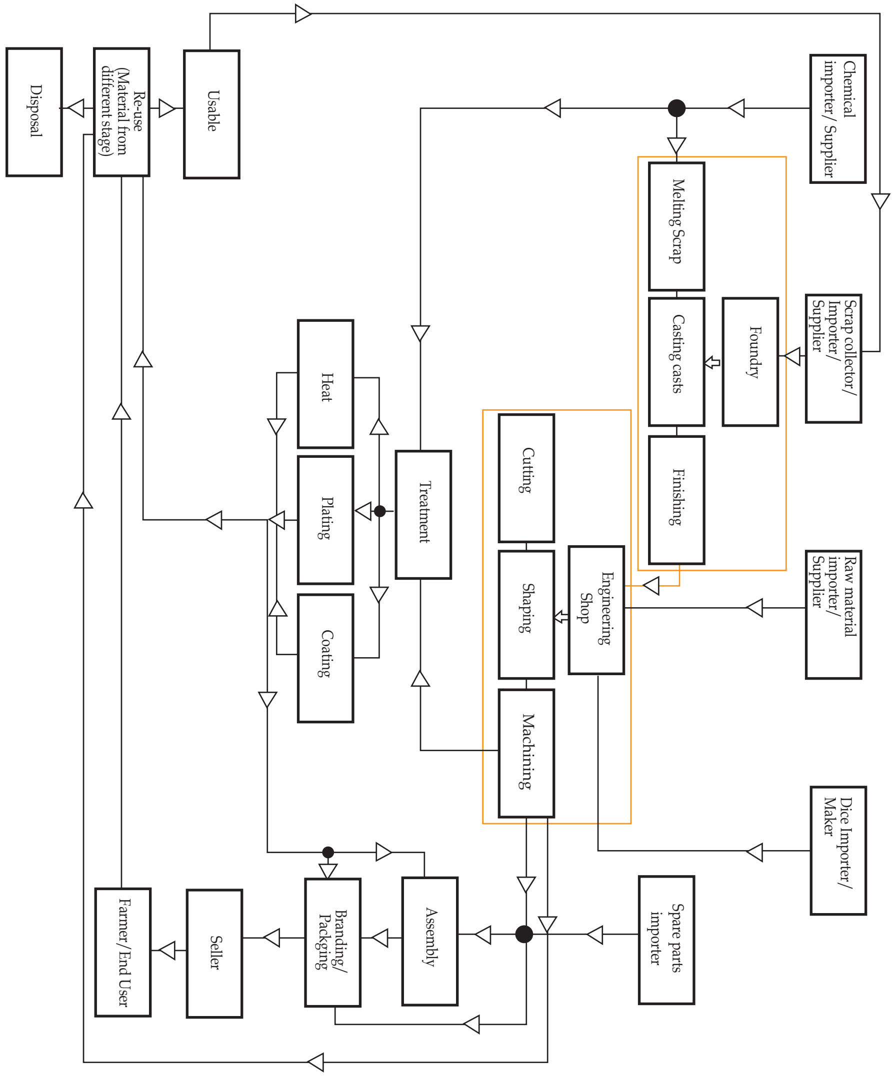


Fig. 4: Manufacturing value chain map

Strengthening manufacturing models

The combine harvester manufacturing strategy focuses on strengthening OEM capabilities to ensure high-quality production. This involves evaluating existing factories, forming strategic partnerships, and facilitating knowledge transfer from advanced units. Joint investments and standardized quality control protocols are encouraged, alongside implementing a digital supply chain management system. Regular reviews, collaborative planning, and a feedback loop with OEMs are also key components of this approach.

Strategy for OEM strengthening approach includes:

Mapping and evaluating existing capabilities

Conduct a comprehensive survey of existing molding factories, engineering workshops, paint shops, and heat treatment facilities. Identify OEMs that specialize in the necessary processes for harvester manufacturing (casting, machining, coating, welding, heat treatment, etc.).

Forming strategic partnerships

Partner with selected OEMs based on their specialization and ability to meet the quality and volume requirements for harvester parts.

Facilitating knowledge transfer

Facilitate the transfer of knowledge from more advanced manufacturing units through international partnerships or technical collaborations.

Encouraging joint investments

Promote joint investments between the harvester manufacturing unit and OEMs to upgrade equipment and technology.

Developing standardized quality control protocols

Implement standardized quality control protocols across all partner OEMs to ensure consistent quality. Set up regular audits and quality checks to maintain high standards.

Establishing a certification program

Develop a certification program for OEMs that meet required manufacturing and quality standards. Offer incentives to certified OEMs to encourage adherence to these standards.

Implementing a digital supply chain management system

Integrate OEMs into a cohesive network through a digital supply chain management system. Use this system for real-time tracking of parts production, inventory management, and logistics coordination.

Engaging in collaborative production planning

Collaborate with OEMs on production planning to align their schedules with the overall manufacturing plan for combine harvesters.

Promoting continuous improvement

Encourage OEMs to regularly review and improve their processes, focusing on efficiency, quality, and cost-effectiveness. Adopt the Kaizen approach of continuous improvement in collaboration with OEMs.

Establishing a feedback loop

Set up a feedback loop with OEMs where performance data and customer feedback are regularly shared to improve the manufacturing process.

By strengthening specific OEMs and integrating them into a cohesive manufacturing network, this strategy minimizes the need for extensive investment in setting up numerous workshops and leverages existing local capabilities to establish a robust and cost-effective harvester manufacturing unit in Bangladesh.

ODM strengthening approach includes:

Enhancing R&D capacity

Invest in dedicated research teams focused on developing innovative, efficient, and locally adapted designs for combine harvesters, covering both design and testing phases.

Establishing a design lab

Set up a design lab equipped with advanced software for 3D modeling, simulation, and rapid prototyping, allowing engineers to experiment and optimize designs before full-scale production.

Setting up a fabrication lab

Create a fabrication lab for prototyping and small-scale production of components, including cutting-edge machinery for machining, welding, and assembly to refine the manufacturing process.

Implementing a heat treatment lab

Establish a heat treatment lab to enhance the durability and performance of critical components like gears and shafts, ensuring in-house control over the heat treatment process.

Developing a painting lab

Equip a painting lab with advanced coating technologies to ensure high-quality finishes that protect machinery from corrosion and wear.

Prioritizing the testing lab

The most critical need is a dedicated testing lab to evaluate prototypes and finished products under various conditions, simulating field conditions to ensure performance, durability, and safety.

OBM strengthening approach includes:

Increasing subsidies on locally made agricultural machinery

Provide higher subsidies on locally manufactured machinery compared to imported alternatives to stimulate domestic production and technological advancements.

Subsidizing local spare parts production

Offer subsidies for locally made spare parts to strengthen the supply chain, reduce dependence on imports, and lower maintenance costs for farmers.

Supporting branding initiatives with subsidies

Subsidize branding efforts for local manufacturers to build strong, recognizable brands that compete with international names, covering marketing campaigns, trade show participation, and promotional activities.

Developing export capabilities

Strengthen local OBMs' export capabilities by adapting products to meet international standards, obtaining certifications, and establishing global partnerships.

Facilitating continuous improvement

Encourage continuous improvement through training, process optimization, and technology upgrades, ensuring competitiveness and responsiveness to market changes.

Manufacturing models provide structured approaches that companies use to produce goods, defining the methods, processes, and systems involved in transforming raw materials into finished products. These models guide how companies organize their production activities to achieve goals such as efficiency, cost-effectiveness, quality, and scalability. They help businesses optimize production processes, aiming for lower costs, faster production, high-quality products, and meeting customer demands effectively. By outlining how manufacturers create and deliver products, these models play a crucial role in defining a company's operations, from product design and part manufacturing to final assembly. They enable companies to focus on their strengths, whether in innovative design, quality manufacturing, or effective marketing. This clear division of roles helps reduce costs, speed up production, and launch improved products more quickly. In sectors like agricultural machinery, these models enhance the quality of equipment, ensuring products are reliable, easier to maintain, and meet specific user needs.

Chapter Five

Manufacturing Process

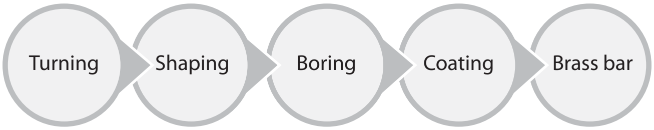
The manufacturing process is a structured sequence of steps which is essential for producing agricultural spare parts, from initial design to final testing. Its importance lies in optimizing performance, durability, and cost-effectiveness. The process must be fit to available resources, considering factors like manufacturing capabilities, supply chain logistics, production scale, and business viability. Choosing the right manufacturing techniques whether casting, machining, or heat treatment depends on these considerations, ensuring that each part meets exact specifications and meet agricultural demands efficiently. This methodical approach ensures that the final products are reliable, functional, and suited to their intended use.

The step-by-step process of manufacturing agricultural spare parts provides numerous benefits. Starting with the design ensures parts are customized to exact specifications, optimizing their performance. Careful material selection guarantees durability, strength, and cost-effectiveness, crucial for withstanding agricultural demands. Techniques like casting, cutting, and shaping allow for intricate designs and precise dimensions, while machining adds intricate features. Heat treatment further enhances durability, ensuring parts withstand harsh conditions. Finally, assembly and testing phases ensure quality assurance, resulting in reliable spare parts tailored for agricultural needs. This methodical approach ensures efficiency, functionality, and longevity in agricultural machinery

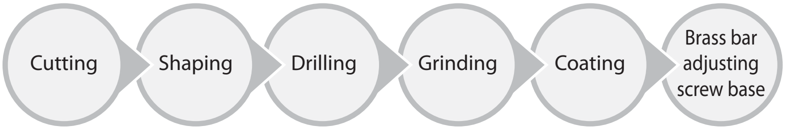
Design the process of manufacturing

The manufacturing process for agricultural machinery parts can vary depending on the specific part and the materials used for it. Combination of technical knowledge and specialized tools and equipment is required to determine the process of work. The manufacturing process for agricultural parts involves several key steps to transform raw materials into finished products. It typically starts with pattern making and casting to create the basic shape of the parts. This is followed by machining processes such as turning, shaping, boring, drilling, and milling to refine the dimensions and achieve the desired precision. Heat treatment is often used to enhance the strength and durability of the parts. Finally, surface treatments like grinding, coating, and plating are applied to improve the appearance and protect against corrosion. Each of these steps is essential to ensure the quality and performance of the final product. Below is the parts-wise flowchart description for the manufacturing process.

