Design and Fabrication of Multi Directional Forging Die for processing of Aluminium Material

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Abstract—

Design and fabrication of multi directional forging (MDF) die and specification of die material (work piece) , and demonstration of required Machining process like milling, facing, grinding, and Harding process. The Preparation of multi directional forging (MDF) die is economic method for the processing of material properties and the effect of multi directional forging (MDF) method in the microstructure evaluation and the grain structure of the conventional aluminium material in the Industries is more because of it's effective mechanical properties. And those results should concluded from these multi direction forging technique.

Index Terms— Aluminium alloy, Multi-directional forging, heat treatment, Tensile properties, Microstructure

1 INTODUCTION

Ultra fine grain (UFG) structure of aluminium and it's alloys have potential for the use in industrial applications due to their superior mechanical properties such as strength to weight ratio, strength to Ductility and fatigue toughness. And an additional advantage of the UFG material is their ability to be deformed into complex shaped parts on the basis of Severe plastic deformation (SPD) method. SPD methods are classified as Equal channel angular pressing (ECAP), Torsion under hydrostatic pressure, Repetitive corrugation and straightening(RCS), and Multi direction forging (MDF). Multi direction forging is easiest and most promising industrial applications from severe plastic deformation techniques. Aluminium material are potential materials for various application due to their good physical and mechanical properties. The aluminium material should be compressed in all the direction at room temperature and deformed material should be process material and collect the results of the material after that change it to certain degrees by providing the heating coil, gather those results and compare with room temperature results .

2 Material and Experimental Details

2.1 Material

HDS material for the preparation of DIE

2.2 Specification and Composition of HDS Material

Table -1: Chemical Data

Material	in g/cm^3
Carbon	0.32-0.45
Chromium	4.75-5.5
Manganese	0.2-0.5
Molybdenum	1.1-1.75
Phosphorous	0.03 max
Silicon	0.8-1.2
Sulphur	0.03 max
Vanadium	0.8-1.2

Table -2: Physical Data

Density(1b/cu.in)	0.283
Specific gravity	7.8
Melting point (°F)	2600
Modulus of Elasticity(GPa)	29

2.3 Experimental work

Fig: Completed die setup

2.4 Heat Treatment process

Steps for the HDS material heat treatment process.

Material	HDS [Hot Die Steel]
Preheating	550-600°C(for 2hrs)
Hardening	1010°C(for 2 hrs)
Air cooling	
First tempering	520°C(for 2 ½ hrs)
Second tempering	590°C(for 2 ½ hrs)
Third tempering	540°C(for 2 ½ hrs)
Hardness	50-52 HRC

3 Literature Review

- **P C Sharath et. al (1) :**Multi direction forging is on important process for producing fine grains in bulk materials by means of Severe plastic deformation **Zn-Al** alloy is used for preparing sleeves of plain bearings. but presence of Porosity degrades it should be usage in industries application.

- **ANJAN B N et. al (2):**Influence of multi directional forging (MDF) on microstructural and mechanical properties of ZA27/SiC 5 weight percentage (Wt%) composites were investigated.

- **GAJANAN M NAIK et. al (3):** Establishing the novel microstructure is an effective method to accelerate the applications of magnesium and its alloys. In this work, an Mg-8%Al-0.5%Zn alloy (AZ80 Mg)with ultra-fine-grain (UFG)size of~1.29 μm was achieved by the combined processes of multi-directional forging (MDF) and equal channel angular pressing (ECAP).

- **G V PREETHAM KUMAR et. al (4):** Zinc aluminium-based alloys (ZA/27) are widely used in bearing application, but due to its density and higher level of porosity of cast component, it limits the usage of these alloys in automobile industries.

- **B KUMAR et. al (5):** The experimental study of hypoeutecticAl-7.3Si alloy on microstructure and mechanical properties processed by MDF at room temperature was reported in this paper. A commercial LM-25 aluminium alloy ingot was melted in an electric casting furnace and poured into a preheated rectangular casting die.

- **MIKHAIL S et. al (6):** The current study observed a grain structure evolution in the central part and periphery of the sample of an Al–Mg–Mn-based alloy during isothermal multidirectional forging (IMF) at 350 ◦C with a cumulative strain of 2.1–6.3 and a strain per pass of 0.7.
  The current study observed a grain structure evolution in the central part and periphery of the sample of an Al–Mg–Mn-based alloy during isothermal multidirectional forging (IMF) at 350 ◦C with a cumulative strain of 2.1–6.3 and a strain per pass of 0.7.

- **Zhanguang Zheng et. al (7):** A newly proposed multi-directional forging (MDF) was successfully applied to a commercially pure titanium (CP Ti).

- **Tomoya Aoba et. al (8):** Microstructural evolution and changes in the mechanical properties of 6000 series aluminum alloys during multi-directional forging (MDFing) and articial aging were systematically investigated.

- **P Bereczki et. al (9):** In the present study the possibilities of grain refinement was investigated by applying large-scale of cyclic plastic deformation to aluminum at ambient temperature.

