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Compressive Strength Prediction of Aa7075/ Sic/Fly Ash/Graphite -Hybrid Metal Matrix Composite

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Abstract: The demand for light weight material with superior strength ,lead to many new inventions in the field of metal matrix composites. This need of composite materials are growing at faster rate in almost all Mechanical engineering applications. Components made with Aluminium metal matrix composites (AMMC) are found to be the best replacement for massive metal components and machine parts in various applications. In this context an aluminium composite designated as AA7075 has been taken for the present Investigation. AA7075 has high strength and high corrosion resistance, which has an extensive applications in Air craft, Automotive heat exchangers and widely utilized in Protective cladding due to its excellence corrosion property.

The present work is intended at the determination of compression characteristics of AA7075 metal matrix composite by means of traditional analytical method and finite element method as well as. This began with the synthesis of composite material, which includes the reinforcement of alloying elements namely Silicon carbide, fly ash and graphite particulates together in the ratio of 6, 9 and 12 % by weight, with an increment of 1% each every time to pure AA7075 metal. This is accomplished by means of vortex method under stir casting route. Two standard sized specimen (H/D Ratio as 1 and 1.5) are fabricated from each of the 3 different compositions mentioned , along with the pure AA7075. The specimen were investigated for the compressive strength and strain behavior by means of Universal testing machine (INSTRON) under no friction condition. The plastic behavior of the specimen were studied as function of various stresses and the same were validated by results obtained from finite element analysis and found to be in good concurrent.

Keywords: Compression, AA7075, Metal Matrix, Reinforcements, Hydro static stress.

I. INTRODUCTION

The use of Aluminium Alloys in structural applications do not have a long tradition despite the fact that their elastic and yield limits may be grater compared to those exhibited by ordinary structural steel elements. They may be potentially considered as significant material for various machine components and structures due to the following favorable properties.

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(i)As alloys are corrosion resistant, reduces maintenance cost and ensures compliance with requirements in corrosion-prone environment.
(ii) Less weight would reduce the inertia forces of various moving machine parts.
(iii)Resistance to brittle fracture (In low temperature range) small susceptibility to temperature gradient and residual stress.
(iv)Easily undergo various metal forming processes due to good ductile nature.

Since composites are most promising materials of recent interest, many studies have been made by researchers for the past years and focused more on Metal matrix composites (MMCs), due to their potential advantages over conventional monolithic alloys are being appreciated. Strengthening of metal matrix composites have a diverse demand profile, which is usually determined by production and processing and by the matrix system of the composite material. The demands like low density, mechanical compatibility, thermal stability, high compression and tensile strength, good process ability and economic efficiency are generally appreciable.

Metal forming process has become increasingly important in almost all manufacturing industries. In large group of manufacturing processes, plastic deformation is utilized to change the shape of the metal work pieces, during these processes compressive stresses setup would play the vital role. The famous processes include Rolling, Forging and Extrusion. Hence the compressive stress developed along with its relevant parameters would judge the plastic behaviour of metal.

II. LITERATURE

Wei Wei ,Wei Zhang, Kun XiaWei , Yi Zhong, Gang Cheng, Jing Hu [1] presents the deformation behavior of the pure copper rod in the continuous ECAP process is analyzed by using DEFORM-2D. The effect of die angle and the friction between the die channels and the specimen on the stress and strain distribution, strain homogeneity, the feature of shear deformation and the torque was investigated. **M. Gopi Krishna, K. Praveen Kumar J. Babu Rao , NRMR Bhargava , K. VijayaBhaskar[2]** reported that, the deformation behaviour of a hybrid matrix A2024 aluminium composite alloy, reinforced with silicon carbide, and fly ash. Here the Circumferential stress component σ_θ increased with tensile nature as deformation continues. On the other hand the axial stress σ_Z increased at the initial stages of deformation, but started becoming less compressive immediately as barrelling starts.**J Babu Rao, D Venkata Rao, I Narasimha Murthy and NRMR Bhargava[3] I**nvestigation, AA 2024 alloy 2 to 10 wt% fly ash composites were made by stir casting route. Identification of Phase and structural characterization was carried out on fly ash by X-ray diffraction studies.Scanning electron microscopy and optical microscopy was used for microstructure analysis. An increased amount of fly ash causes the density of the composites to decrease and the hardness leads to high values. The increase in compression strength was noticed with the increase in quantity of fly ash. **Uppada Rama Kanth, Putti Srinivasa Rao, MallarapuGopiKrishna [4-6]** reports that Al-Zn/fly ash/SiC reinforced composites are fabricated through vortex method using stir casting route. This includes the micro structural evaluation and the study of mechanical behaviour of aluminium-zinc alloy reinforced with fly ash and silicon carbide (SiC). This revealed that presence of fly ash particles in matrix enhanced the hardness and tensile properties like ultimate tensile and yield strengths were improved by the addition of SiC particles and also discussed the wear and corrosion properties.**J. Babu Rao, Syed Kamaluddin and N.R.M.R. Bhargava [7]** investigated the new method of optical strain measurement (Machine vision system) was proposed for the analysis of flow behaviour of pure aluminium as a function of friction, aspect ratio and specimen geometry. video images of square grid were captured during the deformation process, till the initiation of the crack is noticed. The distortions of grid from recorded images were analyzed by offline method. Further a Finite element analysis has been carried out for the the upset forming process by ANSYS**. S Madhusudan, M.M.M.Sarcar, K Sunil RatnaKumar[8]** reported the deformation (cold upsetting) studies being carried out, and behaviour is studied using PC based logging system. Failure of the billet before 50% deformation has been observed for higher concentration of reinforcement composites. Comparative study has been made with the alloy having like composition.