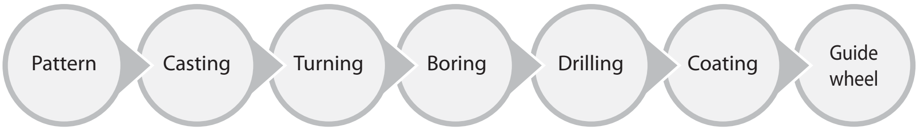
Parts name: Brass bar



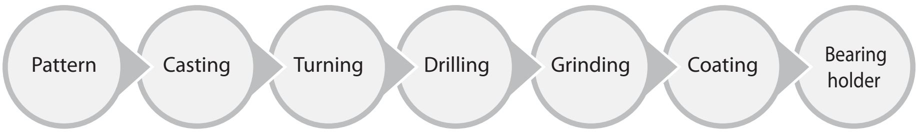
Parts name: Brass bar adjusting screw base



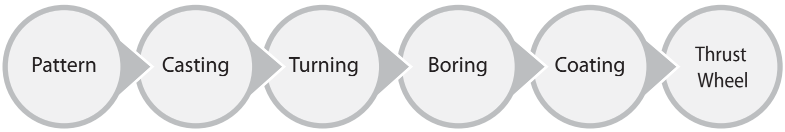
Parts name: Guide wheel



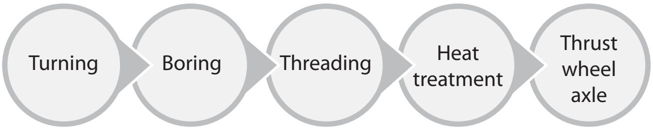
Parts name: Bearing holder



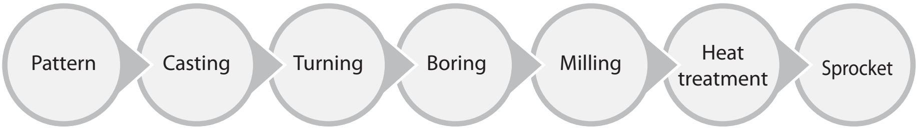
Parts name: Thrust wheel/roller



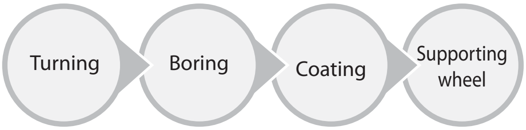
Parts name: Thrust wheel axle/shaft



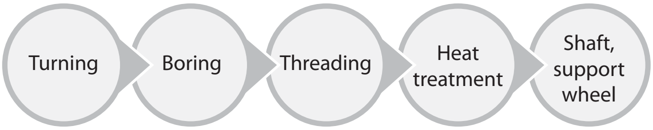
Parts name: Walking wheel/sprocket



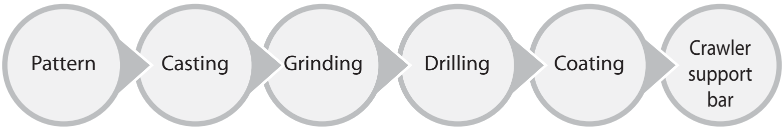
Parts name: Supporting wheel/carrier roller



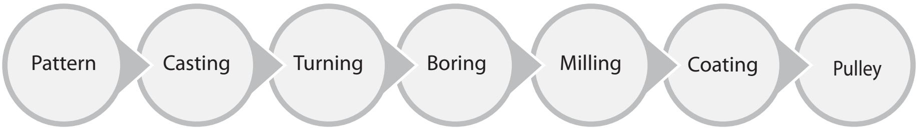
Parts name: Shaft, supporting wheel/carrier roller



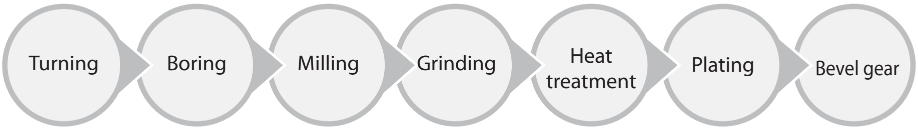
Parts name: Crawler support bar/ guide



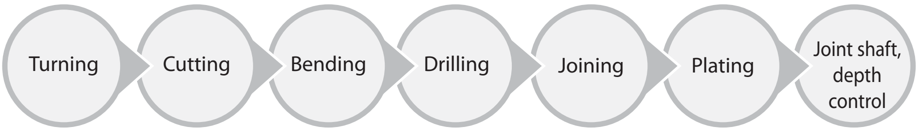
Parts name: Pulley



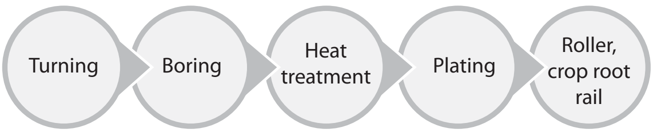
Parts name: Bevel gear



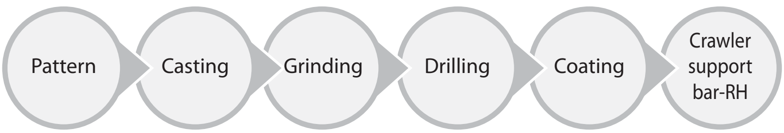
Parts name: Joint shaft, depth control



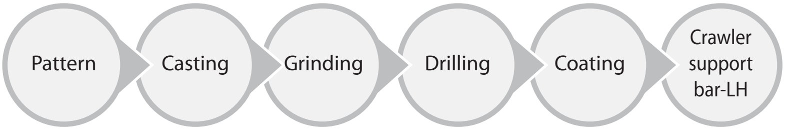
Parts name: Roller, crop root rail



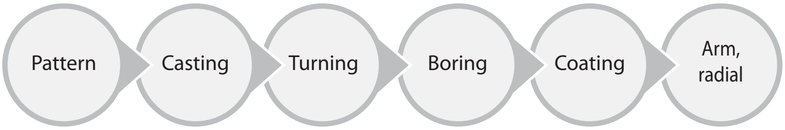
Parts name: Crawler support bar/guide rail-RH



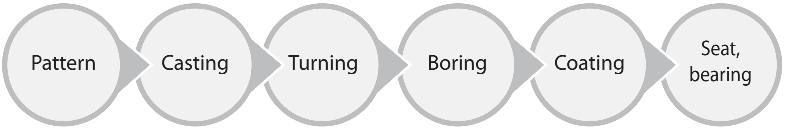
Parts name: Crawler support bar/guide rail-LH



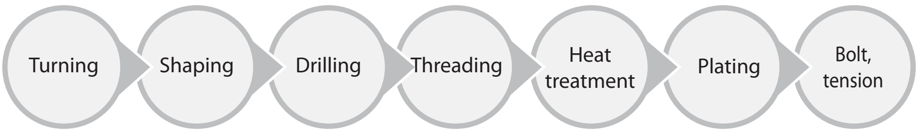
Parts name: Arm, radial



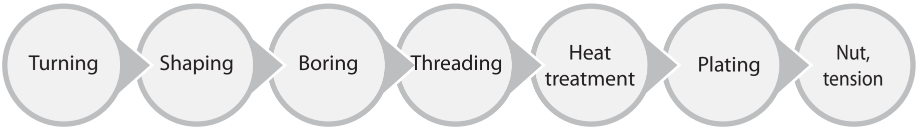
Parts name: Seat, bearing



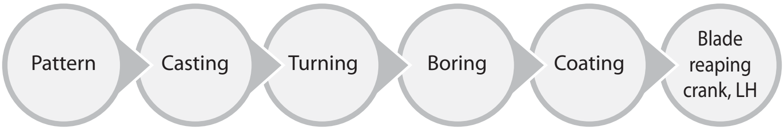
Parts name: Bolt, tension



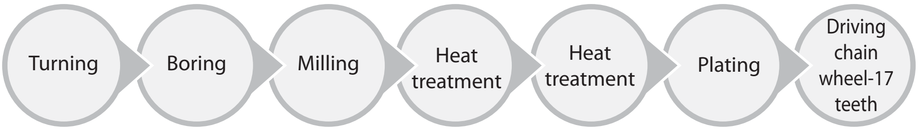
Parts name: Nut, tension



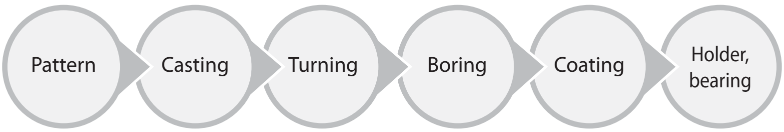
Parts name: Blade reaping crank, LH



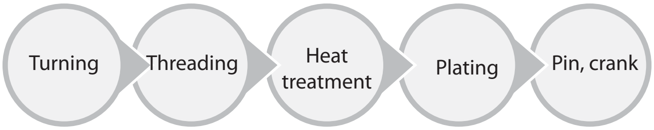
Parts name: Driving chain wheel-17 teeth



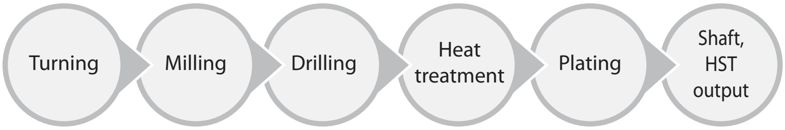
Parts name: Holder, bearing



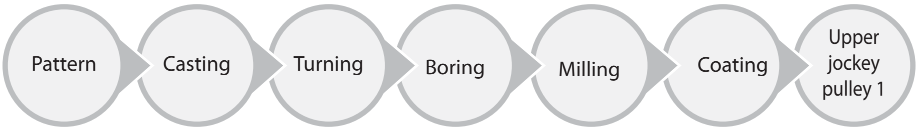
Parts name: Pin, crank



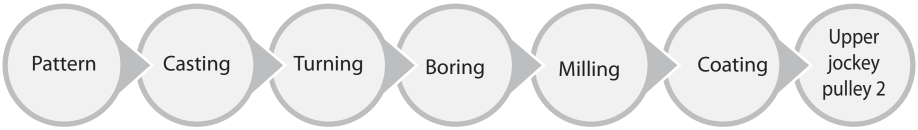
Parts name: Shaft, HST output



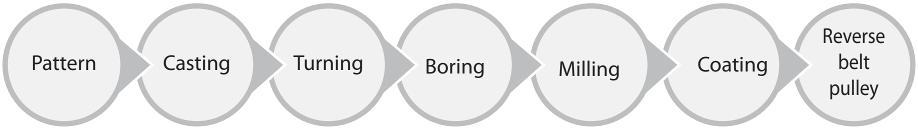
Parts name: Upper jockey pulley (1)



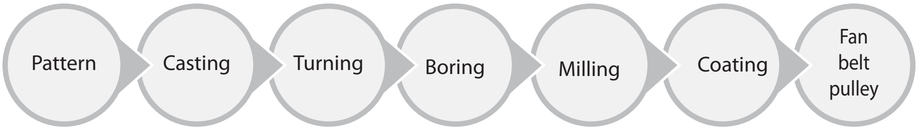
Parts name: Upper jockey pulley (2)



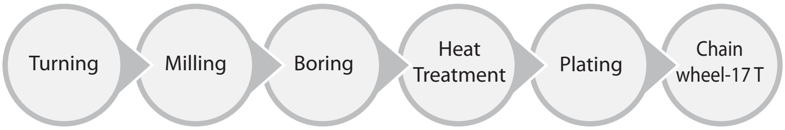
Parts name: Reverse belt pulley



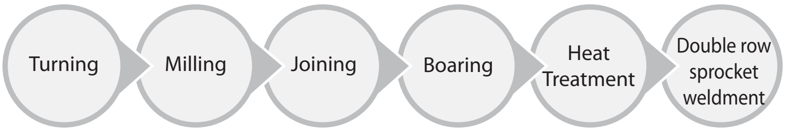
Parts name: Fan belt pulley



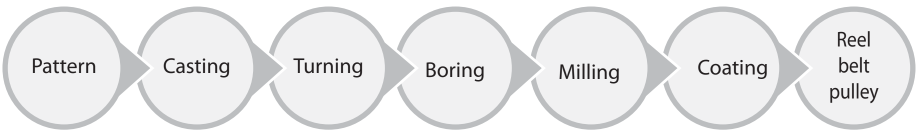
Parts name: Chain wheel-17T



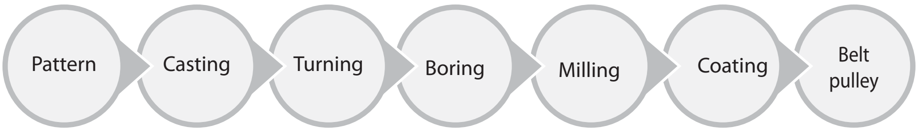
Parts name: Double row sprocket weldment



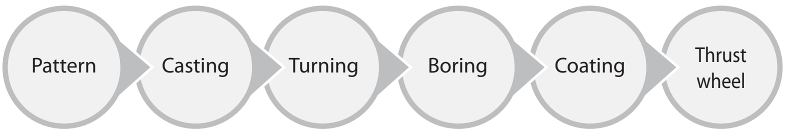
Parts name: Reel belt pulley weldment



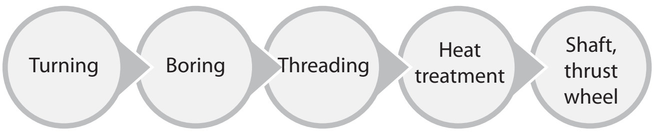
Parts Name: Belt pulley



Parts name: Thrust wheel



Parts name: Shaft, thrust wheel



Metallurgical mapping

Metallurgical mapping is the process of systematically documenting and analyzing the specific metals and their grades used in the various components of a harvester. This practice involves identifying the material properties such as corrosion resistance, hardness, toughness, and wear resistance for each part.

This comprehensive approach facilitates informed decision-making during the selection of materials, enabling engineers to match the mechanical requirements of each part with the most suitable metal composition. Metallurgical mapping aids in identifying potential areas for material optimization or substitution, enhancing cost-effectiveness and resource efficiency in manufacturing processes. Understanding the metallurgical characteristics of each part also important to predictive maintenance strategies, ensuring timely replacements and minimizing downtime in agricultural operations. This documentation plays a vital role in advancing the field of agricultural engineering by driving innovations in material science, manufacturing techniques, and equipment design.

