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Optimization Of Gating Systems For AZ91 Mg Alloys

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Abstract: Nowadays, Magnesium alloys are being used in variety of engineering applications such as automobile, aerospace and biomedical industries. The main objectives of present investigation is to study the the influence of three different mold designs on casting quality of AZ91 Mg-alloy. Click-2-software was used to simulate the flow pattern of melt, temperature and porosity distribution in the final castings using VOF approach. Furthermore, the influences of pouring temperature, mold material and die preheating temperatures on porosity of final casting were also investigated. Simulation data revealed that mold design with proper gating systems made out of carbon steel (preheated at 400^0C) produced sound castings as compared to other mold designs.

Keyword: Mg alloy casting , AZ91 , Gating system design ,Computational Fluid Dynamics , Casting defect.

1. INTRODUCTION

In the current decades, magnesium alloys used in the fabrication of structural and nonstructural parts in various automobile and aerospace industries due to its low density and higher ability regarding strength to weight ratio [1-4]. The main object behind improves fuel consumption and reduction of vehicle weight. In die-casting industries, almost 80% of commercially produced magnesium-based alloys are made out of Mg Al-Zn alloy system which is designated as AZ91 series. Since, Mechanical properties of the castings mainly depend on the porosity of the castings. Casting industries took a lot of efforts to produce good castings with superior mechanical properties based on a trial and error approach. However, they consume a lot of materials, time and energy to optimize the casting parameters to yield sound castings without any defects. Therefore, optimum gating system is one of the important areas which should be taken into account in producing a sound casting. Hence the optimal design of a good gating system is the basic requirements to observe the fluid flow behaviour during the mould filling process. Uniform mould filling is a complex featured phenomenon that influences both the internal and external quality of the casted products. The flow velocity of molten metal in the molding system after being poured is a thermal transient phenomenon accompanied by fluid flow turbulence, separation of the fluid flow from the boundaries of the mold, dividing and combined flow at the junction of the runners and ingates, instantaneous heat transfer during the fluid flow and during the solidification phase of the mold and gating system components [5]. Jong and Wang [6] described the use of optimal design of the gating system. Lee and Kim [7] explained the modified complicated method to reduce the chances of warpage by optimizing the thickness of the different surfaces of the mould. Balasubramanian and Norrie [8] described a multi-agent system, with emphasizing integration of certain design and severe control functions in manufacturing and shop floor control activities. However, there only a few studies have been on the application of a multi-agent system to resolve some of the common problems in the pouring systems, especially the riser design and gating system in sound casting. The objective of this paper to describe how different type of gating system control the casting defect during solidification .gating system is very important if casting is produced by the gravity process for AZ91 alloy .if we use bad gating system, invariably, poor casting quality is obtained, due to disturbance in the flow of molten metal through the gating system.

2. SIMULATION PROCEDURE

CFD modeling was used in respect for simulation of the metal flow in different gating system. This study employed Click2cast software for simulation. In order to filing of simulation, the fluid volume method (VOF) is used to simulate the movement of free surface of liquid AZ91 Mg Alloy in the confirmatory decided gating system .Unpressurized gating system is favored in case of light metal casting such as Mg alloys as Mg is highly sensitive to air oxidation. The scalar variable distribution method employs to find the potential distribution of trapped oxide films in the casting. The defined size of scalar parameters is proportional to the 'possible distribution' of the oxide film defects related to it, describing the susceptible area.

2.1. Flowchart for Simulation

Simulation process should be describe the following steps describe in figure 2.1 flow chart. It describe the firstly we have to put the .stl file of designed mold. After that in click to cast in gate selection and mesh generation with element size.

