Title: **Manufacture of Cylinder Block for Rc Solution Feed Pump**

Implemented by

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Abstract

In Bangladesh, a large quantity of highly expensive cylinder block for RC solution (carbamate) pump is imported by different fertilizer factories to produce ammonium carbamate solution, an intermediate product of urea, which is highly corrosive to iron and steel, especially in parts that operate at the highest temperature and concentration of carbamate in the plant. For this reason, the metallic components to process RC solution is made of highly corrosion resistant materials. Duplex stainless steel (SS) having chemical composition shown in table-1 was used for this purpose. Several attempts were taken to manufacture locally by private industries but fruitful result was not found.

The main aim of this work was to study the feasibility of manufacturing cylinder block using indigenous technology cost effectively. The specific properties under consideration include (i) mechanical properties, (ii) chemical properties and (iii) casting defects of the cast cylinder block.

Chemical composition determination using excel program, induction melting of raw materials, Carbon-di-oxide molding, gating system removal using arc /plasma cutting, heat treatment, Computer Numerical Control(CNC) machining, Non-Destructive Testing (NDT), Optical Emission Spectroscopy (OES)/chemical analysis and hydraulic test were applied to manufacture cylinder block.
Chemical elements such as iron (Fe), carbon(C), silicon (Si), manganese (Mn), sulfur(S), phosphorus (P), nickel (Ni), chromium (Cr), Molybdenum (Mo) were determined using OES /chemical analysis, leakage was detected by NDT and hydraulic test.

The results obtained from this study show that directional solidification, required number, size & shape of riser, sprue and runner position is essential to get flawless cylinder block.

Lot of cylinder blocks manufactured did not satisfy the requirements of NDT, OES /chemical analysis and hydraulic test. Only qualified cylinder blocks were supplied for trial run. Eventually a complete set (one set comprises of 4 nos) of cylinder blocks was manufactured and satisfied the requirements of M/s Urea Fertilizer Factory

Keywords

RC solution, cylinder block, heat treatment, CNC machining, NDT, OES, chemical analysis and hydraulic test.

1. Introduction

Urea process is well known as one of chemical plant treating corrosive fluid. To handle such type of fluid, materials should have highly mechanical strength, excellent corrosion resistance and passivation property [2, 3]. Urea reacts with acids, bases and enzymes to hydrolyze to produce ammonia and carbon dioxide, which is thermally unstable [2]. Urea production processes requires high pressure and corrosive resistive equipment. In addition, the process also requires medium pressure, low pressure and vacuum system. To satisfy the requirements, proper metallic elements were selected and processed to develop sound casting to perform the requirements properly.

2.Objectives of the Research Work

The main aim of this work was to produce sound casting of cylinder block using indigenous technology and raw materials with low cost to reduce import, enhance the skills of the manpower engaged in this field and increase employment opportunities.

3.Methodology

The methodology comprises of Design and creation of drawing, pattern and mold making, raw materials selection and formulation, metal melting and pouring into mold, Cleaning/fettling, heat treatment, machining followed heat treatment and inspection & testing.

3.1. Design and creation of drawing

After getting work order from the client, worn-out sample was collected. From that sample using Auto-CAD/solid works, design and creation of the drawing was done shown in figure-1. In design stage necessary allowance and tolerance were incorporated for pattern making, heat treatment and machining. For CNC machining master CAM software was used.

