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Design of Pouring Stand with Adjustable Pouring Height for Metal Moulding Flask in Green Sand-Casting Application

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Abstract: Casting process had been made long ago, and effectively performing this process was tremendously influential on their gain of power during the Bronze Age. The process gone through many improvements from time to time until the new technology such as investment casting, stir casting, vacuum casting, and others. However, sand casting which is the ancient and conventional casting method still valid to be used till today due to its advantages. Porosity is one of the issues in alloy castings, it can be formed either from the process, materials, or other factor. The main aim for this paper is to design a pouring stand with adjustable pouring heights for metal moulding flask in green sand-casting application. The design is focusing on reducing the turbulence that produce bubble that later will become a defect in casting by determine the specific height which is 10 cm, 15 cm, and 20 cm. Based on the result, the comparative between design I and design I show that design II is more compactible for the use of the adjustable stand. The design of the adjustable stand has been done using SOLIDWORK software and the same design is analyzed using SOLIDWORK software simulation. The analysis for the design showed yellow coloured stress distribution at the ladle holder/cup at the V-shape design II with the value of 2.045e+03 N/m^2 to 2.249e+03 N/m^2. Thus, design II showed better distribution with lower value than design I of stress that considered as high. The analysis also is analyzed using costing analysis to corroborate the conclusions arrived at through cost analysis. The cost of the best adjustable pouring height stand design II (V shape) with ladle holder feature is RM 1117.76. Based on the result, it is revealed that design II is the most optimum design of pouring stand with adjustable pouring height for metal moulding flask in green sand-casting application.

Keywords: Pouring Height, Solidworks Design, Sand Casting

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1. Introduction

Casting is known as the process in the manufacturing in which requires a liquid material to be poured into a mould. Casting process where material such as aluminium were melting and poured into specific mould to solidify. Then the material will become the product that replicating the mould which is called as castings. There are several parameters involved during the casting process such as pouring temperature, pouring height, hydrogen content, oxidation, pouring techniques and other factors that contribute to the quality of the castings. Therefore, the casting process had some problem resulted to porosity formation in the casting. The porosity reduces the product quality and the cost for repairing are high or rectification could not be done. There are two type of porosity which is gas porosity and shrinkage porosity [1]. The porosity in castings seems to be the entrained air bubbles, although sometimes it is a more uniform dispersion of bifilms that partly or fully inflated with a gas from solution in the melt [1]. For shrinkage porosity, it is a mass of oxides generated by the entrainment of the oxide surface in the turbulence during pouring [1]. There is some porosity could be caused by the mould or core blows, or even 'micro blows' fired into the casting from microscopic pockets of volatile binder trapped in recesses in mould particles. Next, the gas porosity also known as subsurface porosity. Subsurface pores are broken into by the loss of surface scale during heat treatment, as is common for steel castings, or are broken into during shot blasting to clean the castings. The subsurface pores can form because of the flotation of air bubbles that have been entrained during the pouring of a casting. These types of defects decreasing the mechanical performance of the alloy castings. Therefore, controlling the casting process parameters is crucial to produce a comparable quality aluminium alloy casting.

1.1 Defects in Sand Casting

The sand-casting process parameters can contribute to the presence of defects in the castings. The defect has various type depending on the condition and situation. The defect that usually found in sand cast products are gas defects, shrinkage cavities, moulding material defects, pouring metal defects, and mould shift. There are some study states that low molten metal velocity and pressure, excess machining stock, and bad chill and vent design are the main causes of defect [2]

1.2 Factors contribute to porosity in casting

In casting, there are several of factor that cause presence of porosity. The porosity contributes directly to customer concerns about reliability and quality. Controlling porosity depends on understanding its sources and causes. The improvements in product quality, component performance, and design reliability can be completed if porosity in castings can be controlled or eliminated. According to research, porosity in castings seems to be entrained air bubbles, although sometimes it is a more uniform dispersion of bifilms partly or fully inflated with a gas from solution in the melt [1]

