ANALYSIS OF GRAVITY DIE CASTING FOR LEAD ANTIMONY ALLOY

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Abstract:- The die casting process is a name given to metal casting processes that utilize metal molds or permanent dies. There are really several distinct processes included under the general name. The die casting process actually has three main sub-processes. These are: (1) permanent mold casting, also called gravity die casting, (2) low-pressure die casting, and (3) high-pressure die casting. The three processes differ mainly in the amount of pressure that issued to force the molten metal into the die. In permanent mold casting, the molten metal is poured into the mold, flows only at the force of gravity and solidifies under atmospheric pressure. Studies of gravity die casting. We give the lead antimony alloy (3-4%) because lead have low melting point lead is mostly uses in battery industries. We give the battery terminal cap for experiment and die material give the cast iron and tool steel. For analysis we consider the parameter blow hole, surface crack, filling time, cold shut, air entrapped, shrinkage effect and liquid frication. For analysing the parameter we give simulation. Simulation we see the filling time and cooling time is affected on gravity die casting.

Index Terms- **-Die casting, lead antimony alloy, permanent mold casting.**

1. Introduction:-

Casting is manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods [2, 4, and 5].

Casting is one of the earliest metal shaping methods known to the human being. Casting process is extensively used because of its many advantages. Molten material flows into any small section in the mold cavity and such as any intricate shapes internal or external can be made with the casting process.it is possible to cast practically any material be it ferrous or non-ferrous. Further, the necessary tools required for casting molds are very simple and inexpensive.as a result, for trial production or production of a small lot, it is an ideal method.it is possible in casting process, to place the amount of material where exactly required.as a result, weight reduction in design can be achieved. Castings are generally cooled generally from all sides and therefore they are expected to have no directional properties. There are certain metals and alloys which can only be processed by the casting and not by any other process like forging because of metallurgical considerations [1-5].

1.1 Gravity die casting:-

Gravity die casting is a permanent mould casting process, where the molten metal is poured from a vessel or ladle into the mold. The mould cavity fills with no force other than gravity, filling can be controlled by tilting the die. The production of castings starts with selecting either a reusable mold or a die having two or more parts. The die would be complete with the impression of the casting along with running, feeding and venting systems. There is provision also for removal of the casting. To maintain the casting's accuracy, the die can easily be cleared of debris such as hot metal splashes and sand. The die is quite capable of a regular cycle of production along with fast dissipation of heat of the metal poured into it. Both simple and complex quality castings can be produced. A unique feature of the gravity die casting method is that it can handle heat treatment of high strength aluminium alloys that pressure die casting still cannot. Suitable for castings requiring complex intricate coring and small production runs [4].

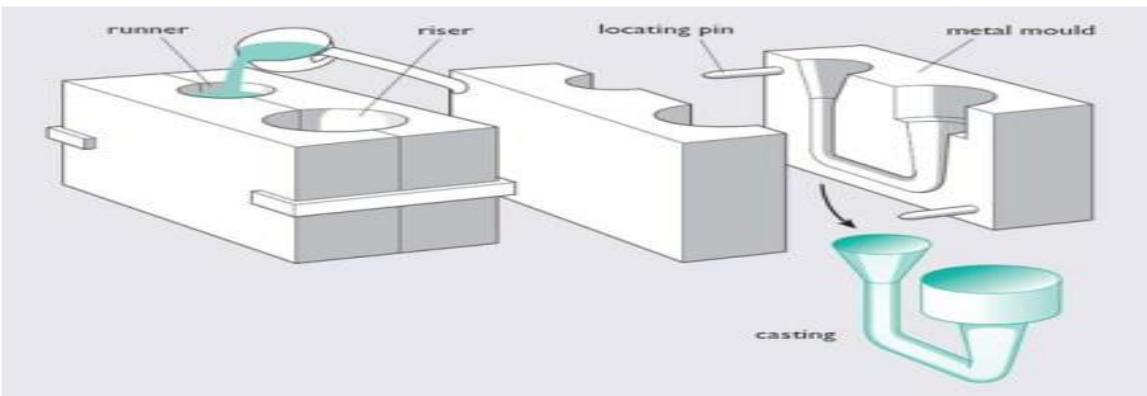

Fig.1.1 Gravity Die Casting

1.2. Lead Antimony Alloy (3-4%):-

Lead has the advantages of low melting temperature and extreme malleability, which allow easy casting, shaping and joining of lead articles. Lead is slow to corrode very high density of lead (11.34). Lead possesses the general physical properties of metals: it is a conductor of electricity and heat (though not as good a conductor as some other metals, such as copper and aluminium), has a metallic lustre, albeit a dull one, and has high density. It has a very low melting point, compared with most other metals, of 327°C. This is useful for ease of casting and joining lead, and also influences some of its mechanical properties [1, 5].

