DETECTION OF NATURE OF THE FABRICATED MATERIAL BY UPSET FORGING: AN EXPERIMENTAL AND SIMULATION STUDY

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ABSTRACT

The preforms are made by taking the aluminum alloy 7075 and filling the SiC, fly ash and graphite reinforcement particles at different weight percentages (6, 9 and 12) using a stir casting method. The casting preforms are machined using conventional lathe machine and different types of cross sections like solid, flange, ring and taper samples are prepared. These samples are tested on UTM and found mechanical compressive properties Max Compressive Strength (MPa), Max Compressive Strain and Young's Modulus (MPa). The axial, compressive and hydro static stress are found using standard analytical equations and same results are validated in ANSYS software, the analytical and ANSYS results are matched very closely. The strength coefficient and strain hardening exponent tell the plastic behaviour of the fabricated preforms. For taper and ring type cross section preform samples of 12 weight % of MMC having more ductile compare to other cross sections and other weight % of MMC (6, 9 and base material). And compressive strength is good for the composites compare to the base material AA 7075.

KEYWORDS: AA 7075, UTM, Reinforcements, ANSYS & Plastic Behaviour

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1. INTRODUCTION

Many investigators have investigated the behaviour of solid cylindrical specimens during cold offset forging due to its huge technical relevance in metal forming process. A comprehensive review of the same has been published by Johnson and Mellor [1]. Another important aspect of axis-symmetric compression from the viewpoint of testing the manufacturing properties of metal is its estimation of forming limits up to plastic instability and subsequently fractures as explained by Shaw and Avery [2]. In upsetting process, the presence of frictional constraints between the work-piece and the material has pertinent effect on the plastic deformation of the former. When a solid specimen (cylinder/square billets/rectangular billets) undergoes axial compression between the bottom and punch plate, the work-piece which is in contact with the plate surfaces undergoes heterogeneous deformation which results in the phenomenon of "barrelling" of the specimen. Friction at the faces of contact of specimen and work-piece causes a retarding effect on the plastic flow of material on the surface and its vicinity. As a result, a conical wedge like crevice of relatively un-deformed metal is formed directly below the point of compression while the rest of the specimen suffers high strains and bulges out in the form of a barrel. This demonstrates that the metal travels

very easily towards the nearest free surface which is called as the point of least resistance, a well-versed principle of plastic deformation. However, the use of lubricants hugely reduces the degree of bulging and under the condition of proper ideal lubrication, bulging can be brought down to zero theoretically. The friction cannot be eliminated completely during upset forging and it is necessary to go for a correction factor for the bulging process during the designing of a die. Kulkarni and Kalpakjian [3] examined the arc of barrel, led to an assumption that it may be circular or parabolic in cross section. Meanwhile, Schley et.al [4] presented a comprehensive report on the varied geometrical factors that affect the size and shape of the barrel. Banerjee and Narayanasamy et al. [5-6] showed theoretically that barrelling radius can be expressed as a function of strain (axial) and subsequently confirmed above said through experimental analysis. Yang et al. [7] developed an upper bound theory to determine the forging load and deformed bulged profile while upset forging cylindrical billets under the dissimilar varied frictional conditions at flat die surfaces. Chen & Chen et.al [8] developed a theoretical solution for prediction of flow stresses during an upsetting operation with consideration of the barrelling effect. Gokler et.al [9] made a comprehensive study of taper upset forging using elastic plastic FEA (finite element analysis). Narayanasamy and Pandey [10] studied the effects of barrelling of aluminium solid cylinders in cold upsetting. Malayappan and Narayanasamy [11] had experimentally analyzed the barrelling phenomenon under different frictional conditions at with introduction of an extrusion die constraint at one. Uppada Rama Kanth, Putti Srinivasa Rao and Mallarapu Gopi Krishna [4-6] stated that the improved Al-Zn / Fly Ash / SiC compounds are manufactured by a vortex method using a casting path. This article indicates that an evaluation of the microstructure and mechanical behavior of aluminum and zinc reinforced SiC ash and alloys was investigated. Incorporation of fly ash particles improved hardness and tensile properties, such as final stress and yield strength, improving by adding SiC particles and also discussing corrosion and corrosion properties. P.J. Kumar et.al refers to the experimental study of the use of vegetable oil as a cutting fluid in the manufacture of EN 353 steel ingots to reduce the cutting temperature under different lubrication conditions, that is, dry, flood and minimum lubrication conditions for quantity. Metallic models for the automotive industry, the prototype test and research laboratories are described in detail. Finally, this review provides an overview of the future automotive industry through metallic models [9-10].