- **Sh Sitdikov et. al (10):** The effect of $Al_3(Sc,Zr)$ dispersoids on the evolution of the cast Al-Mg-Sc-Zr alloy structure under multi-directional isothermal forging (MIF) has been investigated.

- **Paula Cibely Alves Flausino et. al (11):** Experiments were performed to analyze the microstructure evaluation and mechanical behavior of commercial-purity copper (99.8%) processed by up to 48 cycles of multi-directional forging (MDF).

4 PROJECT OBJECTIVES

1. To design and fabrication of multi direction forging die set up.
2. To observe the machining operation like facing, milling, grinding.
3. To know the heat treatment process like quenching , tempering.
4. To study the microstructure of aluminium material through the multi direction forging technique.
5. To evaluate the material mechanical properties by conducting the tensile strength

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test, Hardness test, wear strength test of aluminium material through multi direction forging technique.

5 Results:

DESIGN AND FABRICATION

- From the Solid edge software 2D and 3D modelling sketch's are created with the suitable dimensions for the design of multi direction forging die set up.
  - Fabrication Or manufacturing of material, the manufactured composition HDS material should be obtain from the manufacturing company.

MACHINING

- From the machining Specilieat the obtained material should be shaped as the multi direction forging die By the machining operations like, facing, milling, grinding operations.
- The specifications of the milling machine's , Grinding machine, are tabulated.

HEAT TREATMENT

- The heat treatment process will be conducted to retain the material original properties.
- The steps involved for the heat treatment and procedure steps , and specifications of Gas Carburizing machine, and Tempering machine are given.

Refer from (5th) journal paper

5.1 Microstructure descriptions

Figure 2 depicts an optical micrograph of as-cast, solution heat-treated and MDF-processed Al 6061 alloy samples. Solidification structure of as-cast material consisting of dendrites of Al phase and acicular eutectic Al 6061 particles with different sizes and shapes is displayed in Fig. 2a, b. Figure 2b shows coarse acicular eutectic Al 6061 particle's with an average length of 17 lm and an average width of 4 lm for the as-cast sample. Figure 2d shows microstructure of solutionized sample, where coarse acicular eutectic Al 6061 particles of as-cast samples are significantly transformed into fine round particles with an average length of 7 lm and an average width of 3.5 lm. Figure 2e–h illustrates the microstructure of MDF processed up to three and six passes samples at room temperature. The microstructure of MDF processed up to three passes sample at room temperature shows fine broken Al 6061 particles with an average length of 5 lm and an average width of 3 lm. The MDF processed up to six passes sample at room temperature shows a remarkable change in microstructure, where Al 6061 particles arranged effectively broken into very fine particles with average length of 4 lm and distributed homogenously in aluminium phase as shown in Fig. 2g, h. After six passes, some Al 6061 particles are broken to less than 2 lm. These results show that MDF processing at room temperature has a direct effect on the morphology of Al 6061 particles. The eutectic Al

6061 particle size decreases with increasing number of passes. It is also observed that after six passes at room temperature, grain size of as-cast sample decreases from 60 lm in the as-cast to 23 lm. Composition of Al 6061 alloy is confirmed by EDX and determines the presence of Al 6061 shown in Fig. 3.

5.2 Microhardness Measurements

Microhardness measurements were carried out at various points in each sample, and values were obtained from the average of measurements. Vickers Microhardness values for as-cast, solution heat-treated, MDF processed up to three and six passes are 78 Hv, 89 Hv, 95 Hv and 125 Hv, respectively. Microhardness value of solution heat-treated material is increased from 78 Hv to 89 Hv. The improvement in hardness of solutionized material is due to change in morphology of coarse Al 6061 into fine particles. It is noted that hardness significantly increases for MDF-processed materials and also increases with the increasing number of passes. High hardness has been achieved for MDF processed up to six passes material, which is 1.6 times that of as-cast material. The increase in hardness of MDF processed material has resulted from refinement of Al 6061 particles and strain hardening of aluminium phase.

