CHAPTER III

ANALYSIS OF THE CAUSE OF DEFECTS

In this chapter describes the casting process of the case study company and identify the potential causes of metallic projection, cavities and defective surface. The techniques used for identifying the potential cause are brainstorming and the cause and effect diagram are used to organize the causes.

3.1 A Study of the Casting Process

The casting method of the case study company is sand-casting method. As it stated in chapter three sand-casting method is the most popular method and still plays an important role in today's casting business. This method give more flexibility (this flexibility refers to the convenience in design modification) than other methods. This provides the case study company more flexible in term of design and lower cost than other method. The following steps are the procedure of sand-casting method used in the company.

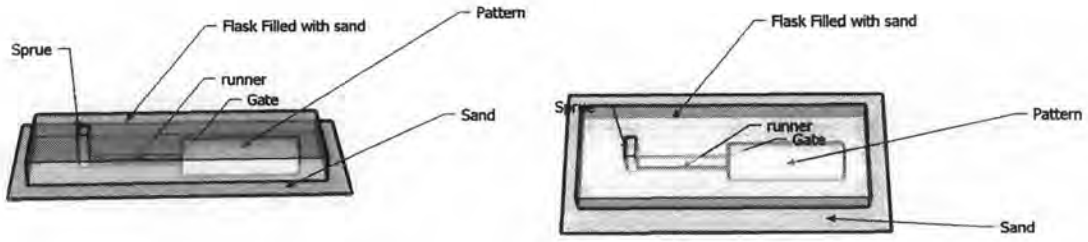

Figure 3.1: Casting Mold

1. **Sand preparation** – sand preparation is the first step of this method. This step purifies the sand before pressing the pattern into it by sieving the sand. This step will remove large element out of the sand and make it mellow (it will be easier to press the pattern against the mellow sand).

2. **Pattern Making** – after the sand is purified and mellowed, the pattern (typically made out of wood or metal) is then pressed into the prepared sand.

3. **Sprue Making** – after the pattern is pressed into the sand, the Sprue maker (the metal that has rectangular shape) will be placed near the pattern which it will be connected later by runner (runner is the run way of the molten material as it shown in figure 4.1). The connection between the runner and pattern calls gate. Gate is the entrance way of molten metal to the pattern. After that maker will be covered by flask that filled with sand. Then the Sprue will be removed in order to make way for pouring the molten material into.

4. **Removal of the Pattern** – After the gate is removed from the flask, open the flask and remove the pattern carefully. The goal is to remove the pattern without breaking the mold cavity. After removed the pattern, make the runner

between the gate and the sprue as it shown in figure 4.1. Then carefully close the flask.

5. **Pour molten aluminum alloy,** molten alloy (the temperature of the molten alloy around 360 – 400°) is poured into the sprue and it will run to runner part then the molten alloy will meet the mold cavity.

6. **Remove Casting,** molten alloy normally turn to solid stage between 3 – 10 minutes depends on the combination of the alloy and room temperature. After the alloy turned into solid stage open the flask and remove the casting out of the sand then the casting is completed.

3.2 Team Set up

This experiment involves with many production processes and operators therefore the team work is necessary. There are five participants including author (experiment conductor), two casting operators, one foundry operator, and one Quality Control (QC).

3.3 Cause Analysis

Referring to *Table 1.2: Number of Defect in the casting process* in Chapter One, there are three defects types in the casting process that are most likely to occur, which are Metallic projection, Cavities, and Defective Surface. The causes of the defects are found from literature and brainstorming.

3.3.1 Defect: Metallic Projection (Joint Flask or Fins)

Causes:

According to the research, the causes of metallic projection can be classified into two groups; operator skill and sand property. Incaution operator might disturb the flask during the molten aluminum alloy is turning to the solid stage. This disturbance can create metallic projection by molten aluminum, which runs into cavity that occurred during disturbance. Rough handling of the mold and careless or improper inaccurate pattern are mistakes that incautious operator generates, which can create unwanted cavity inside the mold and it will lead to metallic projection.

Excessive moisture in sand tends to reduce flowability of the sand, which in turns promotes uneven density in various locations. It can cause cracking of the surface of the mold which will produce fins.