So this advantages we select the lead antimony alloy to study the parameter for defect in casting of lead alloy. Lead concentrates can be easily extracted from the ore and winning the metal from the concentrate does not need much energy. This reflects also in a fairly low price compared with other non-ferrous metals. Lead can be recycled as a secondary raw material from lead-acid batteries, from metallic scrap and from several composite consumer products in conjunction with existing recycling loops, for example for steel, zinc and copper, at moderate costs [1,5 and 6].

1.2.1Applications of lead:-

Shielding against sound, vibrations and radiation, for example as protection for users of computer and TV screens. For these purposes lead is used in metallic form or as lead compounds in lead glasses. Some compounds of lead have their own useful properties, particularly in relation to colour and glass-forming ability.

In lead antimony alloy have some defects like blow hole, liquid fraction, cold shuts, effect of shrinkage [5, 7].

2. LITERATURE SURVEY

[1]N.Y. Tang et al., (1996)**:-**

Lead/acid battery grid alloys, such as low-antimony-lead and lead-- calcium-tin alloys with and without silver, are successfully continuously cast into strip using Cominco's Multi-Alloy Caster TM. The mechanical and electrochemical properties of the continuously cast, low-antimony- lead strip are strongly dependent on the arsenic content in the alloys. On the other hand, the tin: calcium (Sn: Ca) ratio in the Pb-Ca-Sn alloys plays an important role in the development of the microstructure and the mechanical properties of these alloys. Lead grid alloys with wide solidification ranges can be readily cast using Cominco's Multi-Alloy Caster TM due to the high cooling rate realized by the melt-drag process. The overall performance of low-antimony-lead alloys is strongly affected by their arsenic content. In spite of enhanced corrosion, arsenic up to 0.2 wt. % is beneficial to mechanical strength, growth resistance, and deep- cycling capacity retention. 3. Weight losses of low-antimony- lead alloys in potentios- tatic corrosion tests are proportional to antimony equivalent, defined as (Csb + 10.2CA~). 4. The microstructure and properties of a Pb-Ca-Sn alloy are strongly determined by its Sn: Ca ratio.

[2] W.A.Butler et al., (2016)

Die casting process is a name given to metal casting process that utilize metal mold or permanent dies. There are several distinct processes included under general name. The die casting process actually has three main sub processes. These are: (1) Permanent mold casting, also called gravity die casting, (2) Low pressure die casting and (3) High pressure die casting. The three processes differ mainly in the amount of pressure that is used to force the molten metal into the die. In permanent mold casting, the molten metal is poured into the mold, flows only at the force of gravity and solidifies under atmospheric pressure. The term die casting is used to describe processes that utilize metal dies or molds to produce part from various metals. These processes include gravity permanent mold casting in which the liquid metal is poured into the die; low pressure die casting in which the metal is forced into the mold with air pressure and high pressure die casting in which a hydraulic ram is used to inject the molten metal into the die at extremely high pressure. In recent years, enhance high pressure die casting processes such as vacuumed die casting, squeeze casting and semisolid metal processing have created new opportunities for utilizing the advantages of high pressure die casting for structural or leak free components.

[3] R. BabiC et al., (1994)

The electrochemical behavior of lead, antimony and lead-antimony barmy alloys has been studied as a function of sulphuric acid and antimony concentrations in the lead alloy. The investigation was performed by means of cyclic voltammetry and impedance spectroscopy methods. Cyclic voltammetry, performed between the hydrogen and oxygen evolution and over narrower regions of potential coupled with systematic variation of the scan rates and the positive or negative reversal potential, revealed more details on the oxidation and reduction processes in the potential region of Pb(II)-. Pb(IV)- and Sb(III)-containing species which give further insight into the nature of the reactions of the lead acid battery. The impedance measurements performed in the potential range of lead oxide, in which antimony oxidation in the alloys takes place, show the decrease in film resistance with increasing antimony content. The electrochemical behavior of Pb, Sb and Pb-Sb binary alloys has been studied as a function of the concentration of sulphuric acid and Sb in the Pb alloy. The investigation was performed by means of cyclic voltammetry and impedance spectroscopy methods.