1.2.1 The velocity of material during pouring

There is some factor that occur and made the present of porosity which is the pouring height of the molten metal during the process. The quality of casting most depending on the skill of the person that handling the pouring process. The pouring that unstable will make the flow become turbulence and give an impact to the porosity. In the pouring procedure, it is essential to control the outpouring of liquid metal from a ladle and fill the right position of the sprue cup in a mould [2] Other than that, it is also crucial to set the suitable pouring height since problems related to higher pouring are shown in previous studies which the high pouring will make that increase the amount of air [2]The pouring height have influence on the event of a misrun, which is illustrative of casting defects, is emphatically reliant on the molten alloy inflow behaviour which the inflow behaviour is well known to influencing casting quality and most casting defects are came from the turbulence of the molten alloy during pouring process [2]. According previous research, the molten alloy flow rate changes over time with hand pouring and also the importance of quantifying hand-pouring behaviour in the actual casting, not only from the perspective of phenomenology but also for improving thermal fluid analysis [3]

1.2.2 The Temperature during Pouring

Casting molten metal need to be heated before pouring into the mould and solidified before became the product. Some research state that molten metal temperature during pouring process is crucial in determining castings quality. The high pouring temperature can trigger the formation of shrinkage due to the different temperature of mold and liquefied metal in the mould. The porosity in the castings usually in the form of gas porosity, shrinkage porosity, hot tearing and cracks [4]. The prepared mould was pre-heated within a temperature range of 25 to 230ºC. According to previous research, high pouring temperature can cause shrinkage of the castings and mould warping. However, pouring temperature was varied within the range of 700 to 850ºC. The mechanical properties of the Al alloy castings were hardness, impact, and tensile strength. The results showed that the selected process parameters significantly influence the mechanical properties of the Al alloy casting [5]. When the pouring temperature is lower than its optimum value, the mould cavity will not be filled because the gate or riser will solidify too rapidly, and this will intercept directional solidification [5]. There also some research that state that temperature can be one of porosity factor that can be occur during pouring process. Based on the research, lower pouring temperature contributes to the reduction of porosity fraction aside from other factors like casting thickness, material composition, and the type of manufacturing process [6]. The temperature during pouring also crucial to be determined to minimize the probability of porosity presence in the castings.

1.2.3 The Gating System during Process

The assembly of channels which allows the flow of the molten metal to enter the mould cavity is called as the gating system. The gating system refers to all passageways through which molten metal passes to enter the mould cavity. The nomenclature of gating system depends upon the function of different channels which they perform which is down gates or sprue, cross gates, or runner, and in gates or gates. The metal flows down from the pouring basin or pouring cup into the down gate or sprue and passes through the cross gate or channels and in gates or gates before entering the mould cavity. Gating systems are crucial for minimize turbulence to avoid trapping gasses into the mould. Gating system also needed in casting as to get enough metal into mould cavity perfectly before the metal start solidified. The important of gating system also were used to avoid shrinkage and to establish the best possible temperature gradient in the solidifying casting so that the shrinkage if occurs must be in the gating system not in the required cast part. A research state that a well designated gating system should fill the mold quickly, yet quiescently, with a minimum of turbulence which promote directional solidification, minimize aspiration of air [7]. Besides, gating or riser system design plays a very important role for improving casting quality. There are many researchers reported that 90.00 % of the defects in casting are obtained only because of improper design of gating and feeding system. It shows that the proper gating system design are crucial for the good quality of alloy castings. The casting process need to have a proper flow through the gating system to avoid the defect during the process.

1. Materials and Methods

The important focus of this research is the design of the adjustable pouring height stand and the design analysis with regard to the consistency and performance of the casting aluminium alloy through the sand-casting process. There were several parameters that were collected from the literature review involved in the study of the adjustable pouring height design. The adjustable pouring height design was analysed using Solidworks software on stress and displacement study in terms of its efficiency and quality in the sand-casting process.

