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EXPERIMENTAL STRENGTH ANALYSIS OF RED BRICK USING COMPRESSIVE AND WATER ABSORPTION TEST

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ABSTRACT

Burnt clay brick is an age old building material which is used for housing in urban area as well as rural part of India. These bricks are manufactured from good plastic clay, which is obtained from agricultural land. Brick strength was tested experimentally by using Compressive strength test and water absorption test. Compressive strength test was conducted on three samples of two different sizes (220mm x 100mm, 190mm x 90mm) of red bricks and water absorption test was conducted on five samples of red bricks. In this paper, we have performed comparative sustain analysis among three different types of red bricks. Brick samples were taken from Padam brickyard (Jangethi), Abhay brickyard (Khirwa), Mohan brickyard (Sardhana). Mohan brickyard -Sample 3 (220mm x 100mm) was able to sustain 0.26% more load in comparison to Padam brickyard (Jangethi)-Sample-1, Abhay brickyard (Khirwa) Sample-2. When same test was performed on brick size-190mm x 90mm, then it was found that sample-3 was able to sustain 0.19% more load in comparison to sample 1 and sample 2. Also Water absorption capacity of Sample 3 is 106% less than other samples.

Keywords: *Universal Testing Machine, Bricks, Construction, Compressive Strength.*

I. INTRODUCTION

A brick is building material used to make walls, pavements and other elements in masonry construction. Traditionally, the term brick referred to a unit composed of clay, but it is now used to denote any rectangular units lay in mortar. A brick can be composed of

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clay-bearing soil, sand, and lime, or concrete materials. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities. Two basic categories of bricks are fired and non-fired bricks [1]. Different types of bricks based on Raw Materials and grades are given below.

A. Types of Bricks Based on Raw Materials

Depending on raw materials [2] used for making bricks, it can be following types :

- Burnt clay brick
- Fly ash clay brick
- Concrete brick
- Sand-Lime brick
- Fire clay brick

(a) **Burnt clay brick:** These types of bricks are usually made from clay by burning. These are the common type of bricks for construction work.

(b) **Fly ash clay brick:** These types of bricks are usually made when fly ash is mixed with clay.

(c) **Concrete brick:** The main raw materials for this type of bricks are cement and sand. It is also called mortar brick.

(d) **Sand-Lime brick:** Lime is used instead of cement with sand for producing this type of bricks.

(e) **Fire brick:** These types of bricks are made from fire clay. These bricks can tolerate high temperature without distortion and cracking. That's why it can be used in fireplace.

B. Types of bricks Based on Grades

Different types of bricks with their grades, properties and their uses are shown in Table 1.

Table 1: Type of brick Based on Grade

Type of Bricks	Grade	Properties	Uses
1st class brick	A	Well Burnt, sound, Sharp edges, Proper shape and size	Face-worked structure
2nd class brick	B	Irregular in shape and size, blunt edges	Ordinary structures, Brick-work, Under plasters
3rd class brick	C	Under burnt bricks, soft and light in colour	Unimportant and temporary structures, at heavy rainfall places
4th class brick	D	Deformed shape and size, over burnt.	Aggregates for concrete in foundation, floors, roads, etc.

II. LITERATURE REVIEW

Nitin S. Naik et al. [3] discussed the durability and strength aspect of the bricks prepared using fly ash, cement and phosphogypsum. He concluded that such bricks are having sufficient strength to be used as a replacement for traditional bricks. The water absorption of such bricks was found more than 20%.

K. Muhammad nisham et al. [4] studied the durability and strength aspect of bricks prepared using class F fly ash, Cement, metakaolin and quarry dust. The experiment work investigated the effect metakaolin content in class F fly ash cement brick based on trial and error mix proportion methods. The experiments were conducted in two phases to observe the properties i.e. compressive strength and water absorption of fly ash cement brick. In both phase the cement (10%) and quarry dust (35%, 30%) were kept constant and class F fly ash (55% to 35%, 60% to 40 %) was replaced with white metakaolin up to 20 percentages. The fly ash based cement bricks were tested after 7 days, 14 days and 28 days curing in advanced concrete research laboratory of the institute. The test results showed that, the maximum optimized compressive strength was obtained for optimal mix proportion percentage of class F fly ash 40%, cement 10%, quarry dust 35% and metakaolin 15%. In both phases of experiment observed that there is a decrease (Inadequate value) in water absorption ratio of fly ash brick.