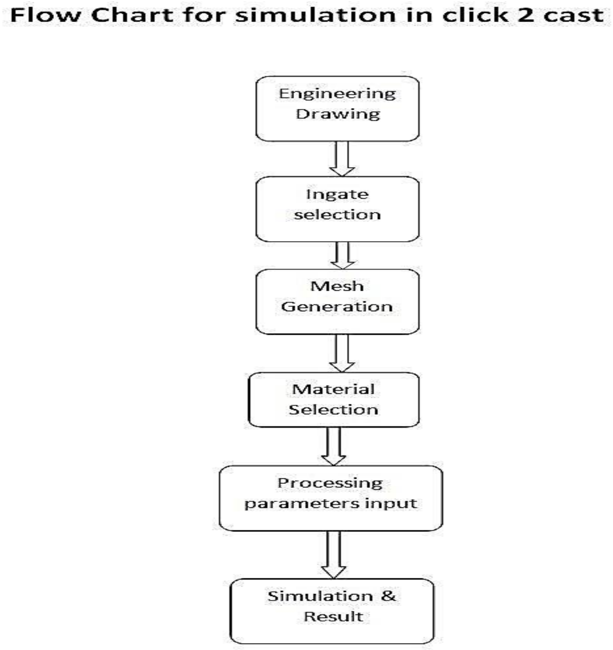

Figure 2.1. Flow chart for whole process

Third one step is put the material properties of mold and pouring temperature of the metal. After these steps we have to submit the simulation for results.

2.2. Procedure for simulation

Click2cast is used to simulate flow & solidification pattern of molten metal. Velocity of Fluid approach is used to simulate the flow & solidification pattern. Requirement of sound casting involves the following point should be consider.

- Liquid metal velocity should be of minimum or less than the velocity of 0.5m/s to avoid turbulence effect and air entrapment.
- (ii) Sprue should be tapered such that no air aspiration takes place alongside walls.
- (iii) Riser modulus should be greater than that of casting modulus so that shrinkage porosity can be avoided.
- (iv) Unpressurized gating system is favored in case of light metal casting such as Mg alloys as Mg is highly sensitive to air oxidation.
- (v) Bottom-gating system is preferred to avoid molten splashing.

2.3. Gating System Design

Possible three different gating system have been designed which are used as shown in figure 3.2. It is to be illustrated that each gating system includes a differently designed sprue, a flat runner and required mold cavity. This system describes a method for direct comparison of flow behavior of the liquid metal and cast ability performance of casting yield is used by different gating systems.