2.1 Designing Pouring Height Stand for Metal Moulding Flask in the Foundry Workshop

The design of a pouring stand is adapted from the previous research. However, the design of a pouring stand is for application of sand casting by manual operation which is different from the previous research. The specification for the pouring stand to be drawn are three different height which is 15 cm, 20 cm, and 25 cm height. The measurement is measure from the pouring tip of the ladle contain molten metal to the top of the green sand mould which is the pouring basin at the green sand mould. There two suggested designs which is the first design (Design I) that able to cater the pouring height 15 cm, 20 cm, 25 cm and 30 cm. The pouring stand also have the ladle holder/cup that can move to left and right by moving the bolt and nut that connect the ladle holder/cup and the body. For second design (Design II), the design has a different compared to the first design (Design I) which are the second design ladle holder/cup is much more spacious than Design I. 'V' shape that can support the ladle while pouring process to be more stabilize with the potential to move to right and left.

2.2 Methods

This project was organized to systematically set up all the activities and plans involved in this project to be carried out smoothly and on schedule, as well as to avoid any errors during the activities, especially in the analysis and preparation of processes. The activities of this research were depicted in the flowchart as in Figure 1.

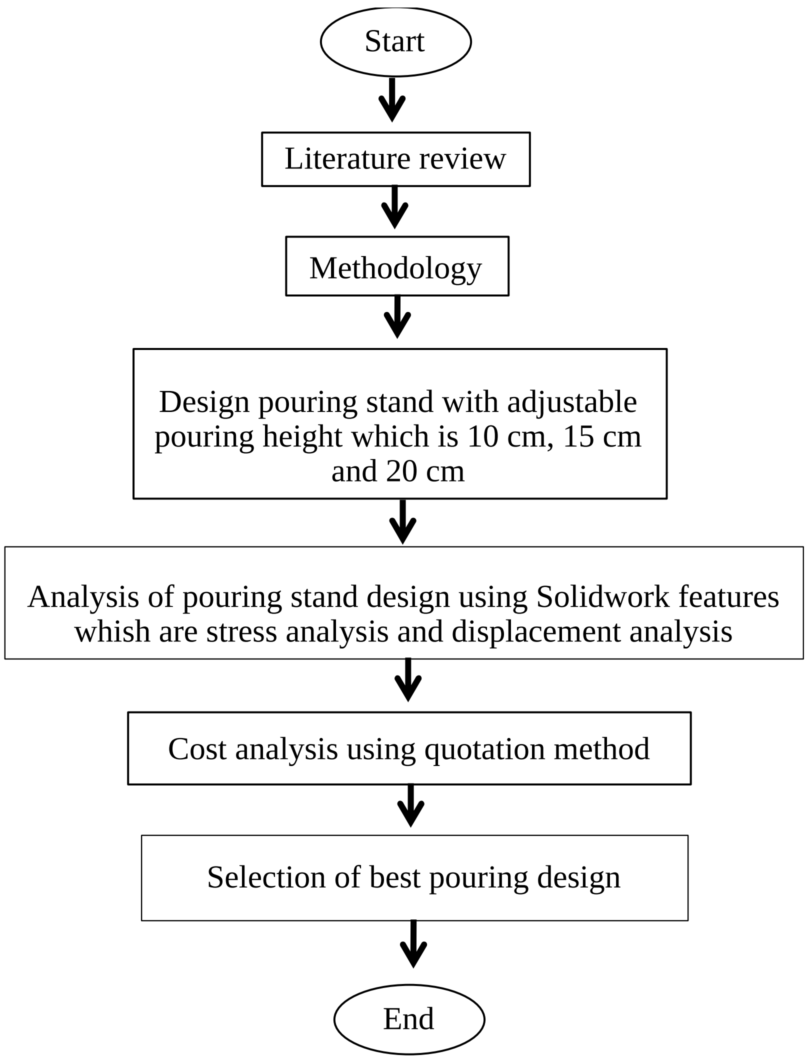

Figure 1: The research activities flow chart

2.3 Design Analysis of Pouring Height Stand

The stress and displacement analysis use the same step to get the result which consist insert part material, connection between part, the fixture of the part and the force that applied on the product. After that, the product will be mesh and run the analysis in the Solidwork software to get the stress analysis and displacement analysis result.