III. EXPERIMENTAL SET UP

Brick strength was tested experimentally by using Compressive strength test and water absorption test. Compressive strength test was conducted on three samples of two different sizes of red bricks and water absorption test was conducted on five samples of red bricks.

Region from where brick samples were taken:

- Sample 1,4-Padam brickyard (Jangethi)
- Sample 2,5-Abhay brickyard (Khirwa)
- Sample 3-Mohan brickyard (Sardhana)

(a) Compressive strength test

The experiments were conducted on Universal Testing Machine (UTM) to know the compressive strength of brick. It is also called crushing strength of brick. In this test a brick specimen was put on universal testing machine (UTM) and load was applied till it breaks [5]. The load at which brick crushed was taken into account.

Test Procedure

- Unevenness observed in the bed faces of bricks was removed to provide two smooth and parallel faces by grinding. It was then immersed in water at room temperature for 24 hour.
- The specimen was then removed and any surplus moisture was drained out at room temperature. All voids in the bed face were filled with cement mortar (1 cement, clean coarse sand of grade 3 mm and down). It was stored under the damp jute bags for 24 hour followed by immersion in clean water for 3 days.
- The specimen was placed with flat faces horizontal, and mortar filled face facing upwards between two plywood sheets each of 3 mm thickness and carefully centered between plates of universal testing machine. Figure 1 shows universal testing machine on which compressive /crushing test was performed.
- Load was applied axially at a uniform rate till failure occurs. The maximum load at failure was noted down. The load at failure was considered the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

Fig. 1 Universal Testing Machine

(b) Water Absorption Test

In this test bricks were weighed in dry condition and immersed in fresh water for 24 hours. After 24 hours of immersion those were taken out from water and wipe out with cloth. Then brick was weighed in wet condition. The difference between weights was the water absorbed by brick. The percentage of water absorption was then calculated [6].

Test Procedure

- The specimen was dried in a ventilated oven at a temperature of 105 °C to 115°C.

- After that the specimen was cooled to room temperature and its weight was measured.
- Then dried specimen was immersed completely in clean water for 24 hours as shown in figure 2.
- The specimen is then removed and wiped out any traces of water with damp cloth and then weight was measured.

Fig. 2 Water Absorption Test

IV. RESULTS AND DISCUSSIONS

Compressive strength test: Three brick specimens were tested one by one and average result was taken as brick's compressive/crushing strength. Compressive strength test by universal testing machine (UTM) is shown in table 2 and 3.

Table 2: Compressive strength for red brick having size (220mm x 100mm)

S. No.	Length (mm)	Breadth (mm)	Area (mm^2)	Load (N)	Result (N/mm^2)
Sample 1	220	100	22000	196200	8.91
Sample 2	220	100	22000	196000	8.9
Sample 3	220	100	22000	196528	8.93

Mean = 8.91+8.9+8.93/3 =8.9 N/mm2

Table 3: Compressive strength for red brick having size (190mm x 90mm)

S. No.	Length (mm)	Breadth (mm)	Area (mm^2)	Load (N)	Result (N/mm^2)
Sample 1	190	90	17100	155420	9.08
Sample 2	190	90	17100	155400	9.08
Sample 3	190	90	17100	155700	9.10

Mean = 9.08+9.08+9.10/3 =9.08 N/mm^2

Water absorption test: Five brick specimens were weighted under dried condition and immersed condition (for 24 hours). Table 4 shows the water absorption test result.

Table 4: Water Absorption Test result

S. No.	Weight of dry brick (W_1)	Weight of water absorbed bricks (W_2)	Water absorption $=(W_2-W_1)*100/W_1$
Sample 1	2.854	3.184	11.56
Sample 2	2.890	3.162	9.41
Sample 3	3.172	3.350	5.61
Sample 4	2.944	3.160	7.33
Sample 5	2.926	3.260	11.33

During experimental investigation, it is found that compressive strength of Sample 3 (Mohan brickyard, Sardhana) made from adding fly ash, lime and gypsum having size 220mm x 100mm is 8.93 N/mm^2 which is more in comparison to Sample 1 and Sample 2 when more load was applied. Crushing strength of good quality bricks should not be less than 3.5 N/mm^2.

Water absorption capacity of Sample 3 came out to be 5.61% which comes under the permissible limit of 20% set up by Indian standards.