[4] P. S. Kolisnyk (1992)

New casting process for the continuous production of low- antimony-lead alloy strip that is expanded to make positive plates for hybrid-design, maintenance-free batteries. The stages of development from initial trials to pilot production plant are reviewed. The advantages of the process and the product are also discussed. Negative plates made from continuously cast calcium-lead strip have shown advantages over conventional grids cast in book moulds. This new method for making positive plates from low-antimony-lead alloy strip should offer similar opportunities to reduce production costs and improve battery performance. Cominco is aggressively developing a casting technology for low-antimony-lead alloy strip. The process will provide battery manufacturers with a new material for reducing the production costs and improving the performance of automotive batteries.

[5] E. Angladaa, (2015)

The simulation of the High Pressure Die Casting (HPDC) process is a complex type of simulation. The industrial procedure is based on consecutive manufacturing cycles that must be taken into account in the simulation. Moreover the part geometries use to be complex and the alloy is injected at really high velocities. All of that usually implies long calculation times that in complex cases can lead to several days. The comparative, shows that the use of simplified models may be a solution that makes possible a big reduction in calculation times maintaining a reasonable level of accuracy. The HPDC is a continuous production process based on consecutive manufacturing cycles. At beginning of the manufacturing process the mold is usually too cold preventing the cavity filling. The alloy freezes partially during the injection and does not fill completely the cavity. The successive cycles go increasing the mold temperature but until it is not hot enough, the quality of the manufactured part will not be good, presenting surface defects and/or internal porosity. The simplified simulation models have been able to reproduce appropriately the thermal behaviour of the mold and of the cast part, with significant reduction in calculation times. The model validations have been achieved by comparison with the results of the detailed model previously correlated, with experimental data.

3. Research Methodology:-

We give the battery terminal cap for analyzing the lead antimony alloy properties. First we prepare the 2D design to understand the component shape.