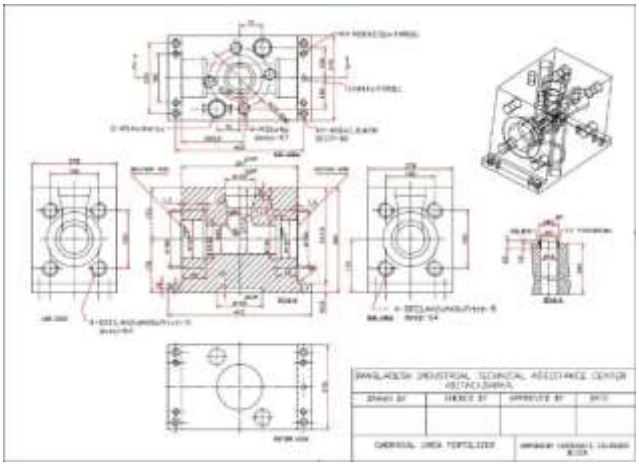

Figure-1

3.2. Pattern and Mold making

Pattern used for this process was wood. Wood was given a coating of graphite powder. Silica sand (clean, dry and free from clay) with 3.5 to 5% by weight of sodium silicate liquid base binder was thoroughly mixed in a sand mixer machine. Coal-dust and wood flour were also added so as to improve the collapsibility of moulding sand. The mixture is then put into mould-boxes. After packing, Carbon-di-oxide **(**CO_2) was forced into the mould at a pressure of about 1.4 kg/cm^2 rapidly and uniformly throughout the sand mass. The sodium silicate present in the mould reacts with CO_2 and gave a hard substance called the silica gel.

$Na_2SiO_2xH_2O + CO_2$ ——— > $Na_2CO_3 + (SiO_2xH_2O)$

The silica gel was a hard substance like cement and hence helped in binding of sand grains. Harden time was about 25 seconds. This process was used for the production of cylinder block moulds as the size of the mould large in size.

3.3. Raw materials selection and formulation

Stainless steel scrap, ferro-silicon, ferro-manganese, ferro-molybdenum, nickel and additives were selected and formulated to manufacture cylinder block as per shown in table-1. All these materials were collected from local market, although most of the items were imported from overseas countries by other vendors.

Particulars	Amount			of elements								value of elements					
	kg	C	Mn	Si	Cr	Ni	Mo	Cu	C	Mn	Si	Cr	Ni	Mo	Cu		
SS316	855	0.03	2.00	0.75	17.00	12.00	2.50	0.00	0.26	17.10	6.41	145.35	102.60	21.38	0.00	500	427500
Cu	42	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	42.00		
Nickel	0	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3000	0
Spoon Scrap	182	0.10	0.57	0.2	17.00	0.00	0.00	0.00	0.18	1.04	0.36	30.94	0.00	0.00	0.00	60	10920
Ferro-Chrome (Fe-Cr)60Cr/0.1C	390	0.10	0.00	0.00	55.00	0.00	0.00	0.00	0.39	0.00	0.00	214.50	0.00	0.00	0.00	650	253500
Ferro-Manganese (Fe-Mn)65Mn/0.1C	6	0.10	65.00	0	0.00	0.00	0.00	0.00	0.01	3.90	0.00	0.00	0.00	0.00	0.00	420	2520
Ferro-Molybdenum (Fe-Mo)60Mo/.1C	25	0.10	0.00	0.00	0.00	0.00	55.00	0.00	0.03	0.00	0.00	0.00	0.00	13.75	0.00	3500	87500
Total	1500								0.86	22.04	6.78	390.79	102.60	35.13	42.00		781940.00
Required Value of elements									0.06	1.47	0.45	26.05	6.84	2.34	2.80		

Table-1

3.4. Metal melting and Pouring into mold

The calculated items were sized and placed into the melting crucible of induction melting furnace one by one depending amount, melting & vaporization temperature of metallic materials and compound and bragging of the compound to make the target casting [1]. After completion of melting of all the items necessary additives were added to refine the liquid metal into the melting crucible as well as pouring ladle.

3.5. Cleaning/fettling

After solidification the cast product of cylinder block was removed the sand. Due to high temperature the surrounding layer fused with the block material. It is here mentionable that mold coat was applied on the interior part of the mold and exterior part of the core. Using hand grinder the fused sand was removed and the sprue, riser and runner part was removed by arc/plasma cutting technique.

3.6. Heat Treatment

Solution treatment, was employed for recrystallizing the cast stainless steel to reduce chromium carbides, precipitated around the grain boundary of stainless steels and homogenizes dendritic stainless steel, into the solution. During heat treatment, the block was heated slowly at temperature of 1050^0C, hold it at that temperature for 4 hours followed slow cooling.