V. CONCLUSIONS

Sample 3 (220mm x 100mm) was able to sustain 0.26% more load in comparison to Sample 1 and Sample 2. Also Sample 3 (190mm x 90mm) was able to sustain 0.19% more load in comparison to Sample 1 and Sample 2. Water absorption capacity of Sample 3 is 106% less than other samples.

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EFFECT OF GRAIN REFINER ON HOT TEARING OF CAST AL-SI-CU ALLOY

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ABSTRACT

Al–Si alloys are the most preferred cast aluminium alloy system due to its excellent casting characteristics. The addition of copper to this alloy system further enhances its mechanical properties. The presence of copper, however, makes the alloy susceptible to a casting defect, known as hot tearing. Hot tears are irreversible cracks that initiate during solidification of the castings. Porosity is also a common problem encountered during casting of Al-Si-Cu alloys. Porosity, if left unchecked, further aggravates the problem of hot tearing. An attempt has been made to record the effect of grain refiners on hot tearing and porosity of the gravity die castings of Al-Si-Cu alloys. In this paper, Macro-analysis along with DSC tests were carried out to confirm the results.

Keywords: *Hot tearing, Porosity, Gravity Die Casting, Grain Refiner, Macro and Micro-Analysis, Hardness, Wear.*

I. INTRODUCTION

Demands of aluminium-silicon alloys have been increased significantly from last few years in automobile and electronics industries [1–3]. The main reasons for increase in demand of aluminium-silicon alloys due to high strength to weight ratio, low density of these alloys, high thermal conductivity compare to other alloys and very low thermal expansion coefficient [4-5]. Because of increment in demands for aluminium-silicon alloys, it is necessary to study the mechanical and wear behavior [6-7]. In the present work, aluminium-silicon alloys containing 9 Wt.%, 10Wt.%, 11Wt.%, and 12Wt.%, of silicon were prepared using suitable casting method [8]. Grain refinement study is done with the suitable casting method [9]. Uniform distribution of silicon particles can be

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noticed by tensile test analysis and compositional analysis. Existence of primary silicon particles can be noticed by the analysis of microstructures analysis. From the earlier studies [2,10–12], it is observed that ultimate tensile strength and percentage of elongation increase with increase in silicon content in these alloys. These characteristics can be further improved by addition of 0.3Wt.%, grain refiner. Computerized pin on disc wear testing machine is used for the wear behavior of the alloy. It is observed from the experiment that with the addition of grain refinement the wear rate can be reduced. Scanning electron microscope is used for the study of the wear behavior of worn surfaces. Because of addition of grain refiner, the mechanical properties of the alloys improved.

II. HOT TEARING

Hot tearing, also referred to as hot cracking, hot shortness or hot brittleness, is an irreversible failure of an alloy during its solidification and remains one of the most severe defects in casting processes. It is the formation of cracks either on the surface or inside the casting. The last-stage solidification of alloys causes hot cracking in the casting while it is still semi-solid. This defect, which typically occurs in dilute and hard alloys, limits the productivity of cast houses and restricts the range of alloys that can be produced. Two factors that generally contribute to the formation of hot tears are insufficient feeding of liquid metal and tensile loading of the mushy zone. Hot tears limit the use of Al-Si-Cu alloys, as their high susceptibility to hot tearing shadows their excellent mechanical properties.

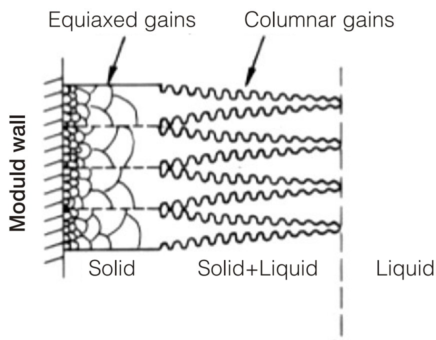


Fig. 1 Mushy zone formation

The region where dendrites and the liquid phase coexist (during solidification) is called the mushy zone. The region which solidifies at last in a casting is where a mushy zone develops. Hot tearing occurs when the liquid feeding to compensate the solidification shrinkage in the mushy zone is inadequate and the thermally induced stress generated exceeds the strength of the mushy zone. Hot tears are generally large and visible to naked eye. Sometimes, they can also be small in size and can only be observed using magnetic particle inspection and penetrating dyes. The defect [4] is easily recognizable from the following characteristics:

Hot tear looks like a ragged, branching crack.