2. EXPERIMENTAL WORK-PREFORMS FABRICATED BY STIR CASTING METHOD

Primary formations are made using the Stir casting method, using cast iron dye, inert gas, electric stirrer, and crucible made of graphite. SiC, Fly Ash and graphite particles are taken as different weight percentages with respect to the base material AA7075 as shown in the table 1 and hybrid composites are made. The melting temperature of AA7075 is about 900 °C. The fly ash and graphite powder are poured into the graphite crucible and spin at a constant speed for at least 5 minutes, and it is rotated with an electric stirrer. The molten metal is poured into the cast iron dye, then the necessary samples are made as shown in Figure 1.

Table 1: Compositions of Hybrid Composite

S. No	Composition of Reinforcements	SiC Wt. %	Fly Ash Wt.%	Graphite Wt.%
1	AA 7075	0	0	0
2	AA7075 + 3 % SiC + 1.5 % Fly ash + 1.5 % Graphite	3	1.5	1.5
3	AA7075 + 3 % SiC + 1.5 % Fly ash + 1.5 % Graphite	4.5	2.25	2.25
4	AA7075 + 6 % SiC + 3 % Fly ash + 3 % Graphite	6	3	3

Figure 1: Stir Casting and Casted Cylindrical Samples.

2.1. Deformation Test on UTM

The deformation test was conducted on UTM upto shear failure or 50 % of reduction in height of the samples. Taper, flange, H / D ratio 1.0 and 1.5 cross section samples are tested on this UTM machine. The load and displacement values are taken for all the samples of various cross sections and all the mmcs and base alloys. Place the samples carefully to maintain the central axis of the top and bottom die of the UTM.

Figure 2: Compression Test on UTM.

Table 2: Compressive Properties

S. No	Geometrical shape	Max Compressive Strength (MPa)	Max Compressive Strain	Youngs Modulus (MPa)
AA 7075	HD1	390.01	0.06	12131
	HD1.5	345.12	0.08	11232
	TAPER	324.25	0.09	10132
	RING	300.05	0.1	10245
AA7075 +6MMC	HD1	499.03	0.09	15712
	HD1.5	323.93	0.1	13152
	TAPER	489.44	0.2	10561
	RING	376.91	0.17	10489
AA7075 +9MMC	HD1	503.05	0.09	16536
	HD1.5	498.79	0.15	6140
	TAPER	496.84	0.16	9548
	RING	349.67	0.18	8433
AA7075	HD1	495.91	0.09	14416

+12MMC	HD1.5	496.87	0.14	11266
	TAPER	470.18	0.24	9420
	RING	413.19	0.21	8317

3. ANALYTICAL METHODS

Triple stress was found for the plastic analysis of MMC of base alloy AA7075 and compounds using the traditional plastic analysis theory. Calculated the engineering stress and engineering strain values using load and displacement data given by the UTM. After that found the true stress and true strains in axial and circumferential directions.

$$\text{The strain in Axial direction } \epsilon_z = \ln \left(\frac{H_f}{H_0} \right)$$

Fit the true stress and strain data in hollow tube power law of equation for finding the strength coefficient and are strain hardening exponents of the samples of various cross sections and made of base alloy AA 7075 and mmcs.

$$\sigma_0 = K \epsilon^n$$

Here K and n are the strength coefficient and strain hardening exponents.

$$\text{Hydro Static stress can be found using the formula } \sigma_H = \frac{\sigma_z + \sigma_\theta + \sigma_r}{3}$$

Here σ_z, σ_θ , and σ_r is axial, circumferential and radial stress respectively. Axial Stress $\sigma_z = \sigma_0 \left[\left\{ 1 - \left(\frac{1+2\alpha}{2+\alpha} \right)^2 \right\}^{-1/2} \right]$, here α is the slope between the axial and peripheral deformation and σ_0 is the flow stress of the material.