The provided data offers a comprehensive overview of the metallurgical specifications and requirements for manufacturing spare parts used in harvesters from different international OEMs (Table 1). It outlines the types of metals, their grades, and the specific components they are utilized for, providing essential information for engineers and manufacturers. The inclusion of details such as alloy percentages, chemical compositions, and similar metals enhances the clarity and precision of the dataset, aiding in the selection of appropriate materials for each application. Additionally, the categorization of parts based on their function, such as chains, sprockets, gears, and bearings, streamlines the understanding of the role of each component within the harvester machinery. This data is invaluable for ensuring the reliability, performance, and longevity of combine harvester, contributing to the efficiency and productivity of farming operations and helps to design the use of raw materials for local manufacturing. Provided data in Table 1 serves as a valuable resource for researchers, engineers, and manufacturers involved in the development and maintenance of harvester machinery.

Table 1: Metallurgical mapping for harvester parts from international OEM

Sl no.	Parts Name	Metal Name	Metal Grade
1	Steel Agricultural chain	Stainless Steel & Alloy steel	SS304 , SS316 & 45Mn, 42CrMo, 20CrMo
2	Bore sprocket	Carbon steel, alloy steel, stainless steel	C45/SUS304/IQ235/C20/C35/Q345/16MnCr5/20CrMo/35CrMo/40Cr/42CrMo/50CrV
3	Conveyor drive Sprocket	Carbon steel	45# steel or 45 Carbon structural steel
4	Cast iron sprocket	CI	24B Cast Iron
5	Conveyor drive roller Chain sprocket	Alloy Steel & Stainless Steel	1045 Steel / Alloy Steel / Stainless Steel 304 & 316

Sl no.	Parts Name	Metal Name	Metal Grade
6	Belt pulley	CI-Gray Cast	Gray cast iron- GG20,GG25, EN-GJL 200, EN-GJL250,HT250
7	Combine harvester knife guard	Alloy steel	ASTM 1045 steel or AISI4140
8	Driving wheel/ sprocket	Carbon Steel	#45 Steel
9	Bevel gear	Stainless Steel	SS304 , SS316
10	Blade	Carbon steel	AISI 1070
11	Fasteners	Soft steel, Medium carbon steel,Alloy Steel & Stainless Steel,Brass	40Gr/45C/ SS300/SS400
12	Auger	Abrasion-Resistant Steel	AR400, AR450, AR500
13	Bearing	High-carbon chromium steel	ASTM A295, SAE 52100, DIN 100Cr6
14	Transmission gear	Carbon steel	AISI 1045 and AISI 4140.
15	HST parts/shafts	Chromium-Molybdenum Steel	AISI 4140
16	Frame and body panel	MS ,High-Strength Low-Alloy (HSLA) Steel	ASTM A572, ASTM A656, ASTM A1011, SAE J1392
17	Engine block	Gray cast iron, Ducktail cast iron	ASTM A48, ASTM A536
18	Crank shaft	Ductile Cast Iron, Alloy Steel	SG, AISI 4340, AISI 4140
19	Piston	Aluminum alloy	Al-Si12, Al-Si16
20	Threshing drum teeth/rasp bar	High carbon steel	1095 steel

Source

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https://bnml.co.uk/manufacturing/

Raw materials available in Bangladesh market

Agricultural machinery spare parts can be made using a variety of materials, depending on the specific parts and its intended use. Some common materials used in the manufacturing of agricultural spare parts include:

1. **Steel:** Steel is a strong and durable material that is commonly used in the manufacturing of spare parts due to its ability to absorbed heavy loads, high temperatures, and rough weather conditions (Fig. 1).

Fig. 1: Steel

2. **Cast Iron:** Cast iron is commonly used for parts that need to withstand high levels of stress or pressure, such as engine blocks (Fig. 2).

Fig. 2: Cast Iron

3. **Aluminum:** Aluminum is a lightweight material that is commonly used in the manufacturing of agricultural machinery spare parts due to its strength, durability, and resistance to corrosion (Fig. 3).

Fig. 3: Aluminum spare parts

4. **Plastic:** Plastic is a lightweight and cost-effective material that is commonly used in the manufacturing of agricultural machinery for parts that do not require high strength or durability (Fig. 4).

Fig. 4: Plastic

5. **Rubber:** Rubber is a flexible and resilient material that is commonly used in the manufacturing of tires, belts (Fig. 5), and other components of agricultural machinery that require high levels of traction and durability.

Fig. 5: Rubber Belts

6. **Composite materials:** Composite materials, such as fiber glass and carbon fiber, are increasingly being used in the manufacturing of agricultural spare parts due to their high strength-to-weight ratio, resistance to corrosion, and ability to be molded into complex shapes.

7. **Copper:** This material is used for manufacturing components such as wiring, electrical connectors, and heat exchangers (Fig. 6).

Fig. 6: Copper and Brass

Types of alloy in agricultural spare parts manufacturing

There are several types of alloys commonly used in the manufacturing of agricultural spare parts. Alloys provide enhanced strength and durability compared to pure metals, ensuring reliable performance in demanding agricultural conditions. Additionally, many alloys offer superior corrosion resistance, protecting spare parts from damage caused by exposure to moisture, chemicals, and agricultural substances. Certain alloys, such as aluminum alloys, contribute to weight reduction without compromising strength, improving fuel efficiency and ease of handling. Moreover, alloys can be customized to meet specific requirements for different harvester spare parts, optimizing performance and durability. While alloys may have higher initial costs, their longer service life and reduced maintenance needs result in cost savings over the equipment's lifecycle. The specific alloys used can vary depending on the particular application, but some of the most commonly used alloys include:

1. **Steel alloy:** Steel is a common alloy used in agricultural machinery manufacturing due to its strength, durability, and relatively low cost. Different types of steel can be used depending on the specific application, such as carbon steel, stainless steel, and alloy steel.

2. **Aluminum alloy:** Aluminum alloys are also commonly used in agricultural machinery manufacturing due to their light weight, high strength-to-weight ratio, and resistance to corrosion. Aluminum alloys can also be easily machined and formed.
3. **Copper alloy**: Copper alloys are used in some agricultural machinery components, such as electrical wiring and motors, due to their high electrical conductivity.
4. **Bronze alloy:** Bronze alloys are used in some agricultural machinery components, such as bushings and bearings, due to their high strength and resistance to wear.
5. **Cast iron:** Cast iron is a common alloy used in the manufacturing of some agricultural machinery components, such as engine blocks, due to its high strength, durability, and good machinability.

Factors influencing material selection in manufacturing

By carefully considering factors such as strength and durability, corrosion resistance, weight, cost of material, availability and compatibility with other materials, manufacturers can enhance product quality, market competitiveness, and overall business success. Material selection presents opportunities for innovation, differentiation, and the creation of value-added solutions that meet the evolving needs of the agricultural industry. Selecting the right materials for manufacturing harvester spare parts involves considering several factors to ensure optimal performance including:

1. **Strength and Durability**: Agricultural parts is exposed to a lot of stress and wear during operation, so materials with high strength and durability are essential. This ensures that the machinery can face the rough conditions of agricultural operations without breaking down.
2. **Corrosion Resistance:** Agricultural parts is often used in environments that expose it to corrosive elements such as moisture, chemicals, and fertilizers. Materials that are resistant to corrosion and rust are preferred to ensure longevity and minimize maintenance requirements.
3. **Weight:** Agricultural machinery should be lightweight enough to be easily transported and operated in the field. Materials that

are too lightweight may not meet the machinery's strength and durability.

4. **Cost:** Materials used in parts manufacturing should be cost-effective and affordable, while still meeting the required strength and durability standards.
5. **Availability:** Materials should be readily available, so that production schedules can be maintained and repairs can be made quickly.
6. **Compatibility with other materials:** Materials used in agricultural machinery spare parts manufacturing should be compatible with other materials, such as lubricants and hydraulic fluids, to ensure optimal performance and minimize the risk of damage or failure.

A balance between these factors should be account to ensure that the selected materials are suitable for agricultural machinery and spare parts manufacturing.

Pattern making

Pattern making is a crucial step in the manufacturing of spare parts, ensuring precision and accuracy in the final products. This process involves the use of CAD (Computer Aided Design) to create detailed digital models of the parts. These models are then utilized in CAM (Computer Aided Manufacturing) to guide the machinery in producing the physical patterns with high precision. The integration of CAD and CAM technologies streamlines the pattern making process, enhancing efficiency and reducing errors. Table 2 represents the updated process of pattern making.

Table 2: Pattern making process

Sl no.	Process
1	CAD (Computer aided design)
2	CAM (Computer aided manufacturing)

Wooden Pattern

Wooden pattern making is a common method for creating casting patterns for various materials, including CI and MS (mild steel) alloys. Here are the steps involved in making a wooden pattern for casting CI and MS alloy

- **Design the pattern:** The first step is to create a design for the pattern. This design will determine the shape and dimensions of the final casting. It is important to keep in mind the material properties of MS alloy or CI, such as its strength and ductility, when designing the pattern.
- **Choose the wood:** Type of wood needs to be choose to use for the pattern. Some popular choices include kerosene and mahogany. The wood should be strong and durable enough to withstand the stresses of the casting process.
- **Prepare the wood:** It needs to cut the wood to the desired shape and size using a saw. Sand the edges and surfaces smooth to ensure a clean final product.
- **Add details**: Depending on the complexity of the design, additional details may need to be added to the pattern using chisels or other carving tools.
- **Apply sealant:** When the pattern is complete, it is required to apply a sealant to the surface to protect it from moisture and other damage.
- **Make the mold:** The pattern is then used to create a mold for the casting process. The pattern is placed inside a container and the space around it is filled with a molding material, such as sand or plaster. The pattern is removed when the mold has hardened.

Wooden pattern making can be an effective method for creating casting patterns for MS alloys. With careful planning and attention to detail, a high-quality pattern can be created that will produce a strong and durable final product. Sprockets, pulleys, thrust wheels, bearing holders, crawler support bars, and over 15 other spare parts are manufactured using wooden patterns (Fig. 7-8).

Fig. 7: Wooden pattern workshop

Fig. 8: Wooden pattern for casting

Casting

Casting is a fundamental method used in the manufacturing of spare parts, allowing for the development of complex shapes and designs. The process involves several techniques as mentioned in Table 3. Each suited for different types of parts and materials. Sand casting uses sand molds and is highly versatile for a wide range of metals. Reusing the sand is a cost-effective advantage in sand casting techniques and, at the same time, environmentally friendly (Adeleke *et al.*, 2022). Investment casting, also known as lost-wax casting, provides precise and detailed parts. Die casting employs high-pressure metal molds for high-volume production with excellent surface finishes. It is a non-destructive technique, unlike sand casting, because the mold can be reused quite many times after casting (Adeleke *et al.*, 2022). Gravity die casting involves pouring molten metal into a mold under gravity, resulting in high-quality, consistent parts. Each casting method plays a vital role in producing durable and reliable spare parts.

Table 3: Casting process

Sl no.	Casting
1	Sand casting
2	Investment casting
3	Die casting
4	Gravity die casting

The process of metal casting involves the following steps:

1. **Pattern making:** A pattern, which is a replica of the final product, is created using wood, metal, or other materials.

2. **Molding:** A mold is created by packing a sand mixture or other materials around the pattern, which is then removed to create a cavity in the shape of the final product.

3. **Melting:** Metal is melted in a furnace to a temperature that is appropriate for the specific metal being used.

4. **Pouring:** The molten metal is poured into the mold through a gating system, which helps to ensure a steady flow and fill.

5. **Solidification:** The metal cools and solidifies inside the mold and form the shape of the cavity.

6. **Finishing:** The final product is removed from the mold and may be finished through various processes such as grinding, polishing, or machining.

MS alloy casting

MS alloy casting refers to the process of using a specific type of alloy, typically made of iron, carbon, and silicon. This process involves heating the alloy until it reaches a molten state, and then pouring it into a mold, where it is allowed to cool and solidify into the desired shape. MS alloys are commonly used in casting applications due to their high strength, durability, and resistance to corrosion. The casting process itself can take on several different forms, including sand casting, investment casting, and die casting. Each of these methods offers its own unique set of advantages and disadvantages, and the choice of casting method will depend on the specific needs of the application.