III. EXPERIMENTATION

The ingots of AA7075 alloy raw materials are procured from the Indira Casting Company , Mumbai,. The Alloy AA7075 matrix is reinforced with hard ceramics like silicon carbide, fly ash and graphite in the grain size of 40 micro metre. The quad metal matrix were prepared using stir casting method as shown in Fig1.1. The quantities of reinforcements all together were taken by weight percentage, as 6, 9 and 12 with respect to the weight of AA7075. The reinforcement started with initially 2% each and every time with an increment of 1% each. The cylindrical samples were casted using cast iron dies as shown in Fig 1.2. The castings are further subjected to fabrication by means of CNC Lathe machine. The compression samples are prepared in to two types, with aspect ratios (H/D ratio) as 1 and 1.5 respectively, for base alloy 7075 and as well as for different reinforcement (6, 9 and 12) of composites.

The deformation or homogenous compression test was carried out on a computer controlled universal testing machine (INSTRON) at the speed of 0.25mm/sec and to a maximum load of 100KN, for all the specimen mentioned with H/D ratio 1.0 and 1.5, as shown in Fig 1.3., The compression test was continued on the machine, either up to the 50 percentage of deformation or till the fracture initiated on the surface of the sample, whichever is observed first in the experiment. The test was carried out under no friction condition between the sample and the contacting surfaces. At the beginning of the deformation, axial stresses are increased and found decreased with upsetting of the specimen. Circumferential and hydrostatic stresses were found high for all specimen with lower aspect ratio compared to high aspect ratio samples. There are different parameters to be considered in the compression test , mainly temperature, pressure and speed. The ideal form of specimen after compression, mainly depends on aspect ratio (Height/Diameter).The following modes usually takes place with respect to the aspect ratio.(a) Buckling takes place when H/D >5, (b)Shearing takes place when H/D >2.5, (c) Double barrelling takes place when H/D>2.0 , with the presence of friction contact.(d). Barrelling when H/D <2.0, with the presence of friction contact,(e). Uniform compression takes place when H/D <2.0 with no longer friction contact of surfaces. The load and displacement data is being generated by the universal testing machine was recorded, which is obtained in the form of MS office XL file. This data is very essential for analyzing the plastic behaviour of the Specimen by the method of analytical equations.

Fig 1.1 stir casting set up

Fig 1.2 Fabricated Cylindrical samples

Fig 1.3 UTM (Instron)

IV. AANALYSIS ON AA7075 ALLOY AND COMPOSITES

The deformation analysis was carried out on samples of pure AA7075 alloy and samples with 6%,9% and 12% reinforcement composites ,with the mentioned aspect ratios of H/D 1.0 and 1.5. The diameter of the samples were taken as 20mm and the heights as 20mm and 30mm respectively to suit the aspect ratios.

The specimen of two different aspect ratios are shown in Fig 1.4 .The change in physical dimensions can be observed , before and after the compression test.