The temperature of sand has directly caused metallic projection, since hot sand can produce condensation. This condensation can cause the sand to stick to a cold pattern and leave a cavity when the pattern is removed from the mold.

Factors:

Refer to the above sentences the causes of the metallic projection can be concluded into three factors which are,

- Worker skill
- Sand moisture
- Sand temperature

3.3.2 Defect: Cavities (Blowholes, Pinholes)

Causes:

The causes of cavities in the casting pieces occur from the gas entraps inside the casting pieces. The gas is generated from the moisture in the sand. Although the moisture is necessary in molding sand, it must be closely controlled if large quantities of gas in the form of steam are to be avoided. Improper gate design is other cause of cavities. Insufficient number gate or size will limit to how far each feeder can feed. The composition of the material is another potential cause of cavities because some composition after transformed shrinks. The pouring speed is also another cause of cavities in the product. The last potential cause of cavities is Flask size. If the flask size is too small because sometimes an undersize flask may be used to save sand and molding cost. The danger is that proper gating becomes impossible or the risers are so close to the flask wall that they cool and freeze before the feeding cycle is complete.

Factors:

As per causes of cavities mentioned earlier, it can be concluded into 7 potential factors as follows,

- Gating design
- Sand moisture
- Pouring Speed
- Gate number and size
- Flask size
- Metal composition

3.3.3 Defect: Defective Surface (Rough Surface)

Causes:

The sand with too high or too low moisture is equally bad. Excessive moisture produces a direct tendency to stick and roughen the mold surface. Sand which is too dry will permit cuts and washes during pouring, or dislocate sand during the blowing out of the mold or during mold closing. Sand cleanness is another problem that can cause the defect. The foreign materials in the sand can directly affect the casting piece's surface if it is on the mold surface. The foreign particles also permit the sand grains to drop away if the foreign body is near without touching the mold cavity. If the foreign material is on the mold surface, the result is direct roughness either through burn out of the foreign material or adherence of the foreign material. The pouring is another cause of defective surface, excessive pouring height creates unusually high metal pressure and forces the metal or oxide into the mold, which metal or metallic oxides have filled the voids between the sand grains with out displacing them. Excessively high pouring temperatures will lead to oxidation, which may react with mold surfaces to increase roughness. Location of gates also can cause the defective surface in the casting piece. Location of gates which promote localized overheating of the sand lead to premature destruction of the mold surface and will lead to localized molds wall movement, minor swells, fusion, penetration, which all of these considered as rough surface.

Factors:

Accordingly, the causes of the defective surface can be concluded into following factors which are,

- Pouring temperature
- Gate design
- Sand moisture
- Pouring height
- Sand cleanness

After the factors have been listed, the team has come to discuss which factors need to be experimented, which the following table is the result of discussion.

Table 3.1: Potential Factor Classification

Responses	Factors	Experimental Factors	Detail	Remark
Metallic Projection	Worker skill	-	The team has decided not to perform experiment on this factor since the operators can be trained	Controllable factor
	Sand moisture	Snow powder quantity	Snow powder can reduce the moisture in the sand	Experimental Factor
	Sand temperature	-	Uncontrollable, due to the casting process locates in the open air	Noise Factor
Cavities	Gating design	Gate size	Insufficient gate size can limit quantity of metal liquid to entry to the mold, which will cause defect.	Experimental Factor
		Gate number	Insufficient gate number may limit quantity of metal liquid to entry to the mold cavity. Insufficient metal liquid will cause defect.	Experimental Factor
	Sand moisture	Snow powder quantity	Snow powder can reduce the moisture in the sand	Experimental Factor
	Pouring Speed	-	Uncontrollable, the pouring is operated by hand, therefore the pouring speed cannot be managed.	Excluded Factor

(continued)