MS alloy casting is a versatile and reliable process that can be used to create high-quality, precision parts for a wide range of industrial, automobile and agricultural (Fig. 9) applications.

Fig. 9: MS alloy casting of rear wheel, sprocket and rear wheel hub

CI casting

CI casting refers to the process of casting parts or components using cast iron as the material. Cast iron is a group of iron-carbon alloys with a carbon content greater than 2%, which makes it hard and brittle. CI has good compressive strength, wear resistance, and damping capacity, which makes it suitable for many applications.

Fig. 10: CI casting of carrier guide track roller and Pulley

CI casting is generally done using sand casting or shell molding techniques, which involve pouring molten iron into a mold made of sand or shell material (Fig. 11). The molten iron is then allowed to solidify. Cast iron has some desirable properties, it also has some limitations. It is prone to cracking under tension and is not as strong as other materials like steel. Cast iron can be difficult to weld or repair if it is damaged. Sprocket and rear rollers are made from MS alloy casting where some carrier roller and crawler guide were made from CI casting (Fig. 9- 10).

Fig. 11 : Mold making, molted alloy pouring and casted unfinished parts

Technical difference between CI and MS alloy cast

Cast Iron (CI) and Mild Steel (MS) alloy casting differ in several technical aspects. CI casting typically contains higher levels of carbon and silicon, resulting in a microstructure with graphite flakes or nodules dispersed in a matrix of ferrite or pearlite, shows high hardness and wear resistance but also brittleness. In contrast, MS casting has lower carbon content and a microstructure primarily consisting of ferritic or pearlitic grains, offering greater ductility and toughness, ideal for applications requiring flexibility and ease of fabrication. CI casting generally requires higher pouring temperatures and longer solidification times compared to MS casting due to its slower cooling rate. CI castings are commonly used for parts requiring strength and durability, such as engine blocks, while MS castings find applications in different parts like roller, guide, bearing holder etc. where ductility is crucial. Heat treatment processes may differ between the two, with CI castings often undergoing treatments to refine the microstructure, while MS castings may be subjected to processes to relieve internal stresses and improve machinability. The mold design and casting parameters may also vary, with CI casting often requiring specialized materials and gating system designs to withstand high temperatures, while MS casting may involve simpler molds and lower temperatures. Overall, the differentiation between CI and MS alloy casting lies in composition, mechanical properties, solidification characteristics, applications, and processing parameters, which dictate their suitability for various industrial applications. Guide wheels, rollers, blade reaping cranks, and over 16 other spare parts are produced using the casting process.

Machining

Machining is a critical process in spare parts manufacturing, involving various techniques to shape and finish components. As well-known, turning, milling, and drilling are the most common machining operations (Gökçe, *et. al.*, 2019). Key processes beside boring, reaming, and CNC machining (Table 4). Advanced methods such as wire EDM (electrical discharge machining), double disc grinding, diamond turning, electrochemical machining, EDM, gear cutting, and thread rolling ensure precision and high-quality results. Each technique plays a vital role in creating accurate and reliable spare parts.

Table 4: Machining process

Sl no.	Processes
1	Turning
2	Milling
3	Boring
4	Reaming
5	Drilling
6	CNC machining
7	Wire EDM (electrical discharge machining)
8	Double disc grinding
9	Diamond turning
10	Electrochemical machining
11	Electrical discharge machining (EDM)
12	Gear cutting
13	Thread rolling

The goal of machining is to create a finished product that meets specific design specifications, such as dimensions, surface finish, and tolerance levels. Machining can involve a range of techniques, including turning, milling, drilling, grinding, and sawing.

Lathe

Lathe machining is a process of shaping a workpiece using a lathe machine. A lathe is a machine tool that rotates the workpiece about an axis of rotation to perform various operations such as cutting, drilling, sanding, or turning. The workpiece is typically clamped in place and rotated at a high speed while a cutting tool is applied to it to remove material and create the desired shape (Fig. 12, 13 and 14). Some of the benefits of lathe machining include high accuracy, repeatability, and the ability to work with a wide range of materials including metals, plastics, and wood.


Fig. 12 : Machining of tension frame and rear roller shaft in lathe machine


Fig. 13: Machining of driving chain wheel and fuel tank cap in lathe machine

Fig. 14: Machining of sprocket and track roller

Brass bars, bevel gears, tension bolts, HST output shafts, and over 10 other spare parts are manufactured through machining, particularly using the turning process on a lathe machine.

Deburring

Deburring is crucial in manufacturing spare parts to remove sharp edges and burrs, ensuring a smooth finish. The main methods include tumbling/deburring, which uses abrasive materials to polish parts; manual or mechanical deburring, which removes burrs by hand or machine; and thermal deburring, which uses a controlled explosion to remove burrs from hard-to-reach areas (Table 5). Each method improves the safety, functionality, and appearance of the final product.

Table 5: Deburring process

Sl no.	Processes
1	Tumbling/deburring
2	Deburring
3	Thermal deburring

Drilling

Drilling refers to the process of making holes or bores in a material. Drilling machines use a rotary cutting tool called a drill bit, which is typically made of high-speed steel or carbide. The drill bit is rotated at high speeds while applying downward pressure to the material, causing it to be removed and creating a hole. Different types of drills and drill bits are used depending on the material being drilled, the size of the hole, and the desired outcome (Fig. 15).

Fig. 15: Drilling of harvester chassis.

Tension bolts, chassis, HST output shafts, and similar parts undergo various manufacturing processes, including drilling.

Grinding

Grinding processes are integral to material refinement in manufacturing, each serving unique roles in achieving precision and surface quality. These include Blanchard grinding, ideal for large parts with high stock removal; surface grinding, renowned for producing flat and smooth surfaces; center-less grinding, used for precise cylindrical parts; CBN (cubic boron nitride) grinding, employing cubic boron nitride for hardened materials; rotary swaging, for forming precise shapes; ultrasonic machining, utilizing ultrasonic vibrations for intricate features; thermal drilling, creating holes through thermal energy; and thermochemical diffusion, enhancing surface properties through chemical processes (Table 6). Together, these processes contribute to the diverse capabilities and applications of grinding in industrial settings. Figure 16 shows the operation of surface grinding.

Table 6: Grinding process

Sl no.	Processes
1	Blanchard grinding
2	Surface grinding
3	Center less grinding
4	CBN grinding
5	Rotary swaging
6	Ultrasonic machining
7	Thermal drilling
8	Thermochemical diffusion

Fig. 16: Surface grinding

Brass bars, adjusting screws, bases, bevel gears, and similar components undergo multiple manufacturing processes, including grinding.

Milling

Milling is a type of machining process that involves using a machine tool called a milling machine to remove material from a workpiece. The milling machine is equipped with cutting tools that rotate at high speeds and remove material from the work piece in order to achieve the desired shape, size, and surface finish (Fig. 17).

Fig. 17: Milling of harvester shaft

Sprockets, pulleys, shafts, and similar components are manufactured through various processes, including milling.

Welding

Welding processes are crucial for joining materials in manufacturing, offering various techniques to suit different applications. These processes include arc welding, MIG welding, TIG welding (tungsten inert gas), plasma arc welding, electron beam welding, gas metal arc welding (GMAW), stick welding, ultrasonic welding, laser beam welding, and resistance welding (Table 7). Each method provides unique advantages in terms of precision, strength, and applicability to different materials and industries.

Table 7: Welding process

Sl no.	Processes
1	Arc welding
2	MIG welding
3	TIG welding (tungsten inert gas)
4	Plasma Arc welding
5	Electron beam welding
6	Gas metal arc welding (GMAW)
7	Stick welding
8	Ultrasonic welding
9	Laser beam welding
10	Resistance welding
11	Friction stir welding
12	Forge welding

Electric arc welding is a welding process that uses an electric arc to melt and join metals. In this process, an electric current is passed through an electrode to create an arc, which generates intense heat that melts the metal work pieces. The molten metal then cools and solidifies, forming a strong bond between the work pieces. The resulting joint from electric arc welding can be very strong and durable. The properties of the joint depend on the type of metal being welded, the type of electrode used, and the welding process parameters such as the welding current, voltage, and welding speed. It can be used to join a wide variety of metals, including steel, stainless steel, aluminum, and copper alloys. It is commonly used in manufacturing, construction, and repair industries.

Precautions: Electric arc welding can produce some imperfections in the joint, such as porosity or cracks, if not done properly. These imperfections can weaken the joint and make it more susceptible to failure under stress. To minimize the risk of imperfections, it is important to use proper welding techniques, maintain clean and dry welding surfaces, and use the correct electrode for the specific metal joining.

Depth control joint shafts and similar components are manufactured through process of joining that include electric arc welding.

Miscellaneous process

Various other manufacturing processes play crucial roles in shaping, joining, and finishing materials. These processes include sintering, extrusion welding, friction drilling, friction stir welding, black oxide coating, hot rolling, plunge EDM, rim rolling, scroll sawing, soldering, spark erosion, stamping, stamp pressing, prototyping, pressing, rolling, sawing, threading, powder metallurgy, burnishing, metal spinning, micro-welding, micro-fabrication, nitrating, plasma spray coating, spray welding, and spray forming (Table 8). Each technique provides unique capabilities to enhance the functionality and performance of products across diverse industrial applications.

Table 8: Other processes

Sl no.	Processes
1	Sintering
2	Extrusion welding
3	Friction drilling
4	Friction stir welding
5	Black oxide coating
6	Hot rolling
7	Plunge EDM
8	Rim rolling
9	Scroll sawing
10	Soldering
11	Spark erosion
12	Stamping
13	Stamp pressing
14	Prototyping
15	Pressing
16	Rolling
17	Sawing
18	Threading
19	Powder metallurgy
20	Burnishing

Sl no.	Processes
21	Metal spinning
22	Micro welding
23	Micro fabrication
24	Nitrating
25	Plasma spray coating
26	Spray welding
27	Spray forming

Heat treatment

Lattice structure of metal

A lattice structure is a repeating arrangement of atoms or molecules in a crystalline solid. Metals are commonly found in a lattice structure, which gives them their characteristic strength, ductility, and conductivity. In a metal lattice structure, the atoms are arranged in a three-dimensional pattern known as a crystal lattice. The lattice is made up of repeating units called unit cells, which contain one or more atoms. The arrangement of atoms within the unit cell determines the overall structure of the lattice. There are several different types of lattice structures that can be found in metals, including the face-centered cubic (FCC), body-centered cubic (BCC), and hexagonal close-packed (HCP) structures. These structures are named after the way the atoms are arranged within the unit cell.

Heat treatment is a group of controlled processes used to alter the properties of a material, typically metals and alloys, by subjecting them to heating and cooling cycles. Heat treatment alters the crystal lattice, enhancing the metal's mechanical properties such as hardness, strength, and ductility. There are several types of heat treatment, each designed to achieve specific material properties and characteristics (Fig. 18).

Heat treatment processes are essential for altering the properties of materials to enhance their performance. These processes include annealing, tempering, quenching, nitriding, induction hardening, cryogenic treatment, hot isostatic pressing (HIP), flame hardening, high-frequency induction welding, and vacuum heat treating (Table 9). Each method offers unique benefits for improving hardness, strength, ductility, and wear resistance of materials in various industrial applications.

Table 9: Process involves in heat treatment

Sl no.	Processes
1	Annealing
2	Tempering
3	Quenching
4	Nitriding
5	Induction hardening
6	Cryogenic treatment
7	Hot isostatic pressing (HIP)
8	Flame hardening
9	High frequency induction welding
10	Vacuum heat treating

Annealing

Annealing involves heating the material to a specific temperature and then slowly cooling it to relieve internal stresses, improve ductility, and refine the microstructure. There are various types of annealing, including:

1. **Full Annealing:** The material is heated above its critical temperature and cooled slowly in a furnace to achieve maximum softening and uniformity.
2. **Normalizing:** Similar to full annealing but with a faster cooling rate, normalizing is used to refine grain structure and improve mechanical properties.
3. **Stress Relieving:** Annealing at a lower temperature to relieve residual stresses without significant microstructural changes.