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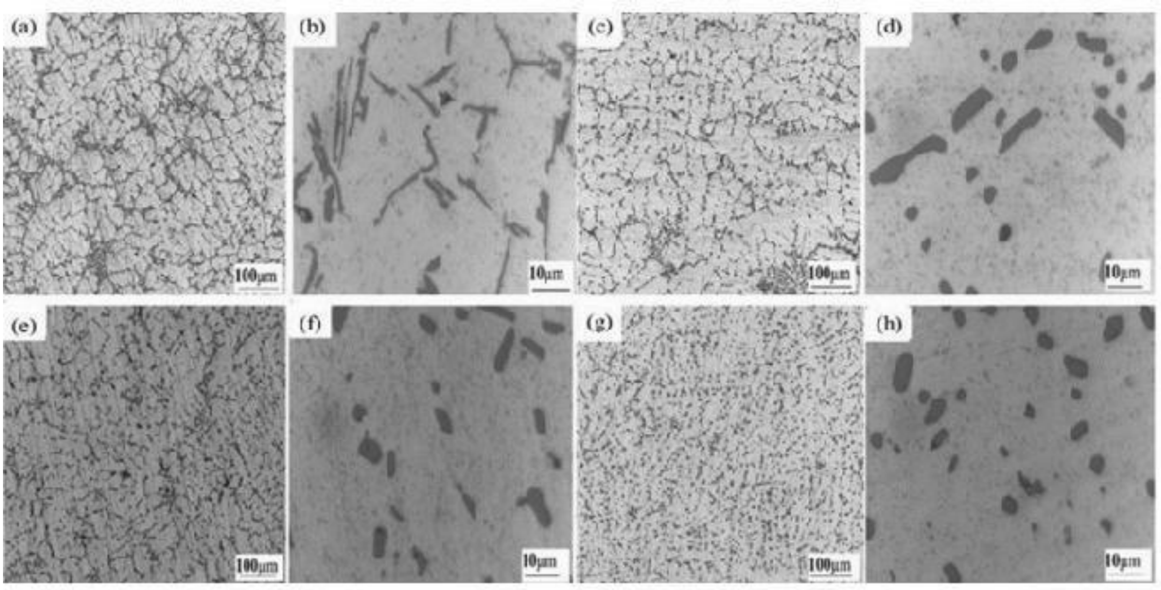
Fig. 2 Optical micrograph of Al 6061 alloy samples: a, b as-cast; c, d solutionized; e,

Fig taken from (5th journal paper)



MDF up to three passes; g, h MDF up to six passes

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5.3 Tensile properties

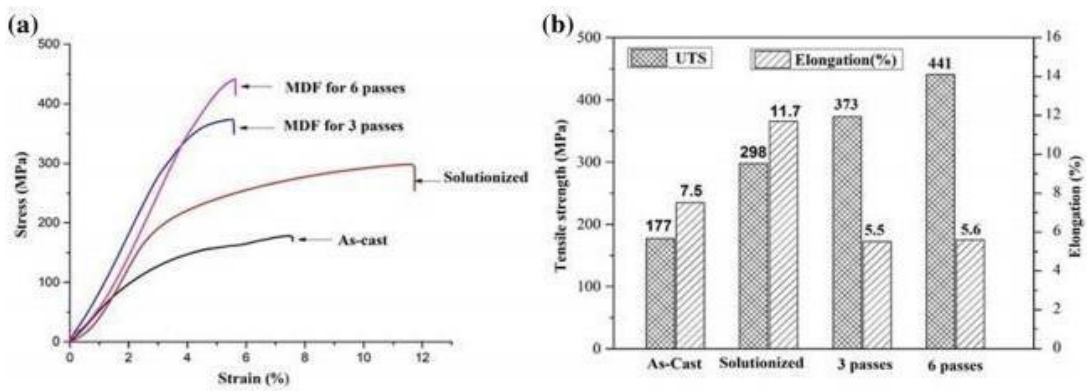
Variation of UTS and elongation for the as-cast, solutionized and MDF-processed specimen is illustrated in Fig. 4a,b. As-cast specimen has low ultimate tensile strength due to the presence of dendrite structure, porosity and large Al 6061 particles. The UTS and elongation of as-cast specimens are 177 MPa and 7.5%, respectively. Furthermore, after solution heat treatment, UTS and elongation of specimen reaches 298 MPa and 11.7%, respectively, which are higher than that of as-cast specimen. Due to the increase in ductility after solution treatment, sample could be processed up to six passes successively. In the solution heat-treated sample, dendrite structure disappears with the transformation of Al 6061 particles into fine round corner particles. UTS and elongation of MDF processed up to three passes specimens are 373 MPa and 5.5%, respectively. After processing the sample up to six passes, UTS and elongation reaches 441 MPa and 5.6%, respectively. It can be noted that UTS remarkably increases for solution heat-treated followed by MDF-processed specimen and increases with an increasing number of passes. The increase in tensile strength of MDF-processed sample is due to uniform distribution of effectively broken Al 6061 particles and strain hardening of aluminium phase.

However, after MDF process at room temperature, ductility of the sample is reduced due to strain hardening. The improvement of UTS, elongation and hardness of solution heat treatment and MDF processed up to six passes sample at room temperature (current work) is compared with other SPD processes as shown in Table 1. The ultimate tensile strength achieved by MDF-processed Al 6061 is higher than HPT, ECAP, ABE and rheoforged and MDF [4, 8–10].

However, there is an improvement in elongation (13%) when processed by ECAP ten passes at room temperature [8]. HPT process is capable of producing average Microhardness of around 185 Hv, which is higher than other SPD processes; however, disadvantage of this process is sample size limitation [2, 11]. But MDF is an important process for producing fine grains in large-scale bulk materials by means of severe plastic deformation.

Fig,3.Stress–strain curves and bar chart of as-cast, solutionized and MDF-processed Al 6061 alloy

Fig taken from (5^{th}) journal paper



6 CONCLUSION

- Design and fabrication of multi direction forging die should be prepared.
- Machining of the multi direction forging die will be completed.
- Heat treatment process should be completed.
- The MDF techniques should be easiest and economic method.
- The material mechanical properties and microstructure of aluminium material should be tabulated.

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