- The main tear and its numerous minor offshoots generally follow intergranular paths.
- The failure surface reveals a dendritic morphology, if viewed under the microscope.
- Its location is often at that spot which solidifies at last in the whole of the casting.

III. MATERIALS AND METHODS

For the study of hot tears in Cast Aluminium alloys, we intentionally promoted hot tears in our casting by having a sharp corner at the 90° junction of down sprue and casting bar as shown in the figure below.

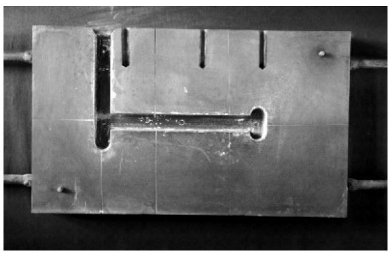


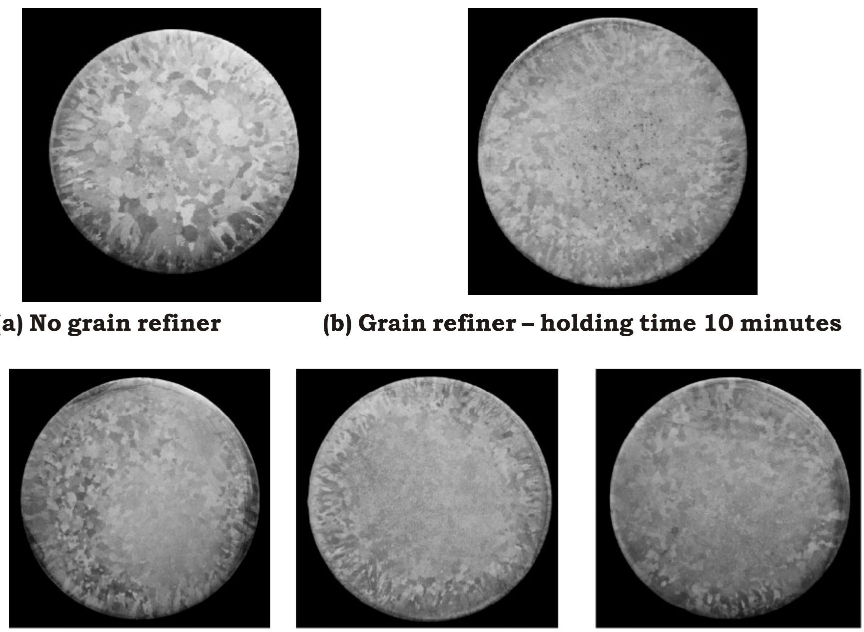
Fig. 2 Original picture of permanent mould die

Melt procedure: Al-13Si, Al-28.5Cu and pure Al were melted in an electric resistance furnace using a graphite crucible, in calculated proportions. The furnace temperature was set to 760°C. Flux was added (4.5 wt% of total melt) to avoid oxidation. Degasifier (C_2Cl_6) (1 weight percent) was added to the melt just prior to the pouring (at 740°C) to remove the gases dissolved in the molten metal. Furthermore, Calcium hydroxide coating was applied to the mould, for easy withdrawal of casting bar from the mould. The coating was removed after each casting and then reapplied for the next casting. Mould coating was also helpful in the good surface finishing of the sample. Then the molten metal was poured into the L-shape die (Two clamps were attached with permanent mould to fix the die so that there was no space for leakage of molten metal) at 720°C. The same procedure was repeated and this time, mould temperature was increased to 200°C by using two heating plates as shown in the setup below. The temperature of the die was checked by using a thermocouple. This was done to show the effect of mould temperature on casting defects. In the third casting, Al-5Ti-1B was used as a grain refiner (1.2 weight percent of the melt); the grain refiner was added in the melt after the addition of the degasifier tablet. After ten minutes of addition of the grain refiner, the melt was mechanically stirred for one minute and then poured into the L-shaped die and the cylindrical mould. The holding time for grain refiner was kept not be more than 10 minutes to avoid fading effect.

IV. RESULTS AND DISCUSSION

Macrostructure analysis

Figure 3(a-e) shows the fading effect of grain refiner with holding time of grain refiner in the molten metal. Fig. 3 (a-b), clearly depicts that the addition of grain refiner refines the grains and produces fine grains. But as the holding time of grain refiner is increased, the effect of grain refiner fades away as shown in Fig. 3 (b-e). The grains become coarse once again. So, as the best result is achieved for holding time of 10 minutes [Fig. 3 (b)], this parameter is fixed for the rest of the study.

