AN EXPERIMENTAL STUDY ON THE MECHANICAL PROPERTIES OF THIXOFORMED COMPONENTS IN ALUMINUM ALLOYS

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Abstract: Semisolid metal processing or Thixoforming is a developing technology where the material is processed in the freezing range. Thixoforming process results in components with better mechanical properties as compared to conventional processes. The material at this temperature is very soft and as a result lower loads may be applied to obtain the final shape of the component. Process parameters like ram speed, temperature of the billet and die temperature influence the mechanical properties like tensile strength, hardness and wear behavior of thixoformed component. In the present study an attempt is made to understand the effect of process parameters on the mechanical properties of aluminum alloy by carrying out experimental studies. The results indicate the significant influence of billet temperature and die temperature on the tensile strength and hardness of the material.

Keywords: Thixoforming, A356, Mechanical Properties, experimental study.

I. INTRODUCTION:

Semisolid metal processing (SSMP) or Thixoforming is a technology employed for production of near net shaped components. This process is carried out at a temperature range between its liquidus and solidus temperature [1]. The origin of SSMP can be traced to the experiments conducted by David Spencer at MIT in 1971 as part of his doctoral thesis under the supervision of Martin Flemings [2]. The process combines a number of advantages of casting and forging. Compared to casting, SSMP provides a more stable filling front places lower thermal loads on the metal dies and less shrinkage. Semisolid metal processing (SSMP) is also known as thixoforming or thixocasting depending on the initial condition of the billet and process adopted [3]. Some of the alloys which are suitable for carrying out the semisolid metal processing are alloys of aluminum and copper A356.0 and 356.0 are a 7% Si, 0.3% Mg alloy with 0.2 Fe (max) and 0.10 Zn. The alloys have very good casting and machining characteristics. They are used in the heat-treated condition. The schematic view of thixocasting and thixoforging processes is shown in Fig.1. The three important steps in this process are billet production, reheating to semi-solid condition and forming operation [4]. The process combines a number of advantages of casting and forging. Compared to casting, SSMP provides a more stable filling front places lower thermal loads on the metal dies and less shrinkage.

The alloys have very good casting and machining characteristics. They are used in the heat-treated condition. The resistance to corrosion is excellent and the weldability characteristics are good. The components when given a solution and aging treatment have very good mechanical properties. However to derive the benefits of this process to the full potential, the billets must have a non-dendritic microstructure. To achieve this several methods are available. For the present study mechanical stirring is employed to modify the dendritic microstructure to a globular form.

II. STUDIES ON MECHANICAL PROPERTIES

The mechanical properties of a material determine the range of usefulness and also service life of the component. The elastic and plastic behavior of the material under various loading conditions helps us to understand the characteristics like bending, deformation and hardness of the material. The mechanical properties are not constant and are functions of temperature, type of loading and relative movement between two components. Some of the properties that give a measure of these characteristics include the tensile strength, ductility and wear resistance. Therefore tensile test, hardness test and wear test are conducted to determine the mechanical properties. Bouzakis K.D. [5] conducted experimental and numerical study to determine the influence of temperature and shear rate and concluded that the increasing both the variables led to deterioration of mechanical and rheological properties. Michel Bellet [6] carried out experimental and simulation studies to characterize the flow behavior of aluminum alloy in semi-solid condition. The experimental results are validated with the finite element simulation results. The process parameters such as initial temperature of the specimen, mould temperature and piston velocity are considered. Freitas De E. [7] performed extensive experimentation to assess the flow behavior, mechanical properties, microstructure evolution and porosity levels. Samples of Al 356 obtained by different methods are prepared and the above properties are evaluated. It is observed that the tensile properties are better as compared to conventionally cast alloys. Shueiwan H. Juang [8] studied the mechanical properties of A356 alloy with preformed billets having thixotropic structure. The results of tensile, impact and fatigue tests are reported for two different heat treated specimens. It is observed that the superior mechanical properties can be achieved with globular microstructure. Manjunath Patel [9] carried out experimental study to optimize the process parameters in squeeze cast process. The process parameters chosen are squeeze pressure, pouring temperature and die temperature. The output parameters of surface roughness and surface density are calculated. The results are analyzed using Taguchi and grey rational analysis methods. Thus it is essential to study the combined effect of process parameters on mechanical properties.

III. EXPERIMENTAL STUDIES

The billets required for this study are initially prepared by stirring the molten alloy of Al 356 in an electric arc furnace and cast into billets. Mechanical stirring is employed as it involves usage of less sophisticated equipment and the process is also economically viable. The billets are now heated to semisolid temperature and load is applied using hydraulic press after placing the hot billet in the die. The process parameters considered for the present study are billet temperature and die temperature. Three levels are chosen for each of two factors. L9 experiments (3 Levels and 2 factors) are designed using Taguchi design of experiment approach. The temperatures considered for billet are 580^0C, 590^0C and 600 ^{0}C and die temperatures chosen are 30^0C, 125^0C and 250^0C.