Fig 1.4 Specimen before and After Compression Test

The true stress and true stain values were calculated for each and every data point being generated by the universal testing machine in the form of MS office XL file, before obtaining the stress strain values from the traditional formulae. During the compression test , the free lateral surface barrels and fractures the form at the barrel level. The barrelled surface results in the development of tensile stress in the circumferential direction and decrease in the magnitude of the axial stress, below the average compressive stress value of the material. In case of severe barrelling the axial stress may also become tensile. By means of cylinder height to diameter ratios and contacting surface friction conditions, the severity of the barrel curvature can be controlled. Thus a variety of stress and strain states can be generated in the equatorial region of the upset cylinders, providing a convenient test for deformation and fracture studies as shown in Fig 1.5.It is assumed that throughout the test, the principle axes of stress and strain increments coincide. the shear stress values are zero on the free surface of the sample. The detailed calculations are presented below for compression test.

H0 = is the initial height of the sample, D0 = is the initial diameter of the sample.

H_f= is the final height of the sample, Df= is the final diameter of the sample

Hi = is the instantaneous height of the sample = H0-ΔH (Where ΔH is the change in height found for every load and displacement data point)

D_i= is the instantaneous diameter of the sample = $D0\sqrt{\frac{H0}{Hi}}$

True strain in axial direction $\epsilon_Z = \ln\left(\frac{Hi}{H0}\right)$

True stress = Compressive stress*(1-Compressive strain)

True strain in circumferential direction $\epsilon_{\emptyset} = \ln\left(\frac{Di}{D0}\right)$

The plastic behaviour of the base alloy AA7075 and reinforced composites are found by knowing the different stress developed on the samples under loading condition. The hydro static stress plays an important role to estimate the plastic properties of the material, can be calculated as the algebraic sum of axial, circumferential and radial stresses respectively. The true stress and true strain data was well fitted into the Hollow Man power law of equation for determination of deformed properties of the material, as given in below.

$$\sigma f = K \in^{n}$$

Where " K " represents the strength co efficient and " n" represents the strain hardening exponent. The values of K and n are obtained for the samples of AA7075 base material and as well as for reinforced composites, with the aspect ratios of 1.0 and 1.5.The Hydrostatic stress (σ_h) can be obtained from the following expression.

The Hydro static Stress, $\sigma_h = \frac{\sigma_z+\sigma_\theta+\sigma_r}{3}$

Where $\sigma_z, \sigma_\theta, and\ \sigma_r$ denotes the axial, circumferential and radial stress respectively, along the orthogonal reference axis of compression test.

Axial Stress $\sigma_z = \sigma f\,[\{1-(\frac{1+2\propto}{2+\propto}) + (\frac{1+2\propto}{2+\propto})\}^{2}]^{-1/2}$, here ∝ is the slope between axial strain and circumferential strain and σf is the flow stress of the material.

The circumferential stress $\sigma_\theta = \sigma_z\,[(\frac{1+2\propto}{2+\propto})]$ and the radial stress is zero on the free surface of the material.

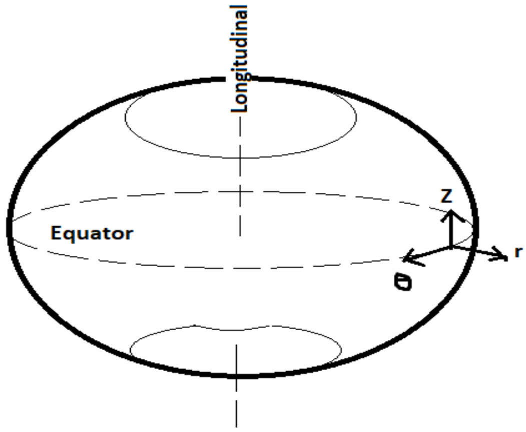

Fig 1.5 Orthogonal Reference axis

V. RESULTS AND DISCUSSIONS

The deformation in axial and circumferential direction was found for base AA7075 and reinforced composites for aspect ratios 1.0 and 1.5 respectively.

The deformation was found maximum, along height and diameter as well, for 9% of reinforced composite compared to pure AA7075 and other composites for aspect ratio 1.0 as shown in Fig 1.6.