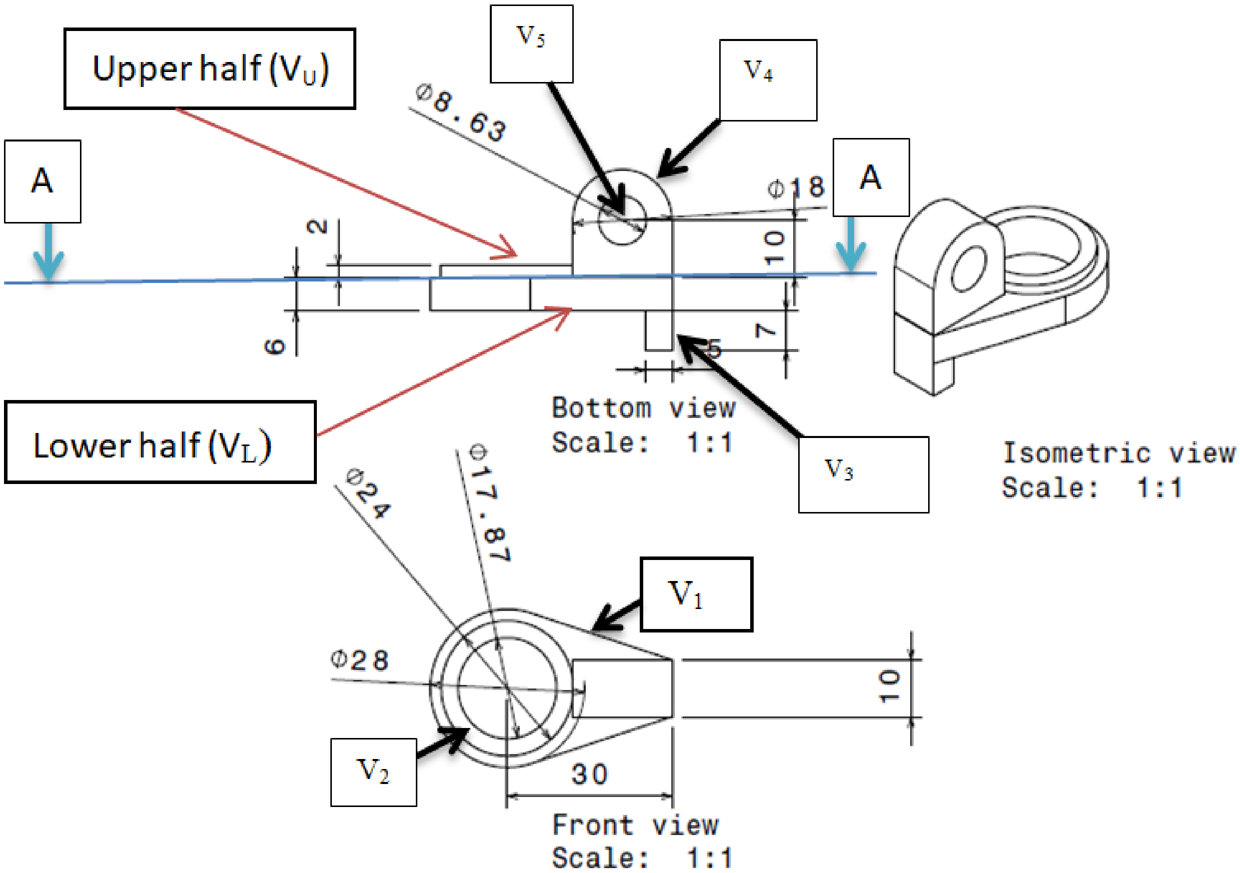

Fig.2.1.2d Design of battery cap

We analysis the design parameter volume of compound and equivalent weight of lead alloy

3.1Volume calculation:-

Lower half section calculation (V_L)

V_1=half circle +trapezium section

V_1= (1/2(π/4*d^2) +1/2(a+b) *h)*Thickness

V_1 = (1/2(π/4*28^2) +1/2(10+28)*30)*6

V_1 = 5267.256 mm^3

Area of Circular section (V_2) = π/4*d^2

V_2= π/4*24^2

V_2= 452.3893*2

V_2=904.778 mm^3

V_3=Rectangular Section

V_3=l*b*h

V_3=5*7*10

V_3 =350 mm3

V_{hole}= π/4*d^2

V_{hole}= π/4*17.87^2

V_{hole} =250.80 *(6+2)

V_{hole} =2006.45mm^3

V_L=V_1+V_2+V_3-V_{hole}

V_L=5267.256+904.788+350-567.04

Lower Section Volume (V_L) =5955.004 mm^3

Volume of Upper (Rectangular + circle section)
V_4=LBH + (π/4*d^2*thickness)
V_4=18*10*10+ (π/4*18^2*10)
V_4=4344.69mm^3
Hole π/4*d^2*L
V_4 π/4 *8.63^2 *10
V_5 = 584.94
V_U = V_4-V_5
V_U=4344.69-584.94
V_U= 3759.75 mm^3
Total volume of component (round) V_T = V_L+V_U
V_T = 5955.004+3759.75
V_T = 9714.754mm^3
V_T=9.714cm^3
Note:-V1, V2, V3, V4 and V5 are the volume of section of body to calculate the volume
W = V*Density
W = 9.714*11.34
W = 110.156 gm.

3.2 Sprue design:-
We give the volume of component 9714.754 cm^2 for single component. We give two cavities so give the large sprue more than the volume of two components and 20% extra volume and calculate the equivalent cup section of 3mm smaller diameter and 40mm height we consider the runner size is 3mm diameter (circular runner).