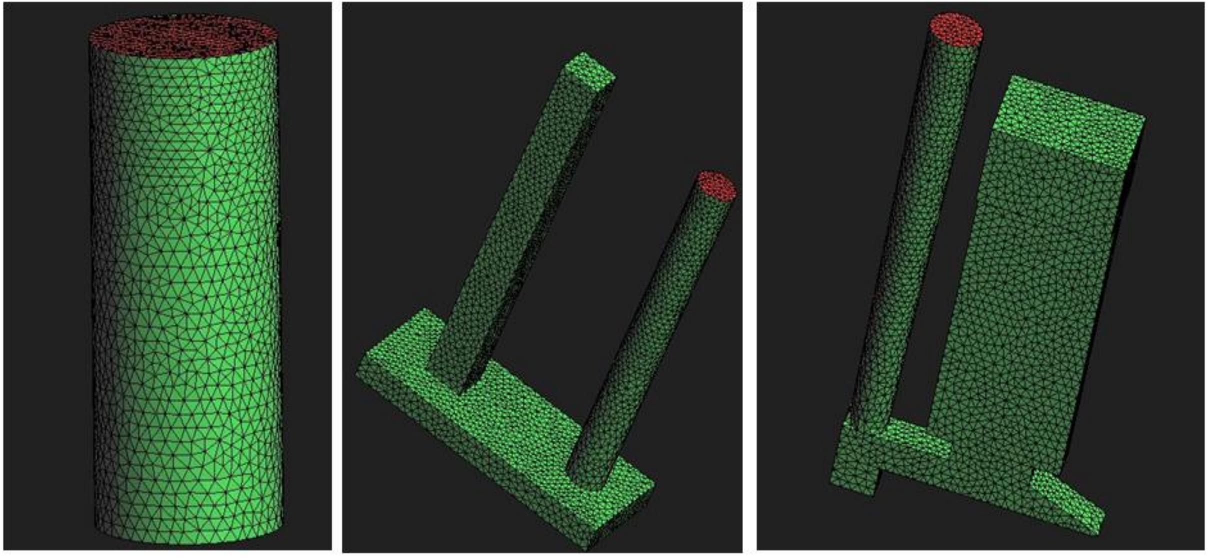

Figure 2.3.(a)Type 1 (b)Type 2 (c)Type 3

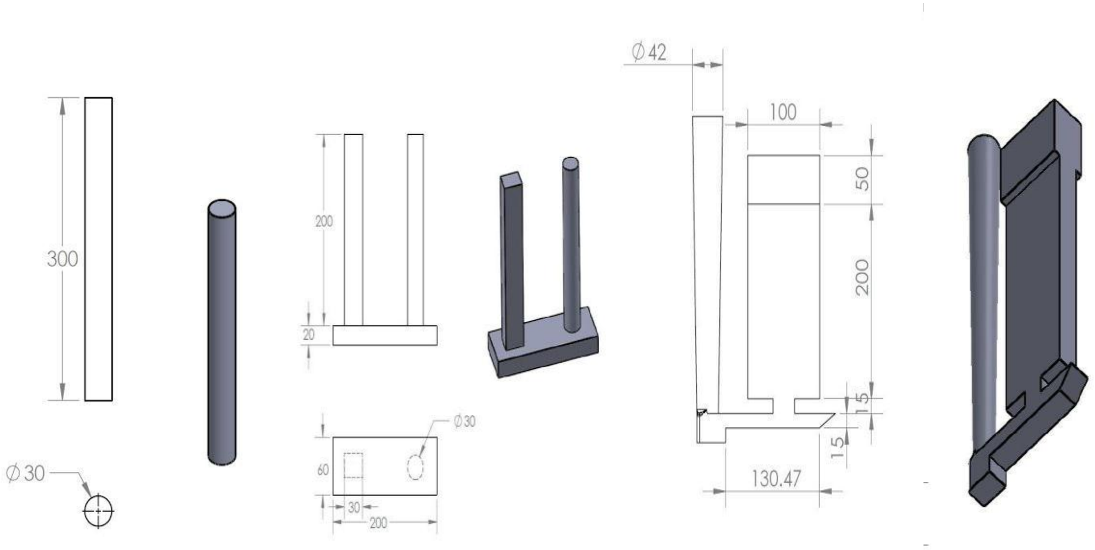

Figure 2.4 (a) Mold 1 (b) Mold 2 (c) Mold 3

Figure 2.4 shows three mold design which are used in our numerical simulation. First mold is a simple rod mold in which simply we have to pour the metal. And second one is a combination of both rectangular and circular mold. These are mold without considering gating system design process. The third one is a proper gating system should be used for designing a mold like proper fluidity of flow of metal via riser runner etc. part of gating system. This is the first step to require for the simulation.

2.4.Simulation parameters

For simulation three different parameter are used for results. In this we are varying a different mold material, pouring temperature and pre-heat temperature for optimize the correct material and temperature for eliminate the casting defect.

Table 1. Different parameter for simulation

Sr. no.	Pre heat temp(k)	Pouring temp (k)	Mould material
1	200	600	Sand
2	300	650	Carbon Steel
3	400	700	Copper

3. EXPERIMENT PROCEDURE

For conducting Experiment, we have to use optimizes result in regard to preheat temperature, mould material, and pouring temperature. After the simulation result given below for the three moulds are used for the experimental procedure.

Figure 3 (a) Circular Mould (b)Combined Mold (c) Rectangular Mould

Figure 3 a. shows a single rod mould without and gating system. This is made up of carbon steel ith 300 mm height and 30 inner dia. Figure 3 b. second type of mould which is used for the experiment. This mould is a combination of both rod and rectangular. This is also without any consideration of the gating system and Figure 3 c.,Rectangular mould which is based on the design of a proper gating system. This mould gives the accurate result for the casting.