Similarly the maximum deformation was observed in sample with 12% of reinforced composite, compared to other composition samples of H/D ratio 1.5, which is shown in Fig 1.7

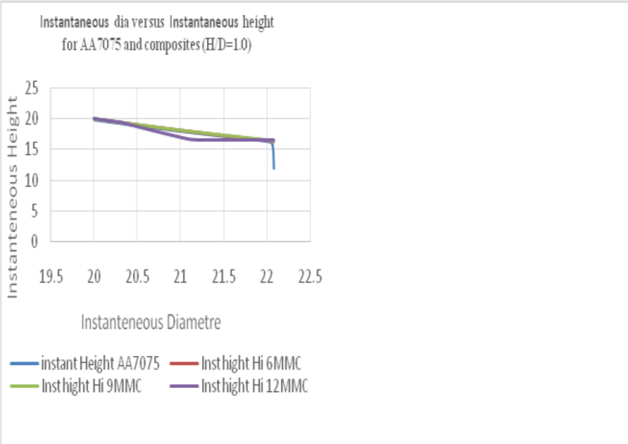

Fig 1.6 Instantaneous diameter versus height for AA7075 and composites (H/D=1.0)

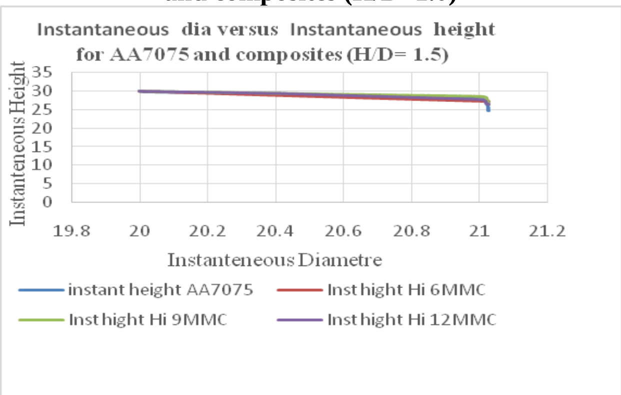

Fig 1.7 Instantaneous diameter versus height for AA7075 and composites (H/D=1.5)

The strength coefficient (K) and strain hardening component (n) are found good for the 9% and 12% of reinforced composites, which indicates the good plastic behaviour compared to base AA7075 and other composites with H/D ratio 1.0, where as good plastic behaviour is being exhibited by the sample of 6% reinforcement, of H/D ratio 1.5 . The Figures 1.8 and 1.9 shows the k and n values are increased with increasing of reinforcement content for H/D ratio 1.0 and H/D ratio 1.5.

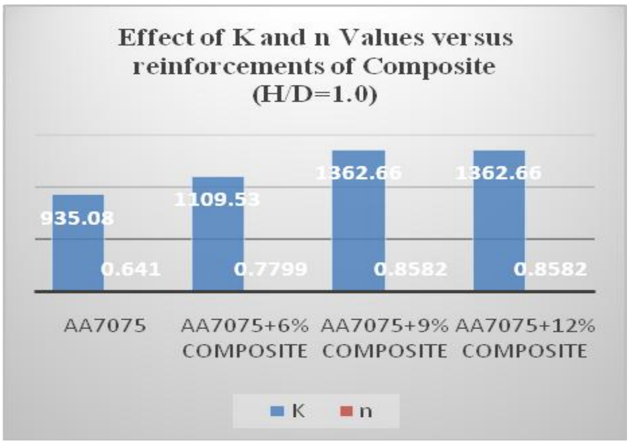

Fig 1.8 Effect of K and n Values versus reinforcements of Composite (H/D=1.0)

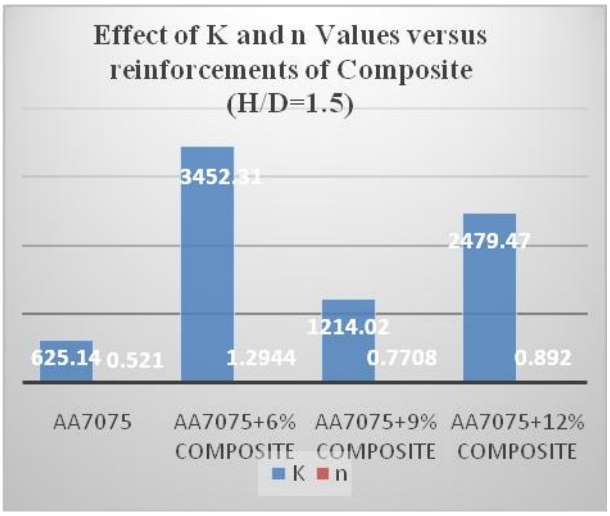

Fig 1.9 Effect of K and n Values versus reinforcements of Composite (H/D=1.5)

In figures 1.8, 1.9 the values adjacent to k –values are representing strain hardening values (n).