Fig. 18 : Gas furnace, electric furnace and water bath of quenching

Quenching

Quenching involves rapidly cooling the material after heating to achieve high hardness and strength. This process is commonly used in hardening steel.

Tempering

Tempering is often performed after quenching to reduce the material's brittleness and improve toughness. The material is reheated to a lower temperature and then cooled.

Hardening

Hardening is the process of heating the material to a specific temperature and then rapidly cooling it to achieve high hardness and strength.

Case hardening

Case hardening is a surface heat treatment process used to increase the hardness of the outer layer of a material while maintaining a softer core. Common methods include carburizing (adding carbon to the surface) (Fig. 19) and nitriding (adding nitrogen to the surface).

Fig. 19 : Carburizing

Precipitation hardening (Aging)

Precipitation hardening, also known as age hardening, is a heat treatment method used to increase the yield strength of materials by forming fine particles of an impurity phase within the material's microstructure. It is commonly applied to structural alloys like aluminum, magnesium, nickel, titanium, some steels, and super alloys to enhance their mechanical properties, especially at high temperatures.

Cryogenic treatment

Cryogenic treatment involves cooling the material to extremely low temperatures (typically below -100°C) to enhance its wear resistance and dimensional stability.

Flame hardening

Flame hardening is a localized surface hardening method that involves heating only specific areas of a component using an oxy-fuel flame and then quenching those areas (Fig. 20).

Fig. 20: Flame Hardening

The choice of heat treatment method depends on the material's composition, the desired properties, and the intended application.

Thrust wheel axles, carrier rollers, driving chain wheels (17 teeth), and thrust wheel shafts are produced using various heat treatment methods.

Coating, plating and painting of manufacturing spare parts process

Coating processes are vital for enhancing material properties and protection in manufacturing. These processes include electroplating, powder coating, electroforming, plating, anodizing, hard anodizing, epoxy coating, PVD (physical vapor deposition) coating, thermal spraying, plasma coating, wear coating, white metal coating, zinc coating, zinc phosphating, zinc plating, ceramic coating, diffusion coating, and vapor polishing (Table 10). Each method provides unique benefits for durability, corrosion resistance, and surface enhancement.

Table 10: Process involves in coating

Sl no.	Processes
1	Electroplating
2	Powder coating
3	Electroforming
4	Plating
5	Anodizing
6	Hard anodizing

Sl no.	Processes
7	Epoxy coating
8	PVD coating (physical vapor deposition)
9	Thermal spraying
10	Plasma coating
11	Wear coating
12	White metal coating
13	Zinc coating
14	Zinc phosphating
15	Zinc plating
16	Ceramic coating
17	Diffusion coating
18	Vapor polishing

Electroplating

This process involves submerging the spare parts in an electrolyte bath and applying an electrical current to deposit a layer of metal (such as chrome, nickel, or zinc) onto the surface (Fig. 21). Electroplating offers excellent corrosion resistance and a decorative finish. The technique by which a protective thin layer is deposited onto a metal body through an electrochemical reaction. If the material is chromium, the electroplating process is called chrome plating.

Fig. 21: Zinc electroplating

Chrome plating

1. **Decorative chrome plating:** It is intended to be aesthetically pleasing and durable chromium layer
2. **Hard chrome plating:** An electroplating technique in where a thick layer of chromium applies to engineering parts (nut-bolt, gear, shaft, etc). Standard hard chrome plating thickness ranges from 0.02 to 0.127 mm. Figure 22 shows hard chrome plating process applied to an HST shaft, enhancing its durability and resistance to wear.

Fig. 22: Hard chrome plating of HST shaft

Powder coating: In this method, a dry powder coating is applied electrostatically to the parts and then cured in an oven. It forms a durable, chip-resistant finish and is often used for parts that require resistance to wear and corrosion.

Anodizing: This is an electrochemical process used on aluminum parts to create a protective oxide layer on the surface (Fig. 23). Anodized parts are corrosion-resistant and can have various colors and finishes.

Fig. 23: Anodizing

Oil film coating

The process of applying a thin layer of oil to machine spare parts to enhance lubrication, reduce friction, and prevent wear is known as oil film coating of machine parts. The oil film coating process, also called oil coating or oil lubrication of machine parts, involves creating an oil layer on the surface of moving and static parts to reduce friction, corrosion due to chemical reactions, and wear. The application method of oil film coating may vary on the basis of specific requirements and part sizes as well as dimensions. Commonly used oil film coating methods are

1. **Dip coating-** Dip coating is a method of oil film coating where the object or spare part to be coated sinks into a coating oil container. The coated part is carefully withdrawn from the container, followed by the draining of the excess oil.
2. **Spray coating-** Spray coating is done by spraying a fine mist or atomized coating oil onto the surface of the spare part to be coated. A nozzle or spray gun is used to spray, and oil particles are spread onto the surface, forming a thin film
3. **Brush or roller coating-** In the brush or roller coating method, a brush or roller is used to apply the oil to the surface. Oil is evenly distributed onto an object's or spare part's surface by dipping the brush into an oil container.

Painting

Painting of spare parts is a common finishing process to protect the parts from corrosion, enhance their appearance, and provide additional durability. There is various color code used worldwide. Among them RAL (European system), PMS **(**Pantone Matching System) are widely accepted color coding system. Table 11 presents a structured prototype system for categorizing harvester spare parts using color codes to indicate their importance and status. Each color, identified by a specific RAL code, corresponds to different groups of components, ranging from standard parts to those that are warns to danger. This color coding system streamlines the identification and management of parts, facilitating efficient maintenance and repair processes. By providing a clear visual reference, it enhances operational effectiveness in agricultural machinery manufacturing (Fig. 24).

Table 11: Color coding of harvester spare parts

Color	Code	Part Name	Main feature of the color
Orange	RAL 2009	Body panel	High visibility, energetic, and vibrant appearance.
Jet Black	RAL 9005	Frame, roller, sprocket, fuel tank, fluid reservoir, Exhaust & intake Manifold, Drive Belts, Tires and Wheels	Provides contrast, looks sturdy, and hides dirt.
Signal White	RAL 9003	Reel, threshing cylinder cover	Clean look, easy to spot control marks, enhances visibility.
Light Grey	RAL 7035	Engine Cover, Protective Grills.	Neutral tone, enhances temperature control, and keeps appearance clean.
Flame Red	RAL 3000	Safety covers, hot surfaces	Warns of danger, heat areas; ensures caution.
Green	RAL 6018	Gaskets and Seals, filters	Standard Components
Blue	RAL 5010	Radiator, Coolant Reservoir,	Cooling system related Components
White	RAL 9010	Prototype spares	Inspection & testing phase

Fig. 24**:** Color combination of full feed combine harvester

Manufacturing of spring

In the manufacturing of springs for combine harvesters, meticulous attention to material selection, manufacturing processes, and quality control measures is paramount to ensure optimal performance and longevity in the demanding agricultural environment.

The choice of material for springs in combine harvesters depends on various factors such as load requirements, environmental conditions, and cost-effectiveness. High carbon steel, known for its excellent tensile strength and resilience, is a popular choice for its ability to withstand heavy loads and repeated cycles of compression and extension (Fig. 25). Alloy steels, including chrome vanadium and chrome silicon, offer enhanced fatigue resistance, making them suitable for components subjected to high stress and strain. Stainless steel grades are preferred for their corrosion resistance, crucial for springs exposed to moisture, agricultural chemicals, and outdoor elements.

Fig. 25 : Raw material of spring (High carbon and Stainless steel)

The manufacturing process begins with the selection of appropriate raw materials in the form of wire or strip stock. The material is then coiled into the desired spring shape using specialized machinery and techniques (Fig. 26). Cold forming or hot forming methods may be employed depending on the material properties and design requirements. After forming, the springs undergo heat treatment processes such as quenching and tempering to optimize their mechanical properties, including strength, hardness, and resilience. Surface treatments, such as coating applications, may be applied to improve corrosion resistance and surface finish.

Fig. 26 : Coiling machine (special type of lathe) and manufactured springs

Strict quality control measures are implemented throughout the manufacturing process to ensure dimensional accuracy, material integrity, and adherence to design specifications. Inspection procedures, material testing, and performance evaluations are conducted to verify the quality and reliability of the springs before they are installed in combine harvesters. The manufacturing of springs for combine harvesters requires a comprehensive understanding of material properties, manufacturing processes, and performance requirements. By carefully selecting materials, employing appropriate manufacturing techniques, and implementing strict quality control measures, manufacturers can produce high-quality springs that meet the demanding performance expectations of combine harvesters, contributing to their efficiency, reliability, and durability in agricultural operations.

Developing durable and high-performance spare parts for combine harvesters relies on careful material selection, efficient manufacturing processes, and thorough quality control. Emphasizing cost-effective and sustainable alternatives like ship-breaking shafts highlights a commitment to innovation. Precise casting processes, including pattern making, CI, and MS alloy casting, are key to achieving the desired properties of each part. Machining techniques such as lathe machining, drilling, and milling are crucial for shaping and refining parts, while electric arc welding ensures strong and lasting connections. Heat treatments like annealing, quenching, and tempering improve material properties, and surface finishing processes such as electroplating, powder coating, and painting protect parts from corrosion, extending their lifespan. The color coding system for harvester spare parts aids in efficient identification and management. Manufacturing springs with careful material selection and stringent quality assurance ensures reliability and performance in demanding agricultural environments. Focusing on material selection, manufacturing processes, and quality control is essential for producing high-quality, durable spare parts that enhance the efficiency and reliability of combine harvesters.

Chapter Six

Manufacturing Spare Parts

Certain fast-moving spare parts were manufactured using locally available materials and then compared with imported counterparts to identify any differences. Key aspects such as weight, dimensions and hardness will be evaluated for potential variations. The goal is to ensure that our parts consistently meet the highest quality standards. Any discrepancies found will be addressed to improve both quality and functionality. The findings from this analysis, along with the steps taken to enhance the parts, will be presented to ensure the delivery of superior products.

Table 1: Comparison between imported and locally manufactured spare parts

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
1	Thrust wheel axle	Picture		
		Length (mm)	195.1	195.1
		Diameter (mm)	30	30.05
		Material	MS	MS
		Weight (kg)	1.038	1.047
		Hardness, HRC	54.5	55.0
		Manufacturing process	Not identified	Turning, drilling, threading, heat treatment, plating
2	Thrust wheel shaft	Picture		
		Length (mm)	234.9	234.4
		Diameter (mm)	39.3	39.3

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Material	MS	MS
		Weight (kg)	1.1	1.1
		Hardness, HRC	49.8	48
		Manufacturing process	Not identified	Turning, drilling, threading, heat treatment, plating
3	Support wheel shaft	Picture		
		Length (mm)	215.8	215.5
		Diameter (mm)	35	34.9
		Material	MS	MS
		Weight (kg)	1.04	1.08
		Hardness, HRC	44	43.7
		Manufacturing process	Not identified	Turning, drilling, threading, heat treatment, plating
4	Tension bolt	Picture		
		Length (mm)	308.4	308.4
		Width (mm)	21.2	21.2
		Diameter (mm)	28	28.9
		Material	MS	MS
		Weight (kg)	0.73	0.82
		Hardness, HRC	33.5	34.6

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Manufacturing process	Not identified	Turning, shaping, drilling, threading, heat treatment, plating
5	Tension Nut	Picture		
		Length (mm)	25.8	25.8
		Width (mm)	31.6	31.3
		Bore diameter (mm)	22.0	22.0
		Material	MS	MS
		Weight (kg)	0.09	0.09
		Hardness, HRC	30.4	31.1
		Manufacturing process	Not identified	Turning, shaping, boring, Threading, heat treatment, boring, coating
6	Fan belt pulley	Picture		
		Diameter (mm)	256.8	257.2
		Material	MS	MS
		Weight (kg)	1.8	2.1
		Hardness, HRC	31	30.9
		Manufacturing process	Not identified	Casting, turning, milling, boring, heat treatment, coating

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
7	Upper jockey pulley	Picture		
		Width (mm)	166.8	168.4
		Diameter (mm)	27.7	29
		Material	MS	MS
		Weight (kg)	3.0	2.9
		Hardness, HRC	31.2	30.8
		Manufacturing process	Not identified	Pattern, casting, turning, milling, boring, coating
8	Carrier roller shaft	Picture		
		Length (mm)	192.3	192.3
		Diameter (mm)	30	30
		Material	MS	MS
		Weight (kg)	1.1	1.2
		Hardness, HRC	47.7	47.9
		Manufacturing process	Not identified	Turning, drilling, threading, heat treatment, plating