2.4 Cost Analysis

Some form of price or cost analysis should be performed in connection with every procurement action, regardless of whether the organization is a vendor or a sub recipient. The form and degree of analysis, however, are dependent on the particular subcontract or purchase, and the pricing situation. Determination of price reasonableness through price or cost analysis is required even though the procurement is source directed by the contracting officer of the sponsoring agency. In some purchases, price analysis alone will be sufficient; in others, price analysis will be used to corroborate the conclusions arrived at through cost analysis. The demand quantity of a commodity is conceived as a function of price in most operational management models, which gives the business flexibility to achieve tradeoffs between revenue and cost [8]. The form and degree of analysis are dependent on facts surrounding a particular subcontracting or purchasing situation. The scope of price analysis performed, and the particular techniques used will depend on whether or not cost analysis is done, as well as on such factors as type of product or service, currency value, purchase method, and extent of competition

2. Results and Discussion

This chapter discusses the results obtained in this study such as designs of the pouring stands, analysis of the pouring stand design using Solidwork software and also cost analysis.

3.1 Design of the Pouring Stand with Adjustable Height

Adjustable pouring height stand were design with three different height which is 10 cm, 15 cm, and 20 cm that were measure from pouring cup to flask. The part in Design I and Design II were differentiate with the shape for the ladle holder on the top of adjustable support as shown in Figure 2 and Figure 3. Design I have a casting ladle holder/cup with U shape that supposed to make the ladle stationary during molten metal pouring process occur. Design II have a casting ladle holder/cup with V shape that make the ladle have a slightly space to moveable during the molten metal pouring process. Design II showed a slightly different cost which are higher that design I because of additional process to made the grip. The grip in design II need to be through a milling process and also a welding process while design I only use welding process.

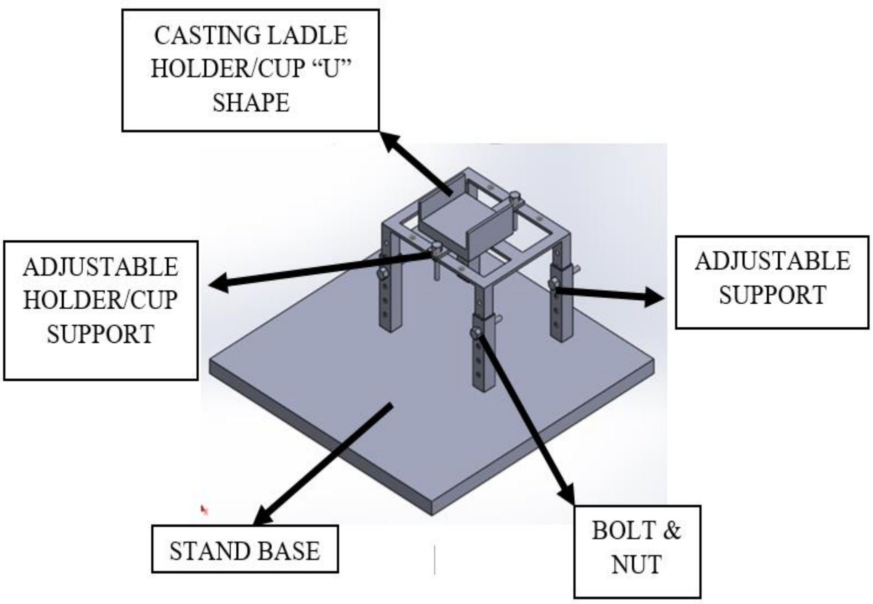

Figure 2: The Design I of Adjustable Pouring Height Stand Design with the Part Specification