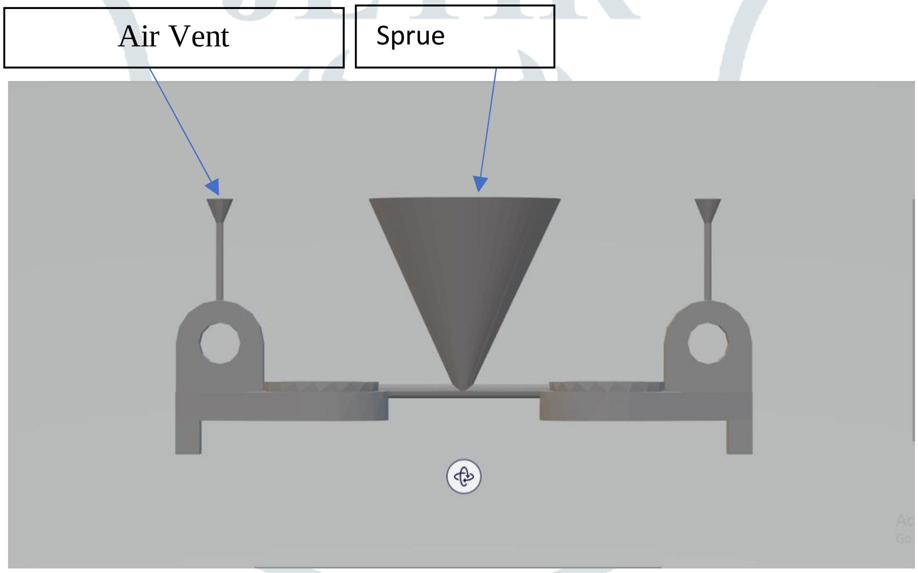

Fig3.1. Design of Runner and Sprue in Component.

3.2 Sprue Calculation:-
V_1=9714.754 *2*1.2
V_1=23315.4096 mm^3
Consider, r=1.5, Runner (3mm)
Volume = π/3*h*(R^3+r^2+ R*r)
23315.4096 =π/3*40*(R^2+1.5^2+R*1.5)
R=22.8mm.
Diameter =22.8*2=45.6mm.
In the design we give the dimensions of sprue are R=φ45.6mm, r=φ3mm, h=40mm
Provide the 3mm runner and provide the circular vent to pass the air and also provide side vent for easily pass the air. This arraignment done we get the simulation for component to analysis easily.