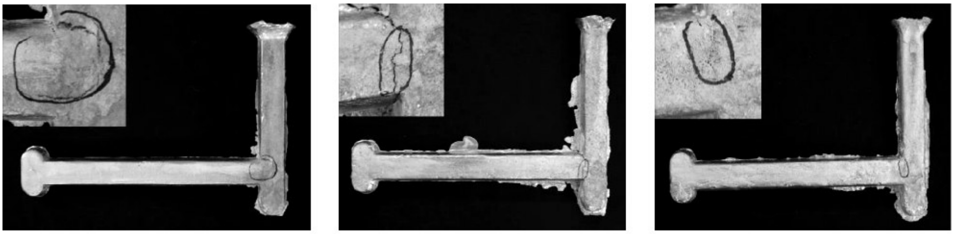


(a) No grain refiner **(b) Grain refiner – holding time 10 minutes**

(c) GR – holding time 30 minutes **(d) GR – holding time 60 minutes** **(e) GR – holding time 120 minutes**

Fig. 3 Al-7Si-3Cu – Fading effect of grain refiner

Visual Inspection of Hot Tears



(a) No Gr (Room Temp Die Cast) **(b) No Gr (Mould temp – 200°C)** **(c) 1.2 wt% Grain refiner (Mould temp-200°C)**

Fig. 4 Al-7Si-3Cu – Effect of mould temperature and grain refiner on hot tearing (Magnified crack area is shown in the top corner)

In Fig. 4 (a-c), the effect of mould temperature and grain refiner on hot tearing is shown by analysis of castings of Al-7Si-3Cu in 3 different conditions. The castings in Fig. 4 (a-b) show that as the mould temperature is increased from room temperature to 200 °C, the crack formed has reduced in magnitude. This is due to the decrease in freezing range of the casting and improvement in the bulk feeding of the casting during final stages of solidification. The castings in Fig. 4 (b-c) show that the addition of grain refiner in (c) casting has reduced the hot tearing significantly compared to (b) casting.