Table 1 lists the arrangement of runs for experimental studies. Fig. 1 represents the schematic representation of die used for making the thixoformed component. Tensile specimens are prepared as per ASTM E8 standards. The tensile test specimen used is shown in Figure 2. The diameter of the specimen is 12 mm. The length of the specimen is about 95mm and the gauge length is about 50 mm. A 40 ton Universal Testing machine is used for conducting the tensile tests. The data is recorded and results are tabulated at Table 2. Fig. 3 represents the tensile specimen after the test. The experimental data is analyzed to determine the effect of process parameters on the mechanical properties of the component formed by thixoforming process. The process parameters used for conducting the L9 experiments are billet temperature and die temperatures. The tensile strength for various experimental data is plotted and is shown in Fig 4. The plot indicates that tensile strength is varying for different runs. The influence of process parameters is observed. A maximum value of 171.602 N/mm^2 is obtained for run order no.1. The BHN values are recorded for all the nine specimens at three different locations and the mean value is tabulated at Table 2. A graph is plotted for the hardness values recorded for different run orders as shown inFig.5.

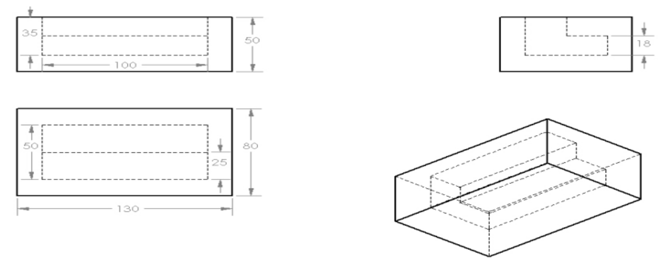

Fig 1 Schematic representation of die used in making Thixoformed Component

Table 1.DOE using L9 Orthogonal array

Run No	Billet Temp ^{O}C	Die Temp ^{O}C
1	580	30
2	600	250
3	590	250
4	590	30
5	580	250
6	580	125
7	590	125
8	600	30
9	600	125

Fig. 2 Tensile test specimen

Fig. 3 Tensile test specimen after the test.

Fig. 4 Plot showing the tensile strength for different run orders.

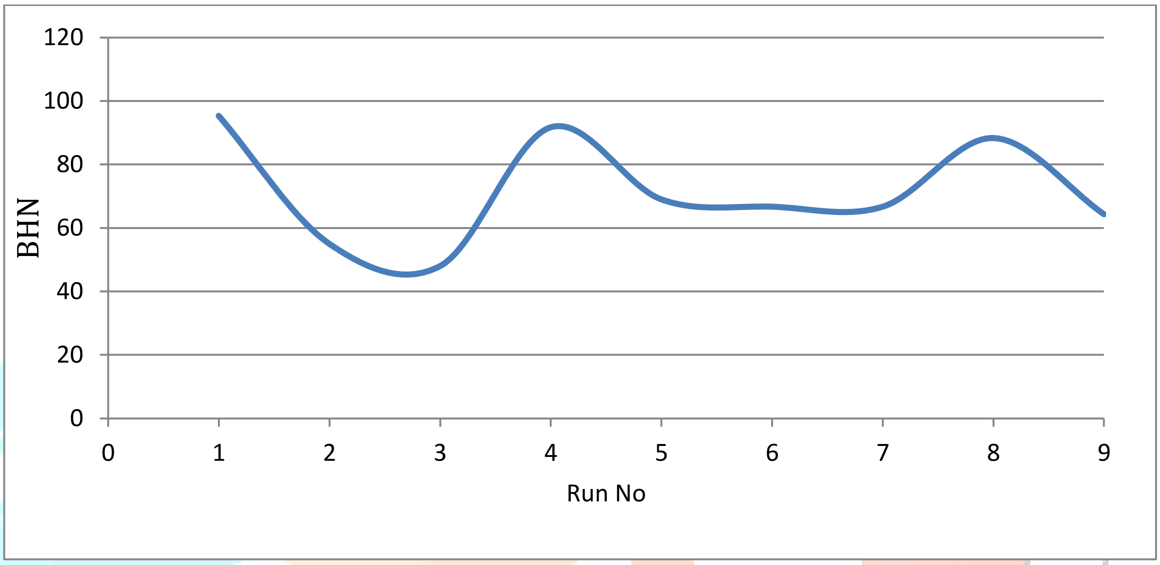

Fig. 5 Plot showing the BHN values for different run orders

Table 2 Results of Tensile Strength and Hardness Tests

Run No	Billet Temp ^oC	Die Temp ^oC	Tensile Strength N/mm2	BHN
1	580	30	171.602	95.3
2	600	250	159.347	55
3	590	250	165.485	48
4	590	30	143.952	91.7
5	580	250	126.987	69
6	580	125	124.28	66.7
7	590	125	168.994	66.7
8	600	30	135.429	88.3
9	600	125	170.691	64.3

IV. RESULTS AND CONCLUSIONS:

It is observed that the process parameters significantly influence the mechanical properties of thixoformed component of A 356 material. The average values of tensile strength obtained is better than as cast values for Al 356 alloy because of improved ductility of the materialat higher loads. It is observed that with an increase in billet temperature the hardness value decreased and stayed constant beyond a value of 590 ^{O}C. The Die temperatures are found to have a major influence on hardness as compared to billet temperature. The hardness value decreased with increase in die temperature.

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