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
9	Reel belt pulley	Picture		
		Diameter (mm)	139.4	139.3
		Height (mm)	62	62
		Material	MS	MS
		Weight (kg)	3.1	3.3
		Hardness, HRC	28.9	30.2
		Manufacturing Process	Not identified	Pattern, casting, turning, boring, heat treatment, coating
10	Sprocket wheel	Picture		
		Diameter (mm)	254.3	254.3
		Material	MS	MS
		Weight (kg)	7.5	7.5
		Hardness, HRC	48.7	48.9
		Manufacturing process	Not identified	Pattern, casting, turning, boring, milling, heat treatment, coating
11	Chain spocket-13 teeth	Picture		

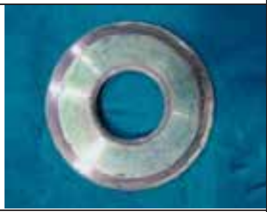
Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Diameter (mm)	58.50	57.50
		Material	MS	MS
		Weight (kg)	0.09	0.08
		Hardness, HRC	57.8	58.0
		Manufacturing process	-	Turning, boring, milling, heat treatment, plating
12	Double row sprocket	Picture		
		Diameter-1 (mm)	199.7	199.4
		Diameter-2 (mm)	24.7	24.4
		Material	MS	MS
		Weight (kg)	2.5	2.5
		Hardness, HRC	51.0	52.2
		Manufacturing process	Not identified	Drilling, boring, turning, milling, joining, heat treatment, plating
13	Bevel gear	Picture		
		Outer diameter (mm)	53.5	53.5
		Inner diameter (mm)	20	20
		Material	MS	MS
		Weight (kg)	0.17	0.17
		Hardness, HRC	56.6	56.6

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Manufacturing Process	Not identified	Turning, milling, heat treatment, plating
14	Driving chain sprocket	Picture		
		Outer diameter (mm)	73.5	73.5
		Inner diameter (mm)	24.1	24.1
		No of teeth	17	17
		Material	MS	MS
		Weight (kg)	0.29	0.29
		Hardness, HRC	54.1	53.8
		Manufacturing process	Not identified	Turning, boring, milling, heat treatment, plating
15	Chain wheel sprocket	Picture		
		Outer diameter (mm)	98	97.5
		Inner diameter (mm)	27	27
		No of teeth	16	16
		Material	MS	MS Sheet & Shaft
		Weight (kg)	0.47	0.46
		Hardness, HRC	48.0	48.4
		Manufacturing Process	Not identified	Turning, Joining, boring, milling, , heat treatment, plating

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
16	Chain spocket-15 teeth	Picture		
		Outer diameter (mm)	66.5	66.5
		Inner diameter (mm)	13.5	13.5
		Height (mm)	32.5	32.5
		Material	MS	MS
		Weight (kg)	0.14	0.14
		Hardness, HRC	49.5	51.0
		Manufacturing process	Not identified	Turning ,boring, , milling, heat treatment, plating
17	Thread shaft	Picture		
		Length (mm)	88	89
		Diameter (mm)	16	16
		Material	MS	MS
		Weight (kg)	0.08	0.08
		Hardness, HRC	52.3	52.2
		Manufacturing process	Not identified	Turning, drilling, threading, heat treatment, plating

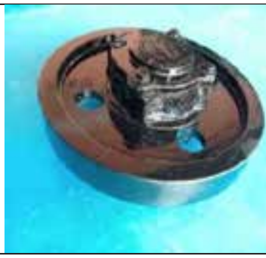
Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
18	Crank pin	Picture		
		Length (mm)	89	89
		Diameter (mm)	25	25
		Material	MS	MS
		Weight (kg)	0.15	0.151
		Hardness, HRC	59.5	60
		Manufacturing process	Not identified	Turning, drilling, Threading, heat treatment, plating
19	Carrier roller-nylon	Picture		
		Length (mm)	137.5	137.5
		Diameter (mm)	30.2	30.2
		Material	Nylon	Nylon
		Weight (kg)	0.43	0.40
		Manufacturing process	Not identified	Turning, boring
20	Carrier roller-metal	Picture		

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Diameter (mm)	30.1	30.1
		Material	Nylon	MS
		Weight (kg)	0.44	3
		Hardness	-	52.0
		Manufacturing Process	Not identified	Casting, turning, boring, coating
21	Main roller-full feed	Picture		
		Length(mm)	179.9	178.6
		Outer dia (mm)	71.2	70.8
		Material	MS	MS
		Weight (kg)	4.1	4.2
		Hardness, HRC	51.1	50.0
		Manufacturing process	Not identified	Pattern, casting, turning, boring, coating
22	Engine pulley	Picture		
		Outer diameter (mm)	277.1	277.2
		Inner diameter (mm)	148.2	148.21
		Length (mm)	272.9	275.3
		Material	MS	MS
		Weight (kg)	18.7	19

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Hardness, HRC	50.2	49.5
		Manufacturing process	Not identified	Pattern, casting turning, boring coating
23	Washer-small	Picture		
		Outer diameter (mm)	43.5	43.5
		Inner diameter (mm)	13	13
		Material	MS	MS
		Weight (kg)	0.05	0.05
		Hardness, HRC	38.2	36.6
		Manufacturing process	Not identified	Turning , boring, coating
24	Washer-large	Picture		
		Outer diameter (mm)	72.1	72.1
		Inner diameter (mm)	30	30
		Material	MS	MS
		Weight (kg)	0.02	0.17
		Hardness, HRC	36.3	36.2
		Manufacturing process	Not identified	Turning, boring, coating

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
25	Blade reaping crank	Picture		
		Length (mm)	217.5	217.5
		Outer diameter (mm)	64.9	64.9
		Inner diameter (mm)	51.5	51.5
		Material	MS	MS
		Weight (kg)	1.2	1.2
		Hardness, HRC	47.2	48.0
		Manufacturing process	Not identified	Pattern casting, turning, boring, heat treatment, coating
26	Bearing seat cover	Picture		
		Length (mm)	92.8	92.8
		Thickness (mm)	16.5	16.5
		Diameter (mm)	39.8	39.8
		Material	MS	MS
		Weight (kg)	0.34	0.44
		Hardness, HRC	58.2	57.0
		Manufacturing process	Not identified	Pattern casting, turning, boring, heat treatment, coating

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
27	Support wheel	Picture		
		Length(mm)	167.9	168.3
		Outer diameter (mm)	121.1	121.9
		Material	MS	MS
		Weight (kg)	2.4	2.7
		Hardness, HRC	51.0	51.1
		Manufacturing process	Not identified	Pattern casting turning, boring, coating
28	Roller shaft	Picture		
		Length (mm)	200.4	199.53
		Diameter (mm)	34.9	34.8
		Material	MS	MS
		Weight (kg)	0.98	0.96
		Hardness, HRC	61.7	61.1
		Manufacturing process	Not identified	Turning, drilling, threading, heat treatment, plating
29	Arm redial	Picture		
		Length (mm)	108	108.1

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Inner diameter - 1, (mm)	51	51
		Inner diameter-2, (mm)	22.5	22.5
		Neck length (mm)	8.0	8.0
		Material	MS	MS
		Weight (kg)	0.39	0.42
		Hardness, HRC	45.5	45.9
		Manufacturing process	Not identified	Pattern, casting, turning, boring, coating
30	Rear wheel	Picture		
		Outer diameter (mm)	256.8	256.9
		Inner diameter (mm)	81.8	81.8
		Material	MS	MS
		Weight (kg)	7.5	7.5
		Hardness, HRC	52.0	51.3
		Manufacturing process	Not identified	Pattern, casting, turning, boring, coating
31	Crawler guide-large	Picture		
		Length (mm)	665	665

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Width (mm)	34.9	34.9
		Material	MS	MS
		Weight (kg)	6.2	6.2
		Hardness, HRC	51.0	52.1
		Manufacturing process	-	Pattern, casting, grinding, coating
32	Rear wheel bearing cover	Picture		
		Length (mm)	106.3	106.3
		Height (mm)	37.2	37.2
		Material	MS	MS
		Weight (kg)	1.1	1.2
		Hardness, HRC	57	59.2
		Manufacturing process	Not identified	Pattern, casting, turning, boring, coating
33	Crawler guide-small	Picture		
		Length(mm)	590	591
		Width (mm)	31.4	31.4
		Material	MS	MS
		Weight (kg)	5.5	5.6
		Hardness, HRC	52.2	52.0
		Manufacturing process	Not identified	Pattern, casting, grinding, coating

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
34	Crawler guide-large	Picture		
		Length (mm)	594	594.3
		Width (mm)	34.1	34.2
		Material	MS	MS
		Weight (kg)	4.1	4.3
		Hardness, HRC	53.15	52.1
		Manufacturing process	Not identified	Pattern, casting, grinding, coating
35	Crawler guide-small	Picture		
		Length (mm)	550	550
		Width (mm)	30.6	30.5
		Material	MS	MS
		Weight (kg)	4.0	4.1
		Hardness, HRC	55.9	55.9
		Manufacturing process	Not identified	Pattern, casting, grinding, coating
36	HST shaft	Picture		
		Length (mm)	224.1	224.3

Sl no.	Name of Parts	Parameter	Imported	Locally manufactured
		Diameter (mm)	30	30
		Material	D2	D2
		Weight (kg)	0.9	0.9
		Hardness, HRC	59.4	59.1
		Manufacturing process	Not identified	Turning , milling drilling, heat treatment, plating
37	Main roller-full feed BRRI model	Picture		
		Height (mm)	177.1	177.1
		Diameter (mm)	70.5	70.7
		Material	MS	MS
		Weight (kg)	8.2	8.3
		Hardness, HRC	51.4	51.0
		Manufacturing process	Not identified	Pattern, casting, turning, boring, coating
38	Brass bar	Picture		
		Length (mm)	136.3	136.3
		Width (mm)	131.7	131.7
		Material	MS	MS
		Weight (kg)	2.5	2.5
		Hardness, HRC	40	41
		Manufacturing process	Not identified	Turning, shaping, boring, coating

The contrasting analysis between the original and locally manufactured parts has been thoroughly discussed. The insights gained from this comparison process provide a foundational basis for ongoing enhancements and refinements. By understanding and addressing the discrepancies between the original and locally manufactured parts, continuous improvements can be made to achieve higher standards of quality and performance. This analysis not only helps in optimizing current designs but also informs future developments, ensuring greater reliability and effectiveness in the final products.

Chapter Seven

Quality Control

Quality control (QC) is a systematic process used to ensure that products meet specified quality standards through consistent inspections, testing, and corrective actions during and after manufacturing. It is essential for ensuring product reliability, safety, and customer satisfaction by identifying and addressing defects early, thereby reducing waste and associated costs. QC is also crucial for compliance with industry regulations, protecting a company's reputation, and enhancing production efficiency. By continuously improving processes based on QC findings, manufacturers can maintain high standards, ensuring that each product, particularly in critical areas like metal casting, machining, heat treatment, and coating, performs as expected and meets customer needs.

Visual inspection

Pouring of molten metal into the empty shaped space was carefully maintained so that non filling or voids was not created in the casted parts. It was also maintained no distortions or bends of the molds before pouring.

Cast micro finish comparators

Cast micro finish comparators are tools used for measuring the surface roughness of machined or manufactured parts (Fig. 1). They consist of a set of standard reference surfaces with known roughness values, which are used to compare against the surface roughness of the part being measured. The comparators are typically made from a cast metal material, such as iron or steel, and have a series of grooves or ridges machined onto their surface to create the known roughness values. These values are typically given in Ra or RMS units, which are standard measures of surface roughness. To use a cast micro finish comparator, the user places the comparator on the surface of the part being measured and visually compares the surface roughness of the part to the reference surfaces on the comparator. The user then selects the reference surface that most closely matches the surface roughness of the part, and the roughness value associated with that surface is used to report the surface roughness of the part. Cast micro finish comparators are commonly used in manufacturing and quality control applications to ensure that machined parts meet the required specifications for surface finish.

