Chapter 4

Plan of Work

As per literature review and related information, methodology was finalized. Small scale investment casting foundry was selected and its conventional pouring process is studied to start the experimentation. Same is discussed in the current chapter.

4.1 Methodology with Suggested Automation

Based on the current system of pour as show in fig. 2.26, following stages were decided for inculcating automation techniques in the conventional pouring process,

1. Using a new ladle for multiple pours by mechanical stopper rod mechanism. Provide spring for controlled pour flow.

2. Add Crane to handle this ladle to reduce travel time of ladle. Following changes made accordingly, Gantry crane system is set up with X,Y axes horizontal planar movement, Z axis vertical movement and 5 MT capacity

3. Use non-contact Laser Gun (Range 50-1800°C) to accurately control and measure temperature of preheated shells from firing oven.

4. For better preheating of the ladle specially designed gas nozzle is used.

After methodology was decided, final plan to carry out experimentation is given as below,

1. Selection of suitable industry.
2. Problem faced for defects related to pouring process in that specific industry.
3. Select a suitable part based on quantity & rejection percent of defects.
4. Make changes to current process with time study & cost saving.
4.2 Selection of the Suitable Foundry For Experimentation

After initial methodology was fixed it was necessary to find a suitable mid-scale foundry for experimentation. Aim of the project is to do experimentation for modified process with suggested automation and observe its effect on the scrap due to pour defects like inclusions and cold shuts. Following casting plants were surveyed and studied towards selection of suitable industry,

1. Paranjape Autocast, Kothrud, Pune: a) Manufacture auto casting. b) Metal used mainly cast iron & aluminum

2. Luminous Technocast Investment Casting, Rajkot, Gujrat: a) Makes automotive walls and dairy related products b) Multiple alloys used like Stainless steel, cast iron etc.


4. Siddhalaxmi Engineering Pvt. Ltd. Solapur: Company details are given below in sub-chapter 4.2.1

Siddhalaxmi Engineering Pvt. Ltd. was selected due to their product range and their interest in supporting the experimentation for their specific concern about rejection percentage due to metallurgical defects. Brief details of the company are given below.

4.2.1 Siddhalaxmi Engineering Pvt Ltd, Solapur

A well-established Company, Siddhalaxmi Engineering and Pvt Ltd was chosen as an experimental base for the experimentation for title of this work. Company manufactures investment castings at Solpapur plant (A12, Chincholi MIDC, Solapur) with following brief details

- **Grades of alloy that are cast currently**: alloys ranging from grades of Mild Steel (IS 10343; 199-3A, 4A, 2Q, 3Q, 4Q, EN18, 42CrMo4, 16MnCr5, 1B) Stainless Steel (SS 304/CF8, SS310, SS316/CF8M), Copper alloys (Aluminum-Bronze), Aluminum (LM24) etc.

- **Weigh range of cast products**: 27 gm to 68 kg

- **Capacity**: 60-150 MT/Month

- **Shell system**: Water based silicon

- **Operations**: All Manual Systems
Following fig. 4.2 through fig. 4.14 show flow of the process in Siddhalaxmi Engineering Pvt. Ltd.
CHAPTER 4. PLAN OF WORK

Figure 4.3: Wax injection

Figure 4.4: Wax assembly

Figure 4.5: Precoating
CHAPTER 4. PLAN OF WORK

Figure 4.6: Sand rain (Stucco)

Figure 4.7: Completed shells

Figure 4.8: De-waxing
Figure 4.9: Oil firing of pouring crucible

Figure 4.10: Preheating of shell

Figure 4.11: One of four furnaces
CHAPTER 4. PLAN OF WORK

Figure 4.12: Manual pouring

Figure 4.13: Cutoff and grinding

Figure 4.14: Quality insurance inspection
After discussions with management and engineering team, they expressed their concern regarding their rejection rate (Average 9.52%), it was decided to review their data from January-Apr 2016. Details of the same are given below.