4. RESULT AND DISCUSSIONS

4.1 Flow pattern

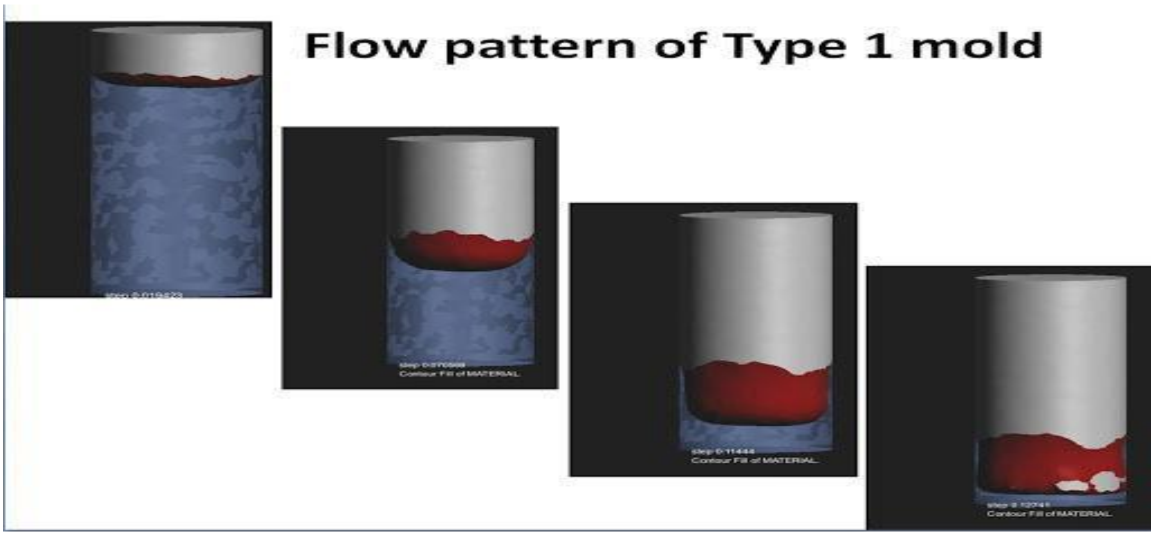

Figure 4.1

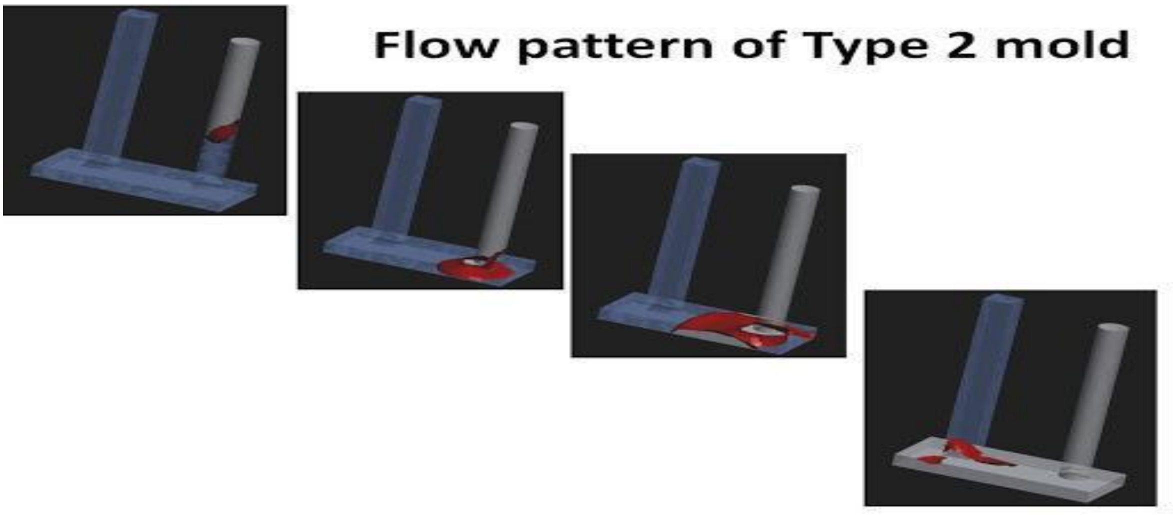

Figure 4.2

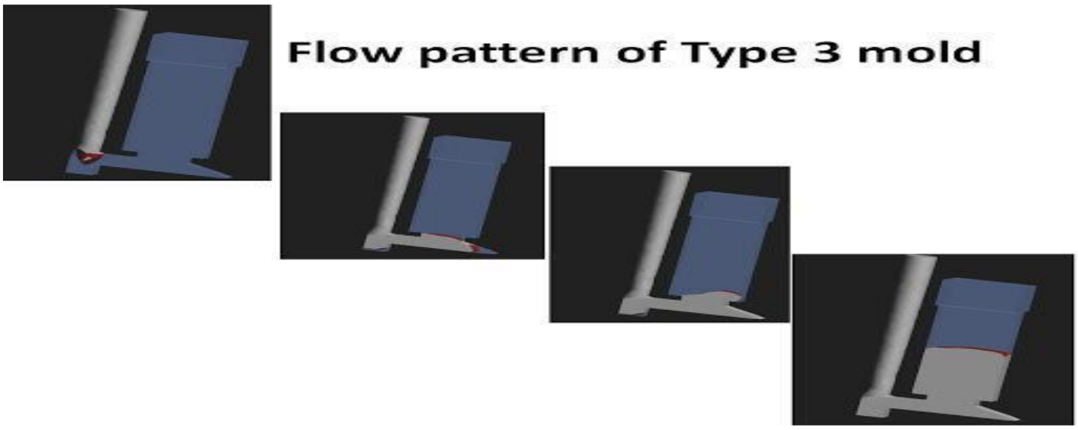

Figure 4.3

Figure 4.1-4.3: Flow patterns of the three different gating system

Fig 4.1 through 4.3 represent the flow patterns of three different gating systems. It can be found that air entrapment (indicated by white in color) is seen for the case of first and second gating mould systems but not in the third gating system. This happens because of the fact the intensity of achieving steady state flow pattern of liquid metal is very high in case of third gating system owing to the low flow velocity of liquid metal during pouring.