Differential Scanning calorimetry (DSC) Thermal Analysis

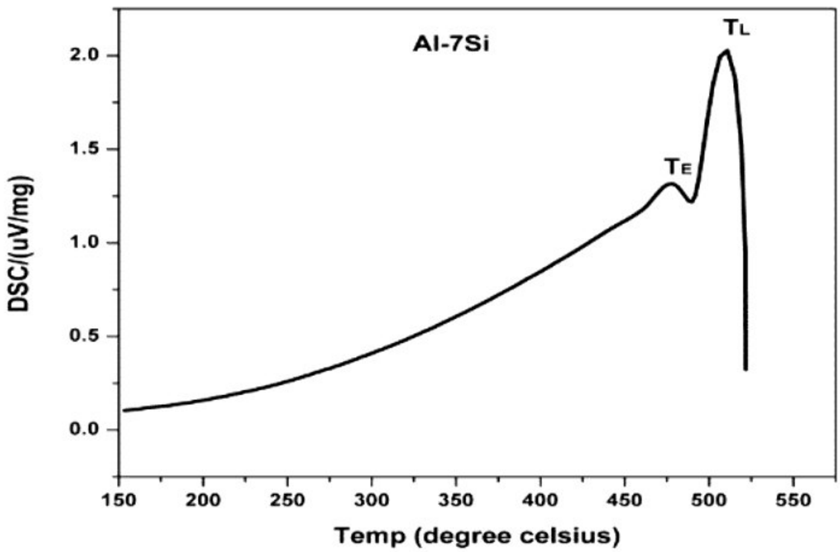


Fig. 5(a) DSC analysis of Al-7Si alloy

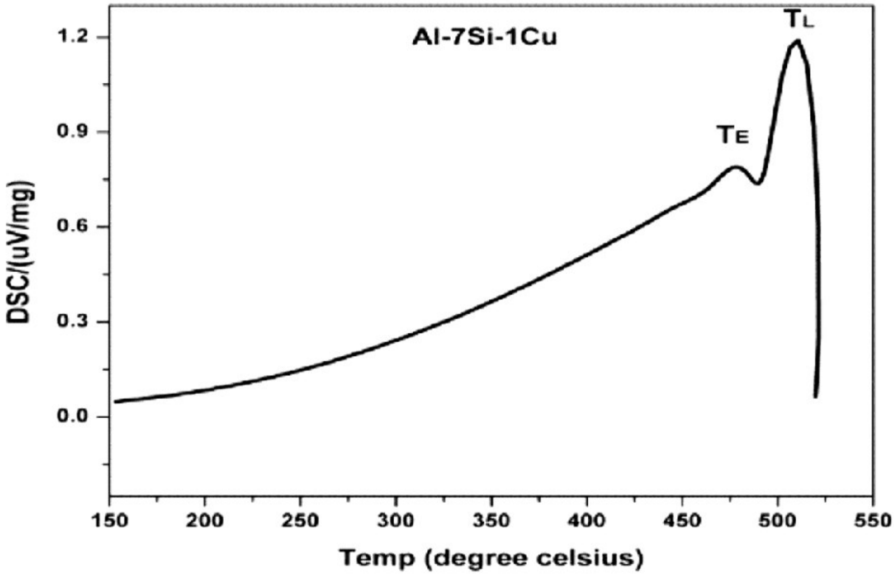


Fig. 5(b) DSC analysis of Al-7Si-1Cu alloy

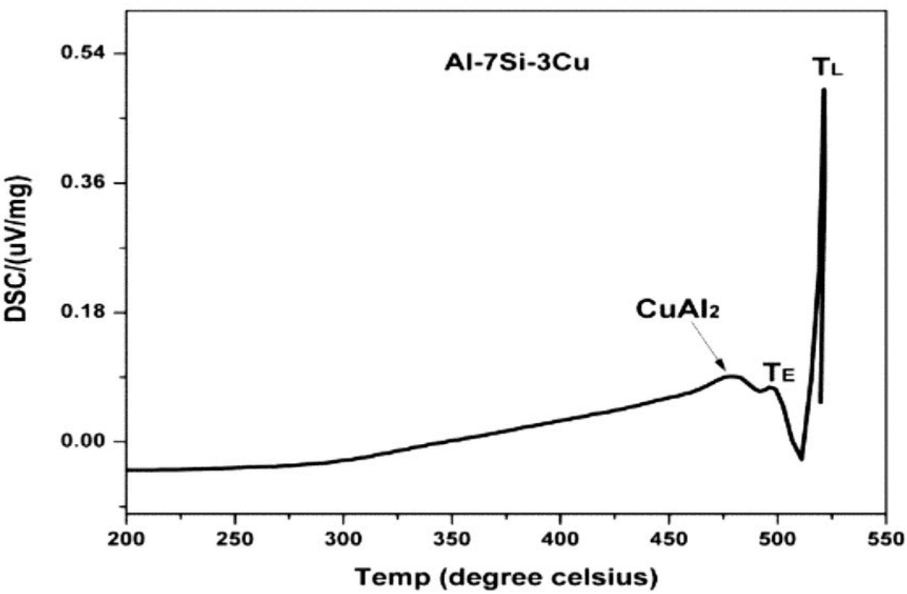


Fig. 5(c) DSC analysis of Al-7Si-3Cu alloy

Figure 5 (a-c) shows the DSC analysis of Al-7Si alloy, Al-7Si-1Cu alloy and Al-7Si-3Cu alloy respectively. TL indicates the liquidus temperature. TE indicates the eutectic temperature. In Fig. 5 (a) and (b), no other peak is observed other than TL and TE. This indicates that in Al-7Si-1Cu, the amount of copper is so low that $CuAl_2$ phase is not observed. In Al-7Si-3Cu, the third peak indicates the formation (i.e. presence) of ample amount of $CuAl_2$ phase. So, it can be concluded that the addition of 3% copper in Al-7Si cast alloy significantly improves the mechanical properties of the alloy (as the formation of a significant amount of $CuAl_2$ phase is necessary for good strength, hardness and other mechanical properties). From above analysis, it can also be concluded that the presence of copper (in $CuAl_2$ form) increases the freezing range of the alloy. This is due to the formation of $CuAl_2$ phase at lower temperatures as the copper content is increased, which increases the solidification range of the alloy causing hot tears.

V. CONCLUSION

Increasing the mould temperature decreased the hot tear susceptibility in cast Al-7Si-3Cu alloy. The addition of 1.2 wt% grain refiner reduced hot tears in the castings but did not eliminate them. Optimum holding time for grain refiner in the molten metal is 10 minutes. Beyond 10 minutes, the effect of grain refiner fades away (fading effect). The increase in copper content increases porosity in the casting. The addition of grain refiner decreased porosity by grain refinement and decreased freezing range.

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