The hoop stress $\sigma_\theta = \sigma_z \left[\left(\frac{1+2\alpha}{2+\alpha} \right) \right]$ and in radial direction stress is zero because on the free surface of the material. The table 3 showed the Strength coefficient (K) and strain hardening exponent (n) values of all variety of cross sections of base and composite materials.

Table 3: Effect of K and N Values

S. No	Geometrical Shape	K	n
AA 7075	HD1	459.43	0.64
	HD1.5	364.30	0.43
	TAPER	522.21	0.56
	RING	580.40	0.67
AA7075 +6MMC	HD1	1109.54	0.77
	HD1.5	3452.31	1.29
	TAPER	1148.14	0.73
	RING	755.89	0.64
AA7075 +9MMC	HD1	1362.66	0.85
	HD1.5	1214.03	0.77
	TAPER	1730.73	0.85
	RING	753.25	0.71
AA7075 +12MMC	HD1	1666.87	0.88
	HD1.5	2479.47	0.89
	TAPER	951.17	0.69
	RING	821.55	0.69

3.1. Finite Element Simulation of Cold Upsetting Process

Upsetting is most broadly utilized metal forming process for assembling of various machine segments. According to viewpoint proportions the samples are designed in ANSYS APDL, the investigation was performed with the assistance of

solid 182 element and contact elements 182 and 183. The contact pair was created using contact elements. The material properties of top and base passes on of the UTM machine was thought to be steel ($E=210\text{GPa}$, $\mu=0.3$) and the readied tests are AA7075 and their composites.

4. RESULTS AND DISCUSSIONS

4.1. Compressive Strength

The compressive strength is high for H / D ratio 1.0 for all MMCs compare to the other cross sections as shown in figure 3 to 4. The reason for high strength is the short length performs will takes more force than other cross sections.

The compressive strength of AA7075 + 9mmc alloy was more for H / D 1.0, 1.5 and Taper cross sections compare to other mmc's of alloys as shown in Figure 4.

Figure 3: The Compressive Strength of AA 7075 and AA7075+6 Mmc.

Figure 4: Compressive Strength of AA 7075 +9 Mmc and AA7075+12 Mmc.

4.2. Ductile Nature of Performs

Figure 5 shows the ring type cross section shows the good plastic behaviour compare to other cross sections as show in Fig 5 for mmc's and alloys. The axial stress is increased for the H / D ratio 1.0 of composite metal matrix composites compare to base alloy AA7075 whereas for AA7075 + 9MMC composite very close to the effective strain line compare to other composites and base alloy it indicates the good ductile properties are presented. H / D ratio 1.5 the hoop stress is increased for 9 and 12 MMC compare to 6MMC and base alloy it indicates that they are exhibit the good plastic properties.

Figure 5: Max Circumferential Stress (MPa) for Ring Type Cross Section.

4.3. Effect of K and n Values

The K and n values are high for solid cross section for the 6MMC material it indicates the 6MMC material having the good ductility properties compare to other cross sections and others MMCs. The K and n values are increased with increasing of reinforcements. Hence the composite system gives the better results compare to the base material AA7075.

4.4. FEM Results

The maximum displacements results of various preforms are obtained in ANSYS software are equal to the experimental results, a good agreement was shown between them.

Figure 6: Max Displacements of Different Cross Section in ANSYS.

5. CONCLUSIONS

The Following Conclusions are made for Estimating the Nature of the Material:

- The preforms are manufactured using stir casting technique.
- The compressive strength is 22.46% is more for AA7075+9mmc of H/D ratio 1.0 compare to the base alloy AA7075 of H/D ratio 1.0.
- Max Circumferential Stress is 63.68% is more for ring type cross section of AA7075+12mmc compare to the base alloy AA7075.

- The ANSYS software was used to determine the stress for analysing the plastic flow of the material and the results are validated and are very close victim to each other.
- Results obtained by finite element analysis closely related to experiment results. The values are thus validated by the FEM model.

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