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COMPARISON AND CFD VERIFICATION OF BINDER EFFECTS IN SAND MOULD CASTING OF ALUMINUM ALLOY

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ABSTACT: This paper presents the systematic finite element analysis to investigate the different binder effects in sand mold casting in cooling of Aluminum alloy. Generally the mold materials controls smooth, uniform and complete filling of the cavity by the molten metal. In this study three different types of binding materials namely clay, molasses and oil were used as binding material of sand. Bottom gating system is used for its low gas entrapment and less surface defect characteristics. Experimentation was carried out for the different binders and computational analysis was also done for selecting the best binder. Best binder was selected based on cooling rate. A CAD model was generated using Solidworks and a fluid flow analysis was done accordingly to verify the effects. Simulation parameters and boundary conditions were extracted from an actual experimental condition. Both the experimentation and CFD simulation shows that clay is the best binder where cooling is more rapid.
Keywords: Sand mold Casting, Binder, Aluminum alloy, CFD simulation

1. INTRODUCTION

Sand mould casting is a metal casting process characterized by using sand as the mould material. Over 70% of all metal castings are produced via a sand casting process. Sand casting is one of the most popular and simplest types of casting. Not only does this method allow manufacturers to create products at a low cost, but there are other benefits to sand casting. Sand casting also allows most metals to be cast depending on the type of sand used for the moulds. In addition to the sand, a suitable bonding agent (usually clay) is mixed with the sand. The mixture is moistened, typically with water, but sometimes with other substances, to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The mould materials controls smooth, uniform and complete filling of the cavity by the molten metal. The bonding agent dictates the rate of cooling of the molten metal poured in the mould which in turn controls the quality of the product. Many research works have been conducted to find the effectiveness of different binders. Fayomi et. al [1] investigated the use of local oils, namely groundnut oil, cotton seed oil and palm oil with Nigeria local clay and silica sand for the production of foundry cores on varying composition. Nuhu A. Ademoh [2] evaluated the mechanical properties of Expendable Foundry Sand Cores bonded with composites made of kaolin clay and grades 1 and 4 Gum- Arabic. Popoola et. al [3] studied the performance of binders on core strength in metal casting by using molasses, starch and Gum Arabic as binders individually. Atanda et. al [4] investigated and compared the use of Bentonite and Cassava Starch as binders on the moulding Properties of Silica Sand. The authors of this paper used clay, molasses and oil as binding material of sand performed the systematic finite element analysis to identify the most effective binder in sand mold casting in cooling of Aluminum alloy using analytical and simulation approach. Bottom gating system was used for its low gas entrapment and less surface defect characteristics. The authors did a computational analysis to select the best binder. A CAD model was generated using Solidworks and a fluid flow (CFX) analysis was done using Ansys workbench software. Simulation parameters and boundary conditions were extracted from an actual experimental condition. The CFD simulation study showed that cooling rate with clay is more rapid and thus can be suggested that clay is the best binder.

2. DESIGN AND COMPOSITION OF MOULD

Sand moulds were made to perform the experimentation. Clay, molasses and oil were used as binding material of the molds in turn. The basic compositions of the molds and the percentages of the binding materials in the molds are shown in Table 1. The sand molds had circular cross section at the gate. First a pattern of the cast product was made with wood. Then the mould was made based on that pattern.

Bottom gating system was used to ensure turbulence free flow of the molten metal inside the mould cavity. The riser, basin and gate were designed by standard formulae to ensure best quality of casting without any defect. The different portion of the sand mold process is shown in figure 1.