Responses	Factors	Experimental Factors	Detail	Remark
Cavities	Flask size	-	The team has decided not to perform experiment on this factor because the size of flask used in the experiment is appropriate. Since there is no report of molten aluminum being frozen before feeding cycle is complete.	Controllable factor
	Metal composition	Alloy combination	Two combinations of two alloy types resilient type and solid type.	Experimental Factor
Defective Surface	Pouring temperature	-	The thermometer for measure molten metal is too expensive, and factory has no plan to invest on this thermometer yet.	Excluded Factor
	Gate design	Gate size	Insufficient gate size can limit quantity of metal liquid to entry to the mold, which will cause defective surface.	Experimental Factor
		Gate number	Insufficient gate number may limit quantity of metal liquid to entry to the mold cavity. Insufficient metal liquid will cause defective surface.	Experimental Factor
	Sand moisture	Snow powder quantity	Snow powder can reduce the moisture in the sand	Experimental Factor
	Pouring height	Pouring Height	Inappropriate pouring height creates unusual metal pressure, which will force oxide into the mold and create defect.	Experimental Factor
	Sand cleanness		Worker always clarify the sand before making the mold.	Controllable factor

Refer to the above table; all 12 factors are categorized into four categories; noise factor, controllable factor, excluded factor and experimental factor. Noise

factors are the factors that fall into this category are the factors that hard to be controlled or cannot control at all such as temperature and humidity due to the location of the casting process, it is located in the open air room. Controllable factors are one that can be managed and control at a specify level such as the skill of the operator. Excluded factors are the factors that case study factory cannot control since the case study company lacking of equipment to control. Experimental factors are the factors that will be tested to define whether they significantly affect the responses. These experiment factors are the factors that the team has a query that it might be the cause of defects and those factors the team can control and measure.

3.4 Factor Level Selection

The following table will be described the detail of level selection of each experiment factor.

Table 3.2: Factor Level Selection

Experiment Factors	**Level**		**Remark**
	-1	1	
Pouring height	10 cm	20 cm	According to the result from brainstorming with the team members, the levels of pouring height are considered from the high average and low average of pouring height of operators in casting process.
Number of gates	1	3	Refer to the research number of gates can cause the defect in casting piece, however number of gates depend on the size of the pattern. The number of gates for chair's leg normally requires only one but according to the research increasing number of gate can reduce the defect in the casting piece because molten alloy can fill up the cavity inside the mold more quickly and efficiently. This can reduce the cavities in casting piece. The team decided to choose three gates as other level of this factor because the team wants to see the effect of number of gates when the number is increased. Three gates is a suitable number for leg size of the chair model under consideration.
Snow powder Quantity	10 grams	50 grams	From operator's experience, snow powder will cause cavities and defective surface. If over 50 grams of powder is spattered, defective surface occurs. When less than 10 grams of powder is spattered, cavities occur. Therefore, the team decided to choose those number as the level for snow powder quantity.

(continued)

Experiment Factors	Level		Remark
	-1	1	
Solidification time	3 minutes	10 minutes	Although the solidification time is not listed in the research of cause of defects but the team has decided to include this factor in the experiment because the team thinks that the solidification time can be the cause of defect. The team thinks that, if the flask is opened too early, the molten aluminum that still does not transform to solid stage will be exposed to the oxygen and might have some reaction and cause cavities inside the casting piece. According to operators' experience, molten aluminum alloy completely turns into solid stage in about 3 minutes and thaw in about 10 minutes. Therefore the team decided to use those numbers as the levels of this factor.
Alloy combination	(18,2)	(14,6)	According to the operator's experience, the resilient alloy type is the cause of defective surface. However the resilient has to be added to alloy combination in order to keep the casting pieces strong. The resilient type has to be added to alloy combination at least 2 bars in order to keep the product not too fragile. On the other hand, the resilient type cannot be added in alloy combination more than 6 bars because the casting pieces will get too resilient which it will compromise the strength of the product. Therefore, the team has decided to use these assumptions as the level of alloy mixture in the experiment.
Gate Size	2x4.5	2x7	There are two gate sizes used in the case study company: gate size 2x7 cm and 2x4.5 cm. Gate size 2x7cm will be used with casting pieces that is larger than 100 cm x 30 cm and 2x4.5 cm will be used for smaller casting pieces. Chair's leg (experimental product) requires gate size 2x4.5 cm. However, refer to the research the gate size can cause the defect in casting pieces therefore the team decided to use these gate sizes to be one of the factors in the experiment to find whether gate size significantly affect this defect on chair leg under consideration. Also, this research is to confirm whether the gate size currently employed really gives the better result than the other gate size used for other products.

Remark: All factors levels are considered for a chair's front leg and chair's back leg.