Fig. 1: Cast micro finish comparators

Mechanical properties inspection

Inspection of mechanical properties of the casted parts can bring the outstanding performance of the produce parts if carefully maintained. Scope of mechanical properties Inspection are:

Dimensional inspection

By setting a standard value range of casted parts and ensuring the values fall within is the procedure of the inspection. Use of micrometer, thread and other required gauges are the steps to ensure the proper casted dimension of the produced parts.

Coordinate measuring machine (CMM)

In spare parts manufacturing, a coordinate measuring machine (CMM) is an indispensable tool used for precise dimensional inspection of components (Fig. 2). This highly accurate device measures the geometric features of machined parts, including dimensions, angles, and surface profiles, ensuring that they meet the specified tolerances and quality standards. By utilizing probe technology and advanced software algorithms, CMMs can capture detailed measurements with micron-level accuracy, enabling engineers to verify part conformity and detect any deviations from design specifications. With its ability to generate comprehensive inspection reports and perform automated measurement routines, CMMs enhance quality control processes, reduce inspection times, and facilitate the production of high-quality harvester spare parts. From verifying critical dimensions to ensuring overall geometric integrity, CMMs play an important role in ensuring the reliability and performance of agricultural machinery components.

Fig. 2: Coordinate measuring machine (CMM)

Hardness testing machine

In harvester spare parts manufacturing, hardness testing is crucial to ensure components can withstand the demanding conditions of agricultural operations. It helps identify potential weaknesses in materials, preventing failures in the field. By providing accurate measurements of material resistance, hardness testing ensures the durability and reliability of harvester spare parts and enhancing ultimately the performance and longevity of agricultural machinery. Figure 3 shows the machine operation of hardness testing machine.

Fig. 3: Hardness testing machine

Height gauge

In parts manufacturing, a height gauge is essential for ensuring precise dimensions and alignments of components (Fig. 4). This tool accurately measures vertical distances, allowing engineers to verify the height of machined surfaces, holes with ease. By providing reliable measurements, the height gauge aids in maintaining strict quality control standards, ensuring parts fit together and function as intended. Its simplicity and effectiveness make it incomparable in the production process, facilitating the creation of high-quality harvester spare parts that meet exacting specifications.

Fig. 4: Height gauge

Microscope

In manufacturing quality control, a microscope serves as an essential tool for detailed inspection and analysis of component features at a microscopic level. This instrument allows engineers to examine surfaces, structures, and defects with unparalleled clarity and precision (Fig. 5). By magnifying objects hundreds or even thousands of times, a microscope enables the detection of minuscule imperfections that may affect the performance or integrity of spare parts. Whether assessing the quality of machined surfaces, identifying microscopic cracks, or inspecting intricate features, the microscope plays a pivotal role in maintaining the highest standards of quality control. Its ability to reveal hidden flaws and anomalies ensures that spare parts meet stringent industry requirements and perform reliably in the field.

Fig. 5: Microscope

Surface roughness tester

Surface roughness measurement is essential for ensuring the quality and functionality of components. This parameter refers to the irregularities or deviations in the surface texture of machined parts, which can impact performance, durability, and aesthetics. By employing surface roughness measurement techniques such as profilometers or optical interferometry, manufacturer can quantitatively evaluate the smoothness of surfaces and identify any deviations from desired specifications. Accurate assessment of surface roughness enables manufacturers to optimize machining processes, minimize friction and wear, and enhance the overall performance of spare parts. It ensures that parts meet regulatory standards and customer expectations for quality and reliability. Surface roughness measurement plays a crucial role in maintaining the integrity and functionality of harvester spare parts throughout the manufacturing process (Fig. 6).

Fig. 6: Surface roughness tester

Ultrasonic flaw detector

In manufacturing, an ultrasonic flaw detector serves as a vital tool for non-destructive testing (NDT) of materials, ensuring the integrity and reliability of components. This sophisticated device utilizes ultrasonic waves to detect internal flaws, defects, or discontinuities in materials such as metals, composites, and ceramics (Fig. 7). By emitting high-frequency sound waves into the material and analyzing the reflected signals, the ultrasonic flaw detector can identify imperfections such as cracks, voids, inclusions, or porosity that may compromise the structural integrity or performance of harvester spare parts. With its ability to penetrate deep into materials and provide real-time inspection results, the ultrasonic flaw detector enables engineers to identify potential issues early in the manufacturing process, facilitating timely corrective actions and preventing costly failures in the field. This non-destructive testing technique ensures that harvester spare parts meet stringent quality standards, enhancing safety, reliability, and customer satisfaction.

Fig. 7: Ultrasonic flaw detector

Tool pre-setter

A tool pre-setter is an essential instrument used for precision measurement and setup of cutting tools used in machining operations. This device allows engineers and machinists to accurately measure and preset tool dimensions, including length, diameter, and cutting edge geometry, before they are installed in machining centers or CNC (computer numerical control) machines. By providing precise tool measurements, the tool pre-setter ensures optimal tool performance, minimizes setup time, and enhances machining accuracy. It also enables efficient tool management by cataloging tooling data and facilitating tool tracking. Figure 8 shows a tool pre-setter used for precise measurement and adjustment of cutting tools.

Fig. 8: Tool Pre-setter

Chemical inspection

Chemical composition of every alloy required to tested and recorded by using optical emission spectrometer or x-ray fluorescence (XRF) analysis machine.

Optical emission spectrometer

In harvester spare parts manufacturing, an optical emission spectrometer is an invaluable tool for analyzing the elemental composition of materials used in component fabrication (Fig. 9). This sophisticated instrument utilizes optical emission spectroscopy to identify and quantify the presence of various elements present in metallic alloys, ensuring they meet specified material requirements. By subjecting samples to high-energy excitation, the spectrometer generates emission spectra characteristic of each element, allowing engineers to determine their concentrations accurately. This information is important for verifying material integrity, confirming alloy compositions, and detecting any deviations that may compromise part performance or durability. With its ability to provide rapid and precise elemental analysis, the optical emission spectrometer is essential for maintaining the quality and consistency of harvester spare parts throughout the manufacturing process.

Fig. 9: Optical emission spectrometer

Handheld XRF

Handheld XRF (X-ray fluorescence) analyzer serves as efficient tool for on-site elemental analysis of materials (Fig. 10). This portable device utilizes X-ray fluorescence technology to identify the elemental composition of metallic alloys quickly and non-destructively. With its compact design and ease of use, engineers can perform rapid inspections directly on the production floor, eliminating the need for sample preparation or transportation to a laboratory. By instantly providing accurate results, the handheld XRF analyzer enables real-time decision-making regarding material selection and quality control. Its ability to detect trace elements and impurities ensures that harvester spare parts meet accurate specifications for performance and durability.

Fig. 10: Handheld XRF

Quality assessment

Quality assessment refers to the systematic evaluation of products or processes to determine whether they meet defined standards and requirements. It involves reviewing, measuring, and analyzing various aspects of quality to identify areas of strength and areas needing improvement. Quality assessment is typically broader than quality control, as it includes both the inspection of finished products and the evaluation of the processes and systems used in production. The goal of quality assessment is to ensure that the overall quality of a product or service aligns with the desired benchmarks and to provide insights for enhancing future performance.

Pattern failure (case study 1)

The first failure step for casting product is pattern failure. Wooden patterns are commonly used for creating molds in the metal casting process. While wooden patterns have some advantages, they also have several limitations, particularly for MS (mild steel) casting. Figure 11 shows the failure pattern of a track roller. Here are some limitations of wooden patterns for MS casting:

Limited durability: Wooden patterns have limited durability compared to patterns made from other materials, such as metal or

plastic. This means that wooden patterns can only be used for a limited number of castings before they start to wear out or become damaged.
Limited dimensional accuracy: Wooden patterns can be affected by changes in humidity and temperature, which can cause them to expand or contract. This can result in dimensional inaccuracies in the final casting.

Limited complexity: Wooden patterns are typically hand-carved, which makes them difficult to create complex shapes or intricate designs. This can limit the range of shapes and designs that can be produced using wooden patterns.

Limited consistency: Wooden patterns are susceptible to natural variations in the wood grain and texture, which can affect the consistency of the final casting. This can result in variations in the quality and strength of the finished product.

Fig. 11: Pattern failure of track roller

Casting Failure (Case study 2)
The failure of a casting made from MS (mild steel) alloy can be caused by several factors, including:

Improper casting design: The design of the casting must take into account the material properties of the MS alloy, such as its shrinkage and thermal expansion characteristics. Failure can be the result in casting defects such as shrinkage cavities, porosity, and hot tears.

Inadequate gating and risering: Gating and risering are critical to ensure proper filling and solidification of the casting. Improper gating and risering can result in incomplete filling of the mold or non-uniform cooling of the casting, which can lead to cracking, distortion, or other defects.

Poor quality of the melt: The quality of the melt used for casting must meet the specified standards for composition, cleanliness, and temperature. Impurities, oxides, and other defects in the melt can lead to casting defects and reduced mechanical properties.

Improper casting process: The casting process must be carefully controlled to ensure proper filling, solidification, and cooling of the casting. Factors such as pouring temperature, cooling rate, and mold material can all affect the quality of the casting.

Mechanical stress: The casting may fail due to mechanical stress such as excessive loading, fatigue, or thermal stress. Proper design and material selection can help prevent these types of failures.
Figure 12 presents the porosity defects observed in sprockets and track rollers due to substandard casting design.

Fig. 12: Porosity developed in sprocket and track roller for improper casting design

Excess metal casting (case study 3)
Excess metal casting is a challenge in spare parts manufacturing where patterns contain dimensions exceeding the required casting allowance, leading to the wastage of resources and compromised quality standards. It often results from inaccuracies in pattern-making, causing surplus metal in the final product (Fig. 13). This excess metal adds unnecessary weight, complicates subsequent machining, and compromises component integrity. Addressing this issue requires enhanced quality control, precise pattern-making, and early detection and rectification of deviations to minimize waste and uphold quality standards.

Fig. 13: Fan belt pulley and its excess metal pouring when casting

In this chapter, the vital aspects of quality control in harvester spare parts manufacturing were explored, focusing on visual, mechanical, and chemical inspections. Visual inspection is conducted to detect surface defects and ensure mold integrity, while mechanical properties are assessed using tools such as coordinate measuring machines, hardness testers, height gauges, microscopes, surface roughness testers, ultrasonic flaw detectors, and tool pre-setters. Chemical composition is verified through the use of optical emission spectrometers and handheld XRF analyzers. Common production failures, such as pattern failure, casting defects due to improper design and inadequate gating, and excess metal casting from inaccurate pattern-making, were highlighted in case studies. These failures indicates the importance of quality control measures. By employing advanced inspection techniques and addressing common issues early, part performance can be enhanced, waste minimized, and components can be ensured to meet industry standards. The importance of effective quality control for producing reliable, high-performance spare parts that maintain the integrity and functionality of combine harvester is emphasized.

Chapter Eight

Manufacturing Challenges

Making high-quality harvester spare parts comes with many challenges. These include a scarcity of skilled machine, deficiency in pattern development expertise, shortage of skilled die makers, difficulties in achieving precision dimensions, as well as challenges related to the availability of raw materials. This discussion will address specific challenges, examining potential solutions to facilitate a more perfect production of high-quality harvester spare parts.

Manufacturing pulley

Making patterns can be sophisticated due to issues like misalignment or inaccurate dimensions, but careful quality control helps maintain accuracy. By choosing the right materials for casting involves ensuring that iron and other materials are consistent across production. During molding, preventing air bubbles in the casting material is crucial; this is done by designing better pouring systems and controlling the speed of pouring to reduce turbulence. Machining processes like turning, milling, and boring can encounter problems such as misalignment or imprecise dimensions, which are resolved by using precise techniques and ensuring everything is properly aligned for better results. Table 1 explains the difficulties faced when making different types of pulleys (belt pulley/pulley/reverse belt pulley/fan belt pulley/other pulley) and how these challenges are managed.

Table 1: Challenges and management strategies in manufacturing pulley

Manufacturing process	Manufacturing Challenges	Managements of challenge
Raw material selection	Un-uniform Iron/ raw material for casting	Ensure uniform materials at molding workshops
Pattern	Misalignment of center and dimensional in-accuracies	Ensuring quality control of patterns that are uniformly centered and maintaining accurate allowance for CI/MS casting in the manufacturing process.
Molding	Air bubbles can become trapped within the casting material during the pouring and solidification stages.	Design the gating system to minimize turbulence during pouring, Incorporate venting channels, control the pouring speed to minimize air bubble.
Turning	Misalignment of the pulley, belt grooves	High-precision and efficient machining operation.