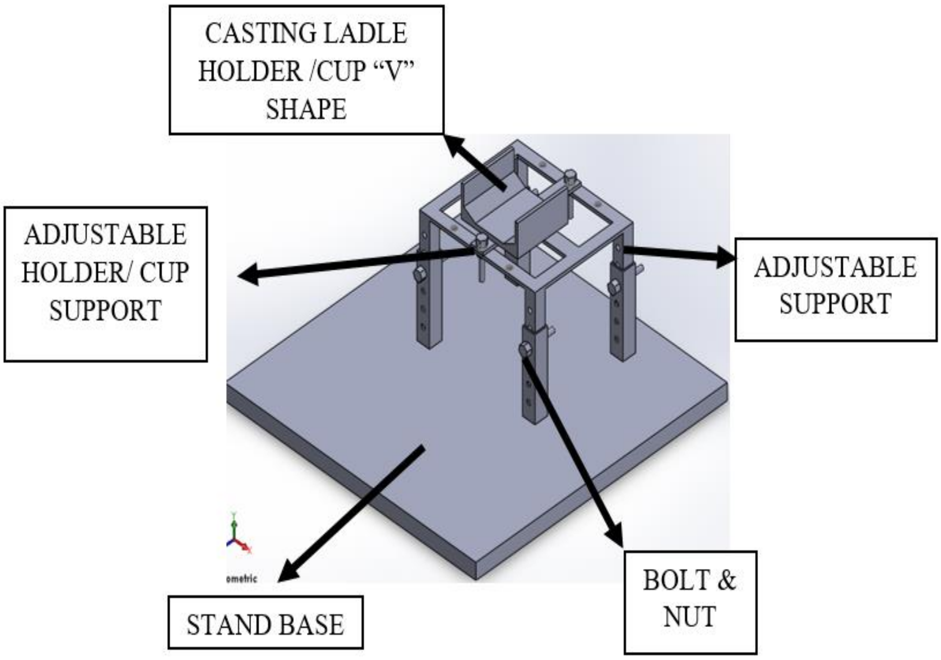

Figure 3: The Design II of Adjustable Pouring Height Stand Design with the Part Specification

3.2 Design Analysis Results using Solidwork Analysis Features

The result of design analysis using Solidwork analysis features were stress and displacement analysis were discussed in subchapter 3.2.1 and 3.2.2. In terms of force applied to a certain cross-sectional area of an object, the term stress (s) is used to express the loading. Stress is the applied force or system of forces from the perspective of loading that appears to distort a body. In addition, stress is the inner distribution within a body of forces that balance and respond to the loads applied to it. Depending on the essence of the loading case, the stress distribution may or may not be standardized. Next, Displacement is defined as the difference in distance between the initial and final points of an object or the change in location. Displacement is a quantity of vector, meaning that it is used for direction and magnitude. This study focuses on the change in the product's location when the full load is applied to the product.

3.2.1 Stress Analysis for Design I and Design II

Stress and displacement analysis using Solidwork software are crucial in designing stage. From the perspective of loading, this analysis were the applied force or system of forces that tends to distort a body. In addition, the internal distribution within a body of forces that balance and respond to the loads applied to it is stress. The stress distribution may or may not be uniform, depending on the essence of the loading situation. Figure 4 show the image of stress analysis of adjustable pouring stand design I using Solidwork software while Figure 5 show the image of stress analysis of adjustable pouring stand design II using Solidwork software