4.2.2 Problems Related to Defect Rejection and Data Analysis

After reviewing the processes, thoughts were used to work on shell system or pour system practices of the company. After rigorous discussions with experts in casting processes and on the basis of average data for last four months rejection data as shown below in fig. 4.15 and fig. 4.16, it was decided to work on manual pour system for automation possible without disturbing their regular production. This decision was taken based on rejection 9.25% due to inclusion and cold shut rejections which are related to pouring process. Even though ceramic inclusions are also related to shelling process, other inclusions like slurry, impurities are possible in melting process which is part of pouring process.

![Four month defect wise rejection data for Production](image)

Figure 4.15: Four month defect wise rejection data for Production
Based on the above data, it is clear that main problems as stated above were inclusions and cold shuts that are almost more than half of the scrap combined (6.02% out of 9.52%) and needed a focus to improve that area of rejection. So based on the fact that automated pour system using crane system in X-Y direction (Gantry) and modified bottom pour ladle will help reducing cold shuts and inclusions caused by floating slag in hand pour system as well. There are two major activities to be followed for new bottom pour method.

1. Consistent and faster flow of pouring
2. Easier movement of ladle from furnace to shell pour area

### 4.3 Selection of Part For Experimentation

Following Part was selected based on yearly order quantity and availability for experiments and schedule requirement. Also we needed a part that has a smaller shell as we were using pour system for low thermal masses.

- **Part Name:** Flange (CD - 50)
- **Material:** SS304 (Properties in Table I)
- **As cast part weight:** 87gms
- **No of pieces per shell:** 60 Nos
- **Use of part:** As a connector in exhaust system
Fig. 4.19 shows the part drawing after machining. Casting machining allowance is decided by the foundry based on cast-ability of the part.

![Figure 4.17: Flange CD -50](image1)

(a) Picture 1

(b) Picture 2

Figure 4.17: Flange CD -50

![Figure 4.18: Mold type](image2)

(a) Wax mold

(b) Shelled Mold

Figure 4.18: Mold type
Figure 4.19: Drawing of CD-50
Based on this data, experimental results were compared for variation mainly on Inclusions and cold shut as measure of rejection analysis. Mechanical properties were also compared to that with same parts produced by regular production process. An attempt is made in this study to see the feasibility of bottom pour in small scale investment casting industries with small thermal masses for advantages of current bottom systems used for large thermal masses for high carbon or silica alloys like cast iron or brass or aluminum cast alloys. For SS304 material Inspection, spectrometer shown in fig. 4.20 is used. These compositions are checked on the spectrometer as shown in fig. 4.10 below with its specific standards for Steel alloys.

Figure 4.20: Optical emission spectrometer for composition verification of alloys

**Spectrometer details:**
- Company: Bruker
- Model Number: Q6 Climbus
- Element scale: C, Si, Mn, Cr, Ni, Mo, Fe, P, S

<table>
<thead>
<tr>
<th>MECHANICAL PROPERTIES</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
<td>70,000 psi Min</td>
</tr>
<tr>
<td>Yield Strength</td>
<td>30,000 psi Min</td>
</tr>
<tr>
<td>Elongation at 2 in</td>
<td>30.00 % Min</td>
</tr>
</tbody>
</table>
Table 4.2: Chemical composition SS 304/ASTM A351A

<table>
<thead>
<tr>
<th>CHEMICAL COMPOSITION</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>0.08 % Max</td>
</tr>
<tr>
<td>Manganese</td>
<td>1.50 % Max</td>
</tr>
<tr>
<td>Silicon</td>
<td>1.50 % Max</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.040 % Max</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.040 % Max</td>
</tr>
<tr>
<td>Nickel</td>
<td>9.0 - 12.0 %</td>
</tr>
<tr>
<td>Chromium</td>
<td>18.0 - 22.1 %</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>2.0 - 3.0 %</td>
</tr>
</tbody>
</table>

4.4 Modification Using Automation Techniques

Every heat of metal for alloy from any of the 4 furnaces (100kg, 150 kg, 300 kg and 500 kg) is checked in house and certified. After details were confirmed, pouring area in the process was selected for an experimentation. Fig. 4.21 shows the current process and process with modification is shown in fig. 4.22. Based on the focus of changing the current process to modified bottom pour process following automation techniques were planned for implementation.