Manufacturing process	Manufacturing Challenges	Managements of challenge
	and dimensional in-accuracies.	
Milling	Key way may not be well fitted.	Use the key/ gauge when milling the key way.
Boring	Misalignment of center.	Properly align the work piece within the chuck to ensure concentricity.

Manufacturing roller

The challenges faced during the manufacturing of rollers, including crop root rails and carrier rollers, along with strategies to address them are documented in Table 2. Challenges in raw material selection involve difficulties in verifying material properties, mitigated through the use of advanced testing equipment to ensure materials meet specifications. Variability in roller dimensions and surface finish during turning is managed by machine calibration and the use of precise measuring instruments. Heat treatment-related defects are addressed through inspections before and after the process.

Table 2: Challenges and management strategies in manufacturing roller

Manufacturing process	Manufacturing challenges	Managements of challenge
Raw material	Difficulty in verifying material properties	Use advanced material testing equipment and techniques to ensure material properties meet specifications and identify proper material.
Turning	Variability in roller dimensions and surface finish	Calibrate machines and use precision measuring instruments for accuracy
Heat treatment	Heat treatment-related defects in rollers	Conduct thorough inspections before and after heat treatment. If defect arises, monitor and adjust heat treatment processes.

Manufacturing gear

Table 3 details the manufacturing challenges and their corresponding management strategies for gears, including bevel gears, spur gears, and general gears. Challenges in raw material selection, such as supply chain disruptions, are managed by ensuring uniform materials and reliable suppliers, alongside implementing through quality checks during material procurement. Turning, milling, and boring processes encounter issues like tool wear and machine breakdowns, which are mitigated by maintaining spare parts inventory to minimize downtime. Misalignment during boring is addressed by ensuring proper alignment of work-pieces within chucks to maintain concentricity. Difficulties in achieving desired hardness and durability during heat treatment are managed through collaboration with experienced specialists and careful monitoring and adjustment of heat treatment processes.

Table 3: Challenges and management strategies in manufacturing gear

Manufacturing process	Manufacturing challenges	Managements of challenge
Raw material selection	Inconsistent material quality and supply chain disruptions	Ensure uniform material and reliable suppliers. Implement strict quality checks when material purchase
Turning and milling	Frequent tool wear and machine breakdowns	Keep spare parts on hand to reduce downtime
Boring	Misalignment of center	Properly align the work piece within the chuck to ensure concentricity
Heat treatment	Difficulty achieving desired hardness and durability	Collaborate with experienced heat treatment specialists. Monitor and adjust heat treatment processes carefully

Manufacturing shaft

Table 4 addresses challenges in manufacturing shafts like joint shafts and depth control parts, emphasizing the importance of consistent metal quality in raw materials. Strict maintenance schedules manage tool wear and machine breakdowns during turning, while specialized dies ensure precise bends in bending operations. Welder training programs ensure high-quality welds, and strict grinding standards maintain smooth, uniform finishes on welded parts.

Table 4: Challenges and management strategies in manufacturing shaft

Manufacturing process	Manufacturing challenges	Managements of challenge
Raw material selection	Inconsistent material quality	Ensure metal quality
Turning	Frequent tool wear and machine breakdowns	Implement a maintenance schedule for machines and tools
Bending	Achieving precise and uniform bends can be challenging	Introduce die for bending for achieving precise dimension
Joining	Inconsistent weld quality or welding defects	Train welders for skill consistency
Grinding	Uneven or poor grinding of welded parts	Ensure the availability of skilled grinders and high-quality grinding equipment

Manufacturing guide rail

Table 5 examines the challenges arise in the manufacturing of guide rails and crawler support bars, along with how these challenges are managed. Ensuring proper material alloy composition for durability is emphasized, with regular material testing conducted to verify alloy consistency and durability. Complex pattern design challenges are addressed by employing skilled pattern makers experienced in handling sophisticate designs. Variation in casting dimensions during molding is mitigated through training provided to casting personnel to identify and address common defects. Inconsistent surface finish after grinding is managed by training grinding personnel to maintain consistent pressure, speed, and dimensional accuracy. Strict quality control checks are implemented during and after drilling processes to ensure alignment and accuracy. Collaboration with experienced coating specialists ensures thorough surface preparation and even coating coverage.

Table 5: Challenges and management strategies in manufacturing rail and support item

Manufacturing process	Manufacturing challenges	Managements of challenge
Raw material	Ensuring proper material alloy composition for durability.	Determine the appropriate alloy composition. Perform regular material testing to verify alloy consistency and durability.
Pattern making	Complex pattern design challenges.	Employ skilled pattern makers experienced in complex designs.
Molding	Variation in casting dimensions.	Train casting personnel to identify and address common defects.
Grinding	Inconsistent surface finish after grinding.	Train grinding personnel to maintain consistent pressure and speed along with dimension maintaining.
Drilling	Drilling inaccuracies and misalignment.	Implement strict quality control checks during and after drilling processes to ensure alignment and accuracy.
Coating	Inconsistent or inadequate coating coverage.	Collaborate with experienced coating specialists and ensure thorough surface preparation before coating and color code management.

Manufacturing nut-bolt

Table 6 examines the challenges faced in manufacturing bolts and tension nuts, along with the strategies employed to tackle them. To address inconsistent material quality in raw materials, a diversified supplier network is utilized for reliable sourcing. Challenges concerning dimensional variations and allowance limits during turning are handled by utilizing CNC lathes operated by skilled professionals. Deviations in thread profiles and issues such as thread breakage during threading processes are controlled through strict process oversight and regular checks with thread gauges. Improved drilling jigs and fixtures are employed to reduce misalignment and inconsistency in hole drilling. Techniques involving careful quenching and tempering with advanced heating methods are applied to manage inconsistent hardness in different sections after heat treatment. Finally, ensuring accurate surface preparation before plating enhances the bond strength of plating on bolt surfaces.

Table 6: Challenges and management strategies in manufacturing nut and bolt

Manufacturing process	Manufacturing challenges	Managements of challenge
Raw material	Inconsistent material quality.	Diversified supplier network.
Turning	Dimension and variation in allowance limit.	Use of CNC lathe with skilled operator.
Threading	Thread profile deviations, thread breakage.	Strict process control and thread gauge checks.
Drilling	Misalignment, hole consistency.	Improved drilling jigs and fixtures.
Heat treatment	Inconsistent hardness in different section.	Quenching and tempering carefully with advance heating techniques.
Plating	Poor plating bond to the bolt surface.	Accurate surface preparation for better adhesion.

Miscellaneous casting parts

Table 7 discusses the challenges and management strategies involved in manufacturing various casting parts such as blade reaping cranks, holder bearings, carrier rollers, bearing seats, and radial arms. Challenges in pattern-making include ensuring accurate designs and addressing misalignment and dimensional inaccuracies, managed by skilled pattern makers and maintaining precise centering and allowances. Raw material issues, like poor quality and inconsistent composition, are addressed through meticulous inspection and selection processes to ensure exact material specifications. Mold cavity defects during molding are minimized through advanced inspection techniques. Dimensional variations in turning and boring processes are managed with precise measuring tools, regular maintenance, and the use of high-quality cutting tools to ensure accuracy and efficiency. Misalignments in drilling are identified and corrected promptly through quality control checks. Achieving durable and corrosion-resistant paint finishes presents challenges, which are minimized by thorough surface preparation and careful management of coating applications.

Table 7: Challenges and management strategies in manufacturing miscellaneous casting parts

Manufacturing process	Manufacturing challenges	Managements of challenge
Pattern	A poorly designed or inaccurate pattern. Misalignment and dimensional in-accuracies.	Skilled pattern makers who can ensure accuracy. Uniformly centered and maintaining accurate allowance.
Raw material	Inherent composition of available material and poor raw material quality.	Inspect and select exact composition of material.
Molding	Mold cavity defects.	Advanced mold inspection.
Turning	Dimensional variation in allowance limit.	Use measuring tools and inspect dimension closely.
Boring	Inefficient boring process can lead to delays, inaccuracies, and increased production costs. Challenges in achieving actuate and precise bores.	Regular maintenance and tool sharpening are essential to ensure consistent and accurate boring. Use high-quality cutting tools.
Drilling	Drilling misalignment.	Implement quality control checks to identify and rectify misalignments promptly.
Painting	Achieving a durable and corrosion-resistant paint finish can be difficult. Inadequate surface preparation.	To ensure uniform and long-lasting coatings. Ensure surface preparation before coating and color code management.

Manufacturing shaft/pin crank

Table 8 discusses challenges in shaft manufacturing for items like shafts, rollers, and pin cranks. Strategies include maintaining a diversified supplier base and negotiating stable contracts to manage raw material cost fluctuations. Strict quality controls, precision tools, and stringent tolerance standards are implemented to address variability in shaft dimensions and thread tolerance during turning and threading processes. Proper selection and use of quenching mediums are essential to prevent quenching cracks during heat treatment.

Table 8: Challenges and management strategies in manufacturing shaft/pin crank

Manufacturing process	Manufacturing challenges	Managements of challenge
Raw material	Cost fluctuations in raw materials.	Maintain a diversified supplier base and negotiate long-term contracts.
Turning	Variability in shaft dimension.	Establish strict quality control protocols and tools.
Threading	Thread variations control and thread tolerance maintain is difficult.	Set strict tolerance standards.
Heat treatment	Development of quenching cracks.	Use appropriate quenching mediums.

Manufacturing sprocket

Table 9 addresses challenges in manufacturing large sprockets such as driving chain wheels and double row sprockets. Strategies include material inspection for consistency, using high-quality cutting tools to combat frequent tool wear during turning, employing CNC machining and specialized tooling for precise tooth profiles during milling, and ensuring consistent hardness through automated furnace controls during heat treatment. Advanced plating techniques with thorough surface preparation are utilized to achieve even coating distribution on sprocket surfaces.

Table 9: Challenges and management strategies in manufacturing sprocket

Manufacturing process	Manufacturing challenges	Managements of challenge
Raw material	Inconsistent and poor raw material quality.	Inspect and select exact composition of material.
Turning	Frequent tool wear and breakage during sprocket shaping.	Use high quality cutting tools, optimize cutting speeds.
Milling	Precise sprocket tooth profiles and dimensions is challenging.	Imparting CNC machining techniques, use specialized tooling.

Manufacturing process	Manufacturing challenges	Managements of challenge
Heat treatment	Development of inconsistent hardness.	Use of automatic controlled furnace.
Plating	Uneven coating distribution.	Employ advanced plating techniques with proper surface preparation.

Manufacturing special shaft

Table 10 discusses challenges and strategies for manufacturing special shaft items like HST output shafts. It emphasizes ensuring a contentious supply of high-quality raw materials to maintain purity. Optimizing tool selection and cutting parameters improves efficiency during turning operations, while proper tool handling minimizes variability in milling processes. To prevent unobservable cracks from occurring after heat treatment, using new shafts is recommended over recycled ones. Achieving dimensional accuracy in grinding is enhanced through the use of precision equipment and tooling. Adjusting plating materials and thickness helps achieve even distribution on shaft surfaces to enhance durability.

Table 10: Challenges and management strategies in manufacturing special shaft

Manufacturing process	Manufacturing challenges	Managements of challenge
Raw material	Maintaining pure grade of material.	To ensure a steady supply of high-quality raw materials.
Turning	Turning operation Inefficiencies.	Optimize tool selection and cutting parameters.
Milling	Milling process variability.	Ensure proper tool handling.
Heat treatment	Using ship breaking shaft may have un-observable cracks. But after heat treatment, the cracking occurs.	Use new shafts, it is safer than used one.
Grinding	Dimensional accuracy is difficult.	Use precision grinding equipment and tool.
Plating	Uneven coating distribution.	Adjust plating materials and thickness.

Overcoming the challenges in manufacturing harvester spare parts requires a strategic approach. Ensuring consistent material quality, implementing precise machining processes, and maintaining quality checks are crucial. Partnering with experts and using advanced methods like heat treatment and coating can enhance the reliability and durability of these components. Ultimately, success in producing harvester spare parts depends on a commitment to high-quality standards and proactive management of these manufacturing obstacles.

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