4.2. Flow velocities

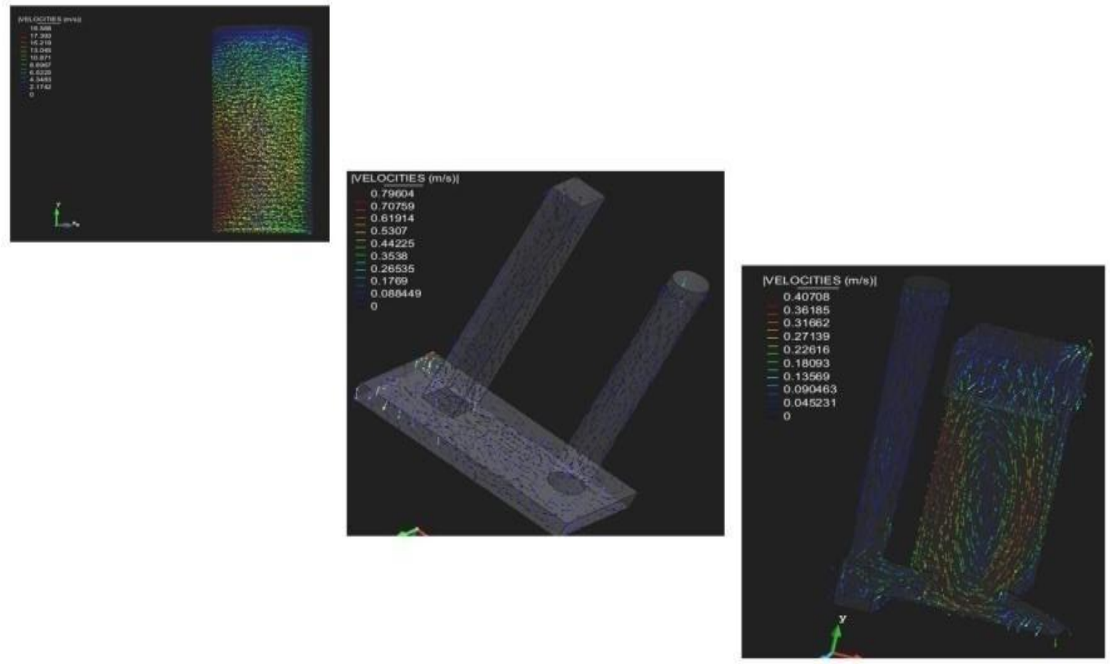

Figure 4.4: Flow velocity

4.3. Shrinkage porosity

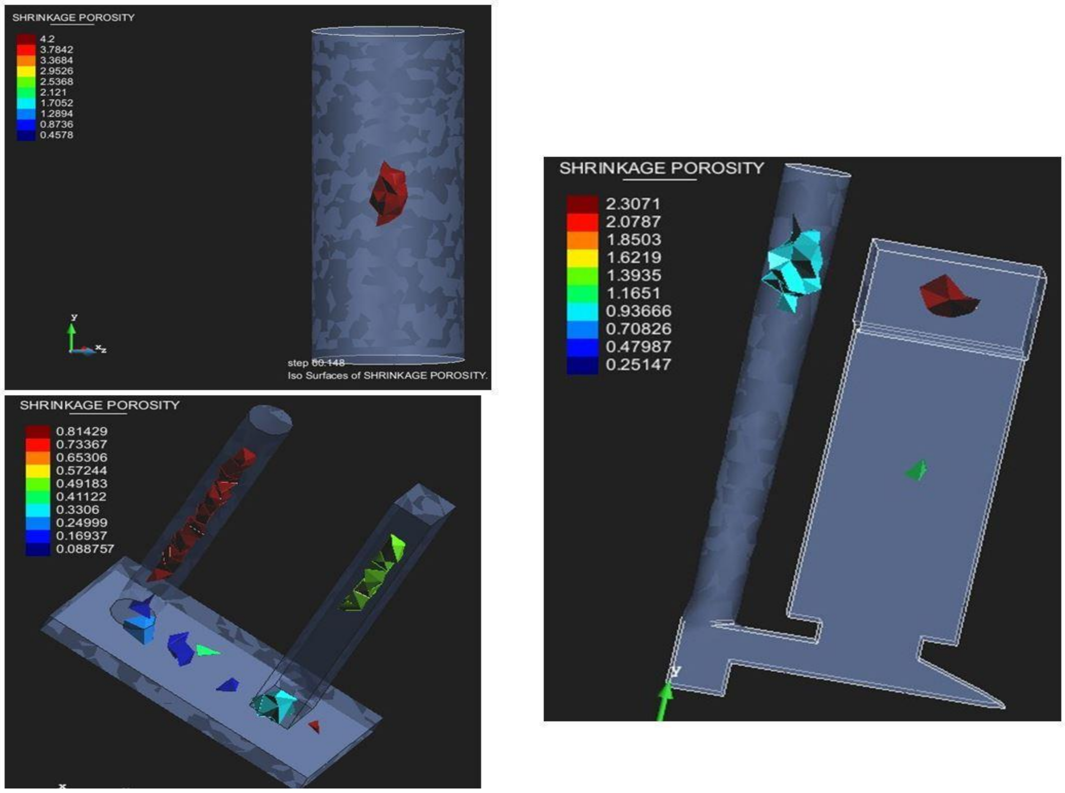

Figure 4.5 Shrinkage porosity

4.4. Influence of die preheat temperature on shrinkage porosity

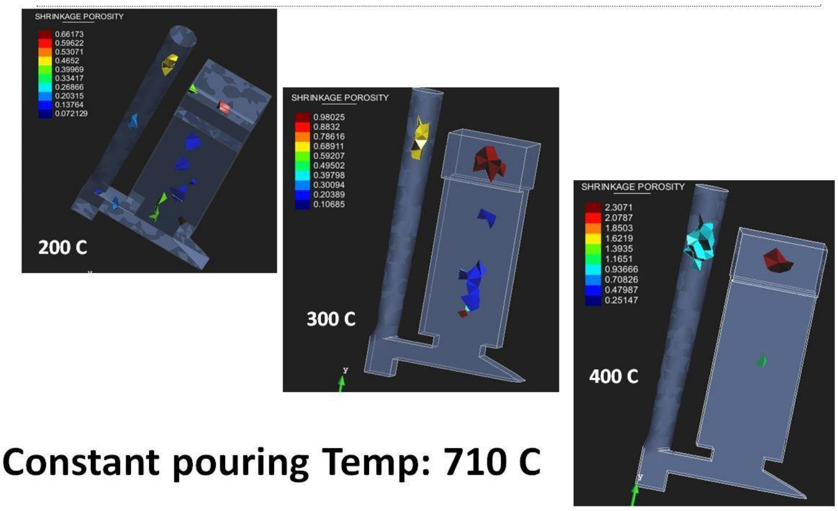

Figure 4.6: Influence of die pre heat temperature on shrinkage porosity

Once, the gating system is selected for sound casting in the laboratory; it is essential to optimize the other casting parameters such as pouring temperature, die preheat temperature and mould materials.

Fig 4.4 illustrates the influence of pouring temperature on shrinkage porosity of the final casting under constant die temperature of 400 ^{0}C$^{.}$ It can be seen that the tendency to form shrinkage porosity reduces with increasing pouring temperature. It is well-known fact that molten AZ91 Mg-alloys alloys should fill the cavity of the mold without forming any local solidification zone during the pouring process. If it forms local solidification zone, then the molten alloys could not fill the space between two dendritic crystals during solidification which causes inter-shrinkage porosity in the final casting. Therefore, AZ91 Mg-alloy must be poured at a pouring temperature of 710 ^{o}C to avoid any chance of shrinkage porosity.

Fig 4.6 shows the influence of die preheats temperature on shrinkage porosity of the final casting under a constant pouring temperature of 710 ^{o}C. It can be observed that the intensity of forming shrinkage porosity reduces with increasing die preheat temperature. The main reason behind this fact is that any increase in die preheat temperature of the mould material leads to a reduction in the humidity absorption which eventually resulting in less shrinkage porosity. Notice that humidity contains water vapour or some other residual gases which get released during solidification of the AZ91 Mg-alloys. Therefore, it is understood that die should be heated to at least minimum temperature of 400^{0}C to avoid minimize the level of shrinkage porosity.