3.7. Machining

A computerized numerical control (CNC) machining center (Model: PC Mill 155, Make: Emco, Austria) shown in Fig.3.3 was used to machine the block. The

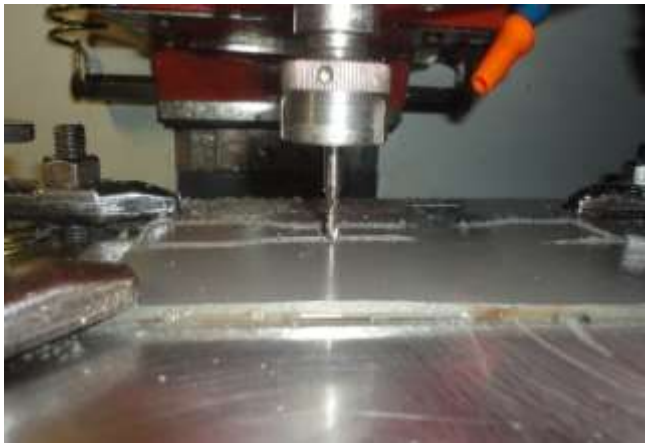

Fig. 3.3: Computerized Numerical Control (CNC) machining center

cutting speed of the machine was 4000 rpm. Care was taken to avoid any scratch or any mark in the edges of the block. During cutting operation, coolant was used to control heat generation so that any degradation of the specimen material does not occur. At the end of machining the burrs remaining at the edges were removed by using hair brush. Then all the surfaces of the specimen were inspected to detect any flaws, scratches or imperfections.

33.8. Inspection and Testing

After removal of block from sand and completion of fetling activities, visual inspection was performed. Dafter passing visual inspection the block was transported to the heat treatment section to remove stress and homogenize the structure. At the end of heat treatment, the block was sent for the machining. During machining if some flaws were detected the block were rejected and back to the melting department. After completion of machining keeping heat treatment allowances, blocks were again sent to the heat treatment for stress removal. After this operation final machining was done and sent for Non-Destructive Test (NDT).

4. Experimental Procedure

The quality of cast block was ascertained by performing tests following the American Society for Testing and Materials (ASTM) standards.

4.1. Chemical Test

For chemical analysis the sample having required dimensions was sent to Bangladesh University of Engineering and Technology (BUET). After getting successful test report, heat treatment, machining followed heat treatment and inspection & testing was performed.

4.2 Pressure Test

After completion of machining followed heat treatment and inspection the blocks were sent for pressure test. This test was done in BITAC. For this purpose, necessary attachments were design and manufactured. After developing pressure upto 300 kg holding at that pressure for 24 hours to observed pressure fluctuation. After getting successful pressure report cylinder blocks were sent for trial run in the factory.

5. Discussion

The cylinder block is the basic framework of urea production. To manufacture this type of cylinder block specific material or technology is required to fulfil the function. Urea synthesis needs to be operated under high pressure. For the synthesis of urea, a certain amount of time [4] is required. For adaptation of highly corrosive environment highly corrosion resistive stainless steel [5, 6] has been used to manufacture cylinder block. Lot of cast cylinder blocks was rejected due to casting defects. To reduce these casting defects many jix and fixture were developed and used to facilitate sound casting.

5. **Conclusion**

It can be concluded that

5.1 Directional solidification and proper gating system ie required no of riser, position, size, sprue size and location and runner position and size should be ensured.

5.2. Source of raw materials should be same as indigenous technology and materials.

5.3 Cylinder block should have homogenous structure and stress free.

5.4 Chemical composition selection and proportioning, metal casting, machining and heat treatment has shown a huge time and cost competitive advantages with respect import from overseas countries.

6. Recommendations for Future Work

6.1. Study on optimization of casting using software;
6.2. Study on the effect of surface roughness;
6.3. Comparative study on the properties of cast and forged cylinder block.

6. Acknowledgments

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