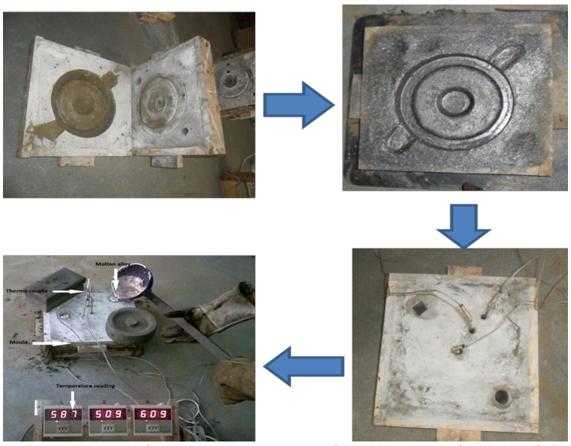

Figure 1. The experimental setup with mould and the temperature measuring device

Table 1. Composition of clay bonded, oil bonded and molasses bonded molding sand

Clay Bonded Molding Sand		Oil Bonded Molding Sand		Molasses Bonded Molding Sand	
Molding Sand constituent	Weight percentage	Molding Sand constituent	Weight percentage	Molding Sand constituent	Weight percentage
Silica Sand	76	Silica Sand	84	Silica Sand	76
Clay (Sodium Bentonite)	15	Lube oil (SAE-40) BP	12	Molasses	15
Wood flower	1	Wood flower	2	Wood flower	1
Coal dust	1	Parting Materials (Chalk Powder)	2	Coal dust	1
Water	6	-	-	Parting materials (Chalk Powder)	1
Parting materials (Graphite)	1	-	-	-	-

To measure the temperature of the molten metal three K-type thermocouple (CD-XMTA-1001) was used at specific point as shown in figure 2 on the mould. To take the reading of the temperature a digital temperature meter was used. This meter can take accurate reading of temperature in a range of 0-999^{0}C.

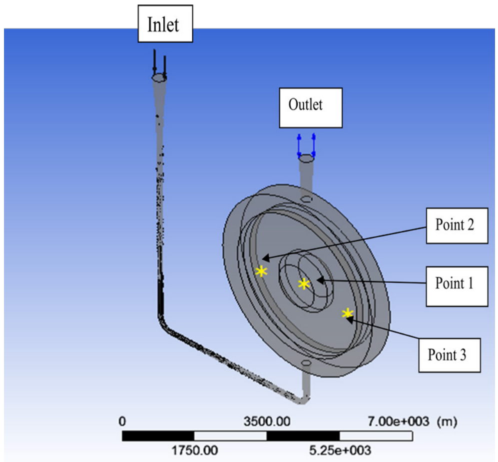

Figure 2. A CAD model showing the three specific points where the thermocouples were inserted to measure the temperature

3. EXPERIMENT

Aluminium was used as the casting metal. A crucible furnace was used to melt the aluminum at a temperature more than 700^{0}C. After the metal was melted the molten metal was poured into the basin of the mould with a ladle. After pouring the reading of the temperature was taken for all three positions. The experiments were repeated with changing binding materials. It was ensured that the initial operating conditions and overall environmental conditions were same in all the three experiments. The recorded data were then used to generate cooling curves. For the experiment a commercially available grade of Aluminum was used. The properties of the Aluminum used for the experimentation are as follows:

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Table 3. Properties of Aluminum used in the experiment

Properties	Values
Molar Mass	26.98 g mol^{-1}
Density	2750 Kg m^{-3}
Specific heat capacity	1047 J Kg^{-1} K^{-1}
Dynamic viscosity	0.0025 Kg m^{-1}s^{-1}
Thermal conductivity	180 Wm^{-1}K^{-1}
Thermal co-efficient of expansion	4x10^{-5} K^{-1}

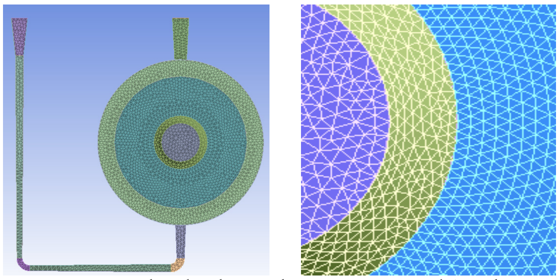


Figure 3. Tetrahedral meshes generated in the mold cavity and pattern.

Table 4. Simulation parameters

Parameters	Value
pouring temperature	700-750°C
Inlet temperature	710°C
pouring speed	2.6 cm/s
Pressure	1 atm

4. SIMULATION

To validate the results obtained from the experimental setup for sand mould casting process for different binders' simulation in Ansys CFD was carried out in a similar way followed by N.A Chowdhury et al. [5] approach used for permanent mould casting process. First geometric modeling of different parts of the mould i.e. sprue; basin, riser etc were designed by Solid works and then assembled together maintaining same hydraulic diameter to ensure same flow characteristics at corresponding points of the model. Points were then created on surfaces such as inlet, opening and wall followed by fluid domain. Tetrahedral meshes were generated for the mold cavity and pattern. The quality of the meshes was checked and refined to obtain the optimum level. At the end mesh files were written in cfx format for further analysis in Ansys CFX. The enlarged view of generated mesh is shown in figure 3. The model with different material properties and boundary conditions followed the flow chart as shown in figure 4 for sand casting process. The values of different boundary conditions and parameters are also given in table 4:

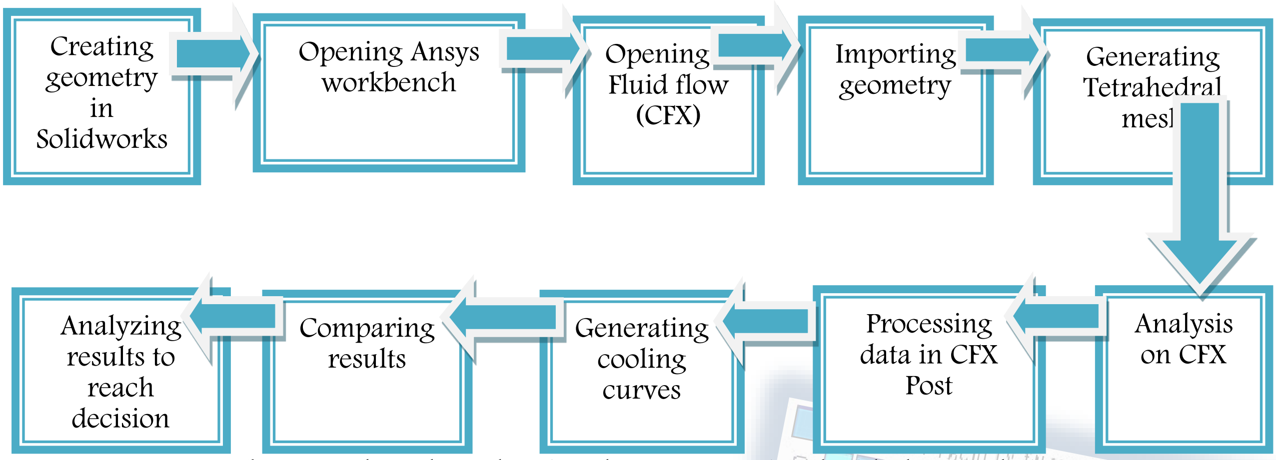
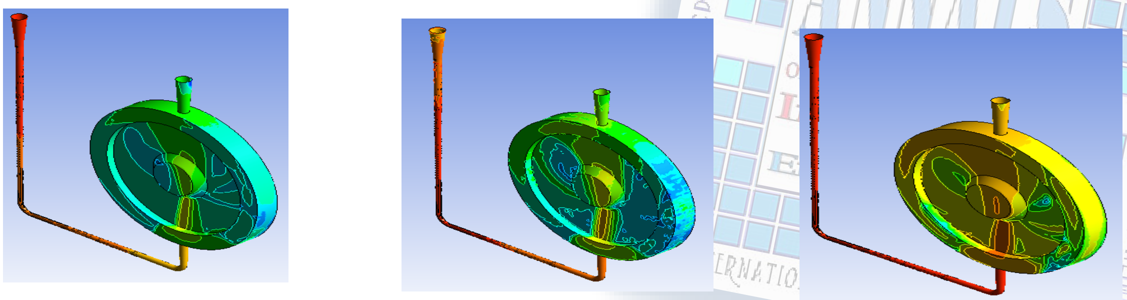