1. New bottom pour ladle was designed and manufactured with spring addition to facilitate easy control of pour then conventional bottom pour system and special ceramic coating was applied to it for reduction of heat transfer between SS 304 molten metal and ceramic coating. This is essential for experimentation as explained before.

2. Gantry crane system was established for easier movement of modified bottom pour ladle.

3. New gas nozzle heater (S-80) to preheat the ladle to appx 1000 °C with reduce rate of heating than conventional method.

4. Non-contact laser gun (EUROLAB 1850) was purchased for accurate measurement of preheated shell coming out of firing oven. This gun was also used for other temperature checks needed in the experiment as required.

5. Vertical movement of bottom pour ladle was set up with an adjustment of pour height (hp) between pour ladle and pour cup opening.

Fig. 4.21 and fig. 4.22 show the flow of the process for CD-50 with current and as per new methodology respectively.
Figure 4.21: Current process with conventional operation
Figure 4.22: Modified process only in melt and pour area
4.4.1 Merits and Demerits of Current Manual Process and Modified Bottom Pour Process

Current manual process

Merits:

1. Workers are comfortable with this routine process as been used for long time.
2. Less investment.

Demerits

1. Inconsistency of pour rate for every pour cycle.
2. Inconsistency of pour height for every pour cycle.
3. Manual labour related like pour angle, time of travel from crucible to pour area etc.

Pour process modified with automation techniques

Merits:

1. Consistency of pour rate for every pour cycle.
2. Consistency of pour height for every pour cycle.
3. Easy movements of ladle due crane system.

Demerits:

1. People will need more training to operate the system.
2. System is still mechanical and need motorized motion.
3. Initial investment is required (for crane system, bottom pour ladle and laser gun.)

Table 4.2 shows the estimated cost saving due to changes in the current pour process shows approximate cost savings per annum. These calculations are made on current time study and labor rates.
<table>
<thead>
<tr>
<th>No.</th>
<th>Current process time</th>
<th>Modified process</th>
<th>Changes</th>
<th>Time saving / annum</th>
<th>Cost saving/ annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wax injection (1 hour)</td>
<td>Wax injection (1 hour)</td>
<td>None</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Wax assembly (1 hour)</td>
<td>Wax assembly (1 hour)</td>
<td>None</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Shelling (5 days)</td>
<td>Shelling (5 days)</td>
<td>None</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>De-waxing (4 days)</td>
<td>De-waxing (3 days)</td>
<td>None</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Melt (1.5 hours)</td>
<td>Melt (1.5 hours)</td>
<td>Temp. control</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Pour for 2 molds (Qty 120)</td>
<td>Pour for 2 molds (Qty 120)</td>
<td>1. Bottom pour 2. Shell pre-heat control</td>
<td>40 sec/2 mold, 2000 molds/yr, 40000 seconds/yr</td>
<td>1 day shift of 5 labor hrs + reduction of 1 labor/annum = 1,30,000 INR</td>
</tr>
<tr>
<td>7</td>
<td>Finishing and fettling (2 hours)</td>
<td>Finishing and fettling (2 hours)</td>
<td>None</td>
<td>None</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>Quality inspection (15 mins)</td>
<td>Quality inspection (15 mins)</td>
<td>Reduction of scrap</td>
<td>None</td>
<td>3036 pcs on an avg of rs 40 per piece = 121440 INR</td>
</tr>
<tr>
<td>9</td>
<td>Dispatch (1 hour)</td>
<td>Dispatch (1 hour)</td>
<td>None</td>
<td>None</td>
<td>-</td>
</tr>
</tbody>
</table>

Total estimated savings = 2,51,440 INR/Annnum

Table 4.2 indicates current pour process time study along with new suggested modified pour process. Accordingly estimated savings in time, labor cost and rejection process is estimated.

After plan of work was decided, details of experimentation were carried out. In the next chapter, details for modifications of current process are explained and details of data collection for fina analysis are discussed.