4. Simulation analysis:-

4.1.LIQUID FRACTION:-

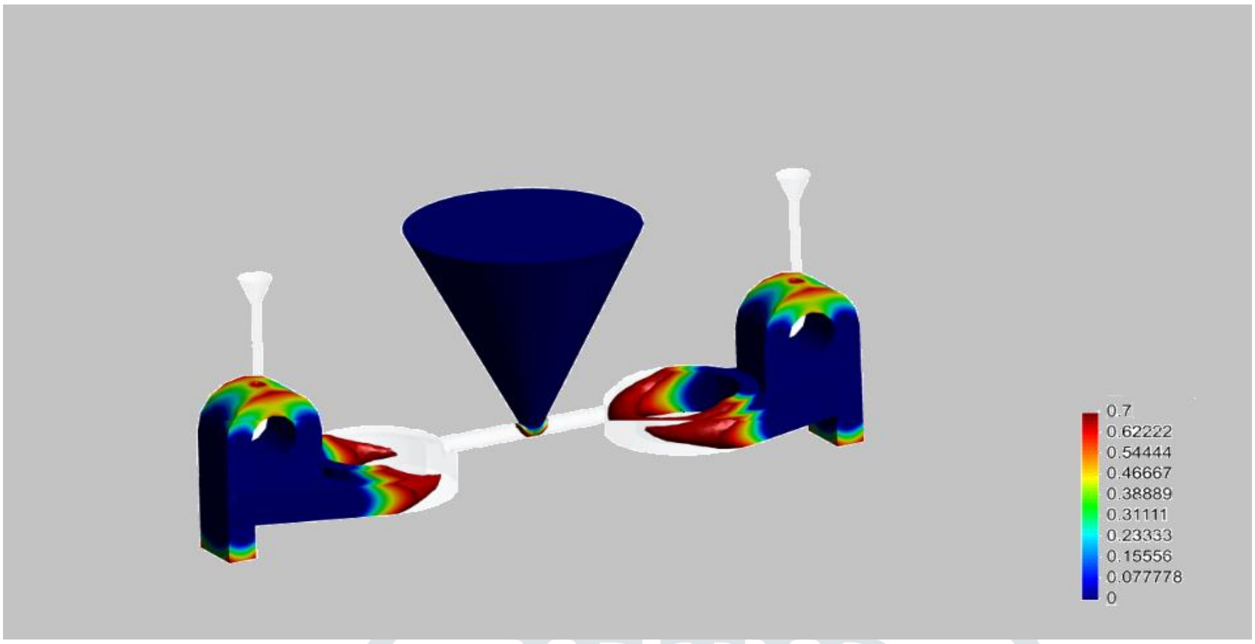

Fig4.1. Liquid Fraction

Liquid friction is the force that resists motion either within the fluid itself or of another medium moving through the fluid. There is internal friction, which is a result of the interactions between molecules of the fluid, and there is external friction, which refers to how a fluid interacts with other matter.Liquid Fraction displays the last areas to solidify (liquid material) in red so you can predict shrinkage porosity. Liquid Fraction is useful for analyzing the behavior of the liquid during solidification. Unlike in gravity casting, overflows and runners won't feed the part during solidification because of the thin in gate sections.

We see in fig 4.1 liquid fill first the dark blue area then fill the light blue area and red colour fill the last time hence we can decide the filling time to fill completely. In simulation we give the 450°C of lead alloy. In fig 4.1.Minimum frication is zero and maximum fractions have 0.7 in the lead alloy and die cavity surface. For solving the problem we provide the draft of 1° for external surface and 2° for internal cavity also fillet and corner radius 0.5mm taking.
Liquid fraction have affected on solidification time also.

4.2. Solidification time:-

Solidification have time in which metal have change the phase liquid to solid to get desired shape in the lead antimony alloy solidifying temperature affect the component surface defect and crack formed. In simulation we can see the transformation of metal to solid step wise to give the idea of maintain the solidification time. In fig 3.2 we see the solidification time. Solidification time we need the maintain the melting point of lead antimony alloy 450°Cto fill properly and depend upon the die material is cast iron, pouring of metal, die material specific heat. Specific heat of cast iron have 0.11 (kcal/ (kg °C) is affected on the solidification time. Also affected the wall thickness we provide the thickness is 40mm.density of cast iron is

SOLIDIFICATION TIME

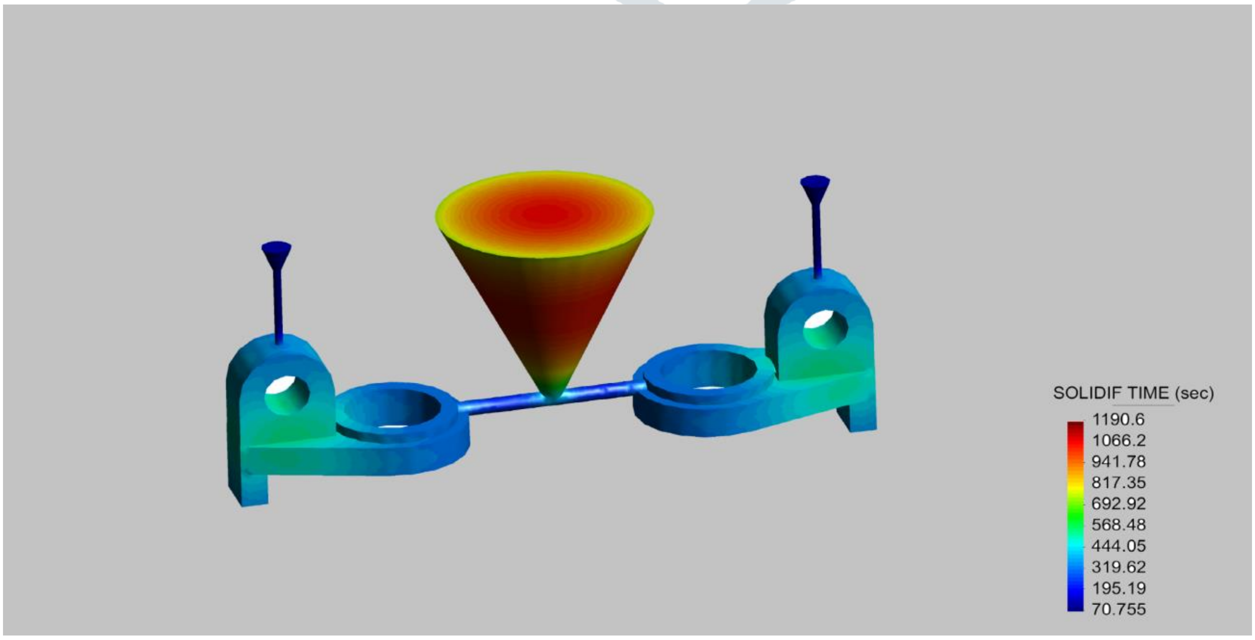

Fig.4.2.Solidification Time (sec)