4.5. Influence of pouring temperature on shrinkage porosity

Figure 4.7: Influence of die pre heat temperature on shrinkage porosity

4.6. Influence of mould materials

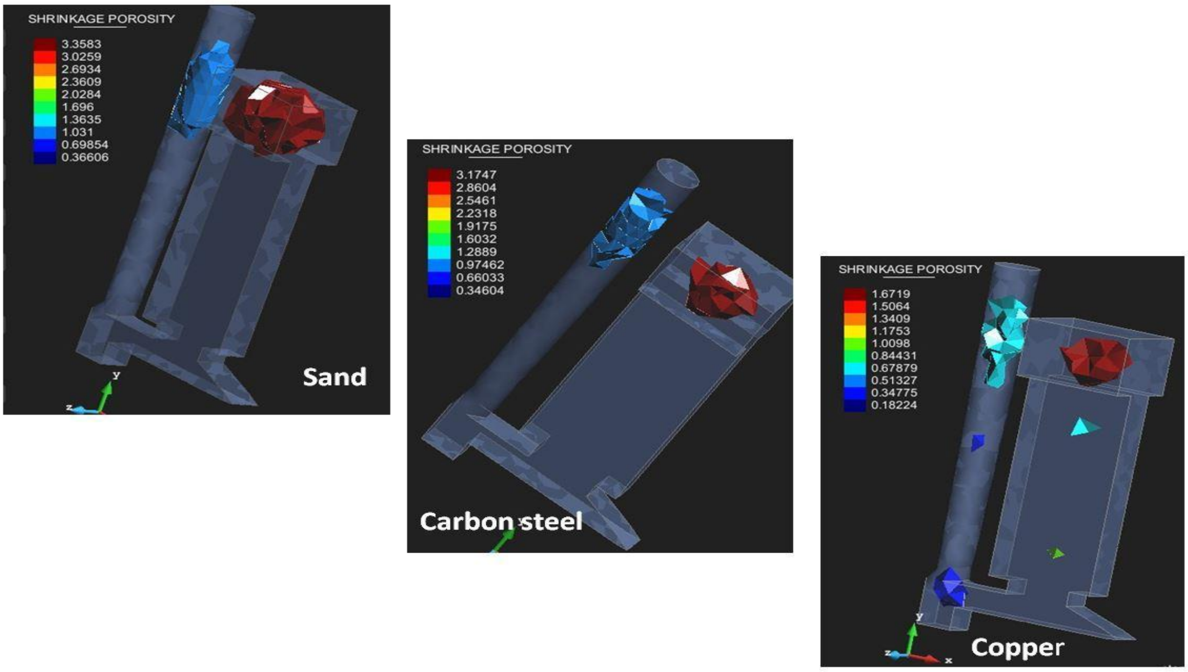

Figure 4.8. Influence of mold materials on shrinkage porosity of the final casting.

Fig 4.8 depicts the influence of mold materials on shrinkage porosity under the constant pouring temperature, and constant die preheat temperature. It can be understood that both the sand mould and carbon steel results in no shrinkage porosity within the casting area where as there is a small chance of forming shrinkage porosity for the case of copper mould. Higher the thermal conductivity of mould materials, lesser the chance of providing liquid metal to fill the inter-dendrite crystals during solidification. In the present work, we tend to choose to die carbon steel mould materials when compared to sand mould material as one can save timing, as well as wastage of sand materials for permanent, die steel mould casting.

After experiments, the different attachments of the gating system has been removed, and following different castings, defects have been encountered after the solidification or during solidification which is represented as follows. The below figure represents the various components of the gating system attached when the mould is broken after solidification which is useless from the application point of view. The different optimized gating system yields a diverse cross-section of the casted products.

Figure 5.1.1.Mould Product

5. CONCLUSION

In this study, the proposed optimization framework managed to autonomously obtain six optimal design choices after 60 design evaluations. Regardless of the infeasible initial population optimal gating and riser system designs were successfully accomplished even with the absence of analytical information. Gating system for the sound casting of AZ91 Mg-alloy is optimized with the significant operating parameters.

Following key conclusions have been summarized which briefly described the outcomes of the present work as:

1. The optimized bottom-gating system is preferred to achieve a higher filling rate and to overcome severe casting defects.
2. The most striking advantage of this integrated optimization approach is to achieve sound casting in regards to its quality and durability. This could be required for laboratory scale specimens with less number of experiments and having better mechanical properties.
3. It has been found from this study that the flow velocity of liquid metal should be less than 0.5 m/s to avoid turbulence effect and air entrapment inside the mold cavity. It reduces the fatigue failure chances of the casted products.
4. The design for the gating system elements such as sprue dimensions should be tapered so that if higher velocity may be induced in such a way reduces air aspiration phenomena which eventually takes place alongside the walls of sprue. So while designing the gating system it has been priorly noticeable to consider the appropriate design for the elements of the gating system should be considered.
5. The various optimized parameters used in this study reveals that prior to experiments gating design should be optimized in order to develop appropriate filling conditions and better fluid properties that could be benefitted in obtaining sound casted products. Some of the parameters used in this study for the casting of AZ91D alloy has been taken as:

i. Die design - Gate Type 3
ii. Pouring Temperature - 710 ^{o}F
iii. Die preheat Temperature - 400 ^{o}F

iv. Mould material - carbon steel
v.

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