Figure 4. Flow chart showing the steps associated with the simulation

5. RESULTS AND DISCUSSIONS

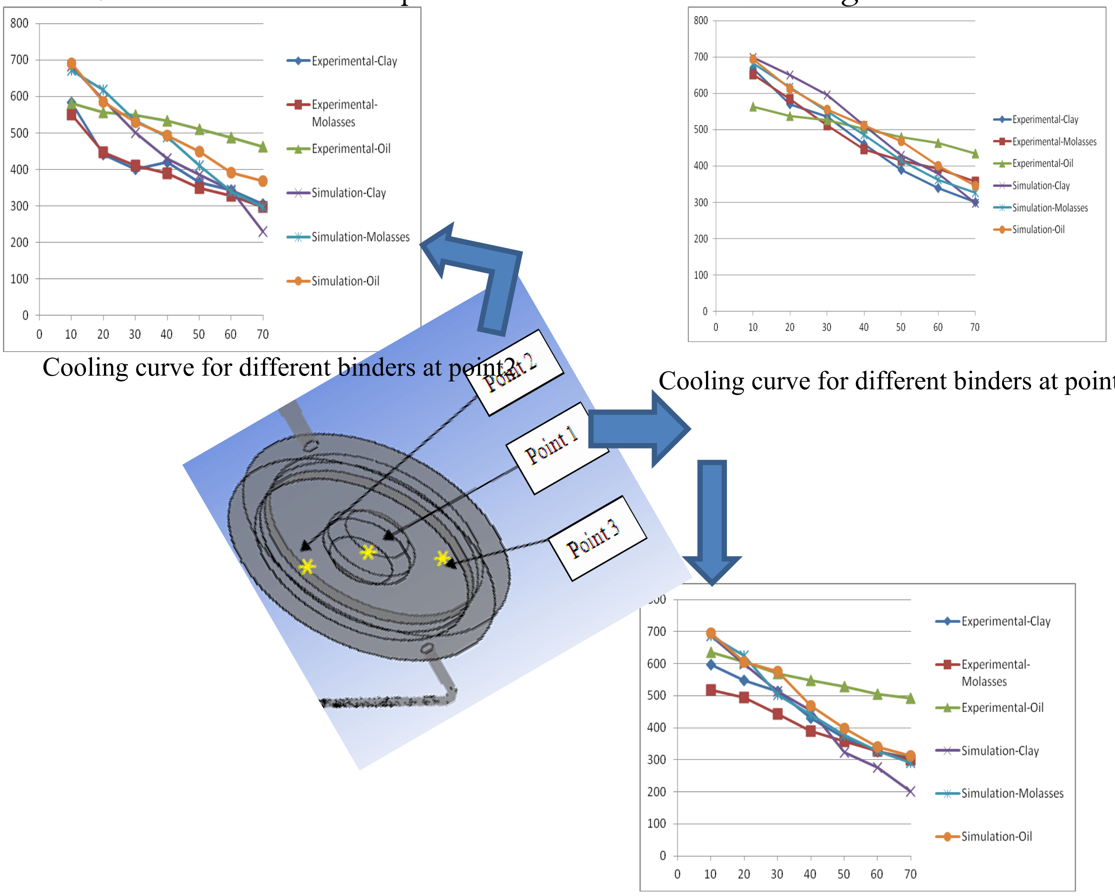
After the simulation, the simulation results were plotted against the experimental results for comparison. The calculated distortion of the element mesh for different binders is shown in figure 5.



Clay **Molasses** **Oil**

Figure 5. Calculated distortion of the element mesh at different binding composition.

From the figure it has been observed that the cooling rate is comparatively better in case of clay as the binder for the casting process. The cooling rate variation at the three locations for the different binders for both simulation and experimental results are shown in figure 6.



Cooling curve for different binders at point2

Cooling curve for different binders at point 1

Cooling curve for different binders at point3

Figure 6. Cooling rate variation for three locations for three binders-simulation and experimental.

From the cooling curve at different three locations it has been found that clay as a binders show more rapid cooling compared to other binders. Both the experimental and simulated results showed the similar tendency and are good agreement.

6. CONCLUSIONS

The systematic finite element analysis was performed to identify the most effective binder amongst clay, molasses and oil in sand mold casting in cooling of Aluminum alloy. Both the experimentation and CFD simulation showed that clay was the best binder where cooling is more rapid. Thus it can be suggested that clay may be used as an effective binder in sand mold casting processes.

References

[1.] Fayomi O. S. I., O. O. Ajayi, and A. P. I. Popoola, “Suitability of local binder compositional variation on silica sand for foundry core-making”, International Journal of the Physical Sciences, Vol. 6(8), pp. 1940-1946, 18 April, 2011

[2.] N.A. Ademoh, “Evaluation of the Mechanical Properties of Expendable Foundry Sand Cores Bonded with Composites Made of Kaolin Clay and Grades 1 and 4 Gum Arabic”,American-Eurasian Journal of Scientific Research, Vol.4 (3), pp. 117-123, 2009

[3.] A. P. Popoola and O. S. Fayomi, “Accessing the performance of binders on core strength in metal casting”, International Journal of the Physical Sciences”, Vol. 6(34), pp. 7805 - 7810, 16 December, 2011

[4.] P. O. Atanda, O. E. Olorunniwo, K. Alonge, and O. O. Oluwole, “Comparison of Bentonite and Cassava Starch on the Moulding Properties of Silica Sand”, International Journal of M aterials and Chemistry , Vol.2(4), pp. 132-136, 2012

[5.] N. A. Chowdhury, Arif M Khan, M. N. Mahmood, and Anayet. U. Patwari, “Investigating of the Effect of Rectangular and Trapezium Cross Section of Gating System by CFD Simulation in Cooling of Aluminium Alloy in a Permanent Mould Casting”, International Journal On Advanced Science, Engineering And Information Technology, Vol. 2(3), pp. 4-8,2012