Fig 4.2 we see the solidification time behaviour at different position. Blue colour indicate the solid metal and bluish green indicate the semi-solid also in process this transformation take place at the after the 70.75sec form filling that time we stay the die then we can remove the component form die. We remove form die metal open to atmosphere and it cool fast in the 1129.6sec (19min) we get the complete solidified component. Than we can use product to application. For the cavity cooling need the 444.5sec (7min) to complete solidify. Areas in the casting that cool rapidly generally have a more favorable grain structure and therefore tend to have better mechanical properties. We give the solidification time is equal to simulation analysis.

4.3. AIR ENTRAPMENT

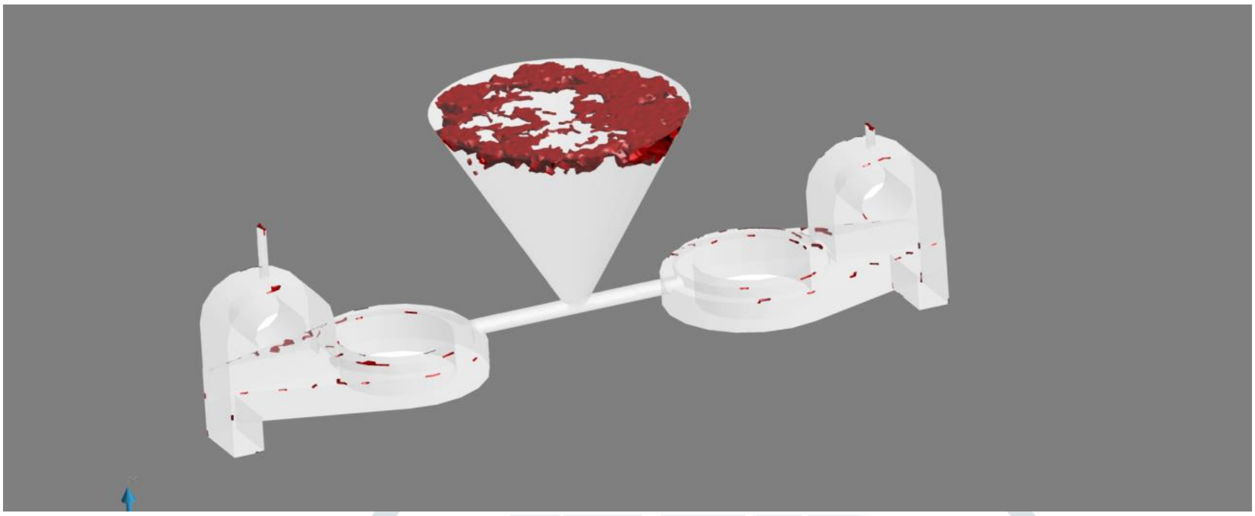

Fig4.3.Air Entrapment

In die casting main problem of air entrapment in cavity to produce the defect in the internal cavity and surface crack. Defect have affected on the strength and toughness. In fig3.3 we can see the red circle shows the main area of trapped air during filling. Flow Front shows how the material behaves as it enters the mold, so you can detect where air is being trapped during filling**.** Air is go through by the improper filling by the worker to increase the problem also this problem occurs by the small vent in die this can't pass the complete air form cavity .For air passing provide the horizontal vent .

5.0 CONCLUSION:-

In gravity die casting for lead antimony alloy (3-4%) main problem is the blow hole in cavity and surface crack is solve by the simulation to give the solution of problem to analysis of liquid fraction, air entrapment in cavity and solidification time. For minimum fraction we need the smooth surface of die cavity to flow the liquid metal easily and fill the cavity with minimum fraction. Provide the draft and fillet to cavity and improve the surface quality of die.

Solidification time we need the maintain the melting point of lead antimony alloy 450°Cto fill properly and depend upon the die material is cast iron, pouring of metal, density of die material specific heat is affected.

Air entrapment is removed by the giving the horizontal and vertical vent.

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