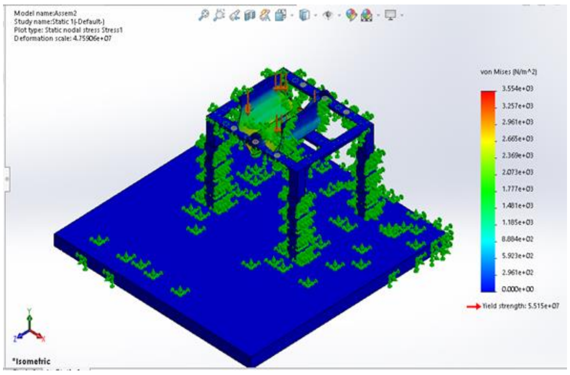

Figure 4: The Image of Stress Analysis of Adjustable Pouring Stand Design I

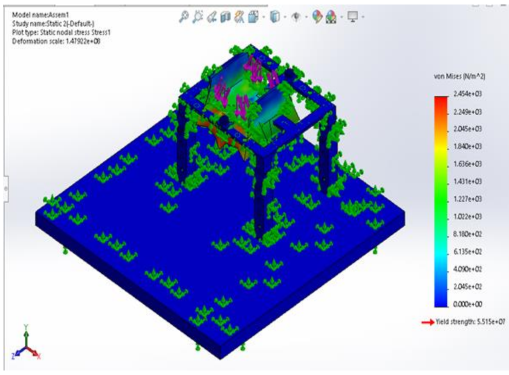

Figure 5: The Image of Stress Analysis of Adjustable Pouring Stand Design II

v ... ress distribu ... f in betwee ... s identified that the rest of pouring stand part such as the base and the middle structure of the stand were in blue colour showing low stress value of 2.961e+02 N/m² and below. However, in the analysis showed slightly yellow coloured stress distribution at the ladle holder/cup at the U-shape Design I with the value of 2.369e+03 N/m² to 2.665e+03 N/m². Yellow colour stress distribution shows slightly high stress at that point causing slightly high stress compared to other pouring stand. Previous researcher state optimization of stress is one of the main factors in a wide variety of engineering problems for structural design [8]. The researcher also state that in the concept of the structural component, if stress is not taken into account, the design is susceptible to post processing or rework, resulting in unexpected costs [8]. Based on the design at pouring stand with V-shape ladle holder/cup (Design I), it can be said that the pouring stands able to distribute the load evenly to the 4-leg stands represent by the green and blue coloured stress distribution as shown in Figure 3. The green-coloured stress distribution can be considered as medium stress.

The stress distribution of adjustable pouring stand with V shape (Design II) is shown in Figure 3.4. It can be seen that the stress distribution for Design I (U-shape) is a quite different with Design II (V-shape). The green-coloured stress distribution to the stands/leg and also to the base of the pouring stand. The value of stress in the green coloured was between 8.180e+02 N/m² to 1.227e+03 N/m² while the stress distribution at the ladle/cup was found to be in green colour too with value of 1.022+03 N/m² to 1.431e+03 N/m². However, in the analysis showed slightly yellow coloured stress distribution at the ladle holder/cup at the V-shape Design II with the value of 2.045e+03 N/m² to 2.249e+03 N/m². The value in design II are slight lower than value in design I. The stress distributed at the ladle holder or cup top was found at medium level as show by green coloured. The rest of the pouring of the pouring stand base was in blue colour with the value of 2.045e+00 N/m² and below which is low stress distribution. Both design (I and II) showed comparable result of stress distribution. However, Design II showed better distribution with lower value than Design I of stress that considered as high

3.2.2 Displacement Analysis for Design I and Design II

Displacement is defined as the distance difference between an object's initial and final points or the position change. Displacement is a vector quantity, which means it is used for direction and magnitude. This analysis focuses on the change in the position of the product when the maximum load is applied to the product.

Figure 6 shows the displacement analysis result of adjustable pouring stand design I with U-shape ladle/cup. It can be seen that the displacement distribution at the pouring stand generally were in green colour indicating medium displacement of the value in between 4.054e-07 mm to 8.107e-07 mm. There was no yellow to orange colour that represent high displacement. While the base of pouring stand showed low displacement with blue colour.

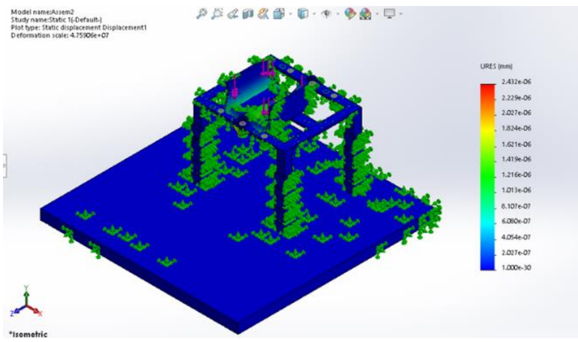

Figure 6: The Image of Displacement Analysis of Adjustable Pouring Stand Design I

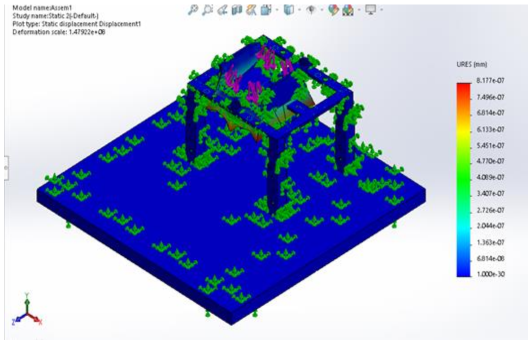

Figure 7: The Image of Displacement Analysis of Adjustable Pouring Stand Design II

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was no yellow to orange colour that represent high displacement. While the base of pouring stand showed low displacement with blue colour.

The result of displacement analysis for pouring stand design II (V-shape) ladle/cup is shown in Figure 7. It was formed that the displacement was simulated to occur slightly higher with value of 2.726e-07 mm to 6.814e-07 mm at the bottom part of the ladle/cup indicated by red arrows. However, the displacement at the pouring stand of both design I and II are small which only about range 4.053e-07 mm for design I and 4.088e-07 mm for design II.

3.3 Cost Analysis of the Pouring Stand with Adjustable Pouring Height.

Cost Analysis of adjustable pouring height were determined with the quotation analysis. The analysis consists the current market price for the material and also price for the service that done in the fabrication process. Table 1 shows the price of the material used for the fabrication of the adjustable pouring height stand design while Table 2 the price of the service involved in the adjustable pouring height stand design fabrication process.

Table 1: The Price of the Material in the Adjustable Pouring Height Stand Design I and Design II

No	Material	Description	Quantity	Price (RM)
1	Aluminum sheet	500 mm x 800 mm x 3mm	2	178
2	Aluminum Square tube	30 mm x 30 mm x 500mm, 2mm	4	80
3	Aluminum Square tube	20 mm x 20 mm x 500mm , 2mm	4	55
4	Aluminum Plate	300mm x 60mm x 5mm	2	65
5	Aluminum Flat Bar	200 mm x 200 mm x 20 mm	2	200
6	Bolt	Hex bolt size m14 x 100 mm	6	93.54
7	Nuts	M14 hexagon nuts	6	26.22

Table 2: The price of the Service Involved in the Adjustable Pouring Height Stand Design II Design II fabrication process

No	Process	Description	Price (RM)	DESIGN	
1	Welding	210 cm x 100 cm	200	I	II
2	Drilling	Using a drill to drill 18 holes	50	I	II
3	CNC Milling	Estimation based on product	150	-	II
4	Finishing	Surface finishing	20	I	II

Cost Analysis of adjustable pouring height were determined with the quotation analysis. The analysis consists of the current market price for the material and also price for the service that done in the fabrication process. Table 1 show the price of the material used for the fabrication of the adjustable pouring height stand for both Design I and Design II while Table 2 show the price of the service involved in the adjustable pouring height stand design fabrication process. Based on the elemental price as listed in the Table 1 and Table 2, the total cost of Design I is RM 967.76 while Design II is RM 1117.76.

3.4 Best Pouring Stand Design

Based on the finding, the most suitable adjustable pouring height design met the requirement are design II. Even though design II and design I had slight a different result of analysis, design II were compatibility in term of fixed movement for the ladle during the molten metal pouring. The design analysis is important to know the limitation of the design after the load were applied on the design. For cost analysis, the different of total cost, design I is RM 967.76 while design II is RM 1117.76. Design II showed a slightly different cost which are higher that design I because of additional process to made the ladle holder/cup become more fixed. The different cost between design I and design II is RM 150 which is the additional cost of milling process. The ladle holder/cup in design II need to be through a milling process and also a welding process while design I only use welding process. From the cost analysis, adjustable pouring stand design were selected based on the important need that were happen during the molten metal pouring process. A cost analysis for both design need to looks at the individual elements of the price (labor rates, direct & indirect materials and overhead, expenses, profit/fee) and analyzes these. Overhead or indirect rates may be verified and found reasonable by verifying such rates with the awarding agency, in many cases. The technical staff that handle the fabrication should determine the number of hours proposed, not the price. The reasonableness of the fee or benefit percentage is the responsibility of the customer. Therefore, the suitable design for the stand design is design II even though the price for the design has a slightly high.

3. Conclusion

It can be concluded that the objectives of this study are achieved. The best pouring height stand design is the Design II (V shape) with ladle holder/cup feature. The cost of the best adjustable pouring height stand Design II (V shape) with ladle holder feature is RM 1117.76. The optimum design for the adjustable pouring stand is possible to be applied for sand casting application. The design and cost analysis based on different for each design had been conducted and evaluated. The result of analysis that obtained had slightly different value which giving advantage for each design in term of strength and cost. The utilization for the adjustable pouring height stand will decrease the porosity problem in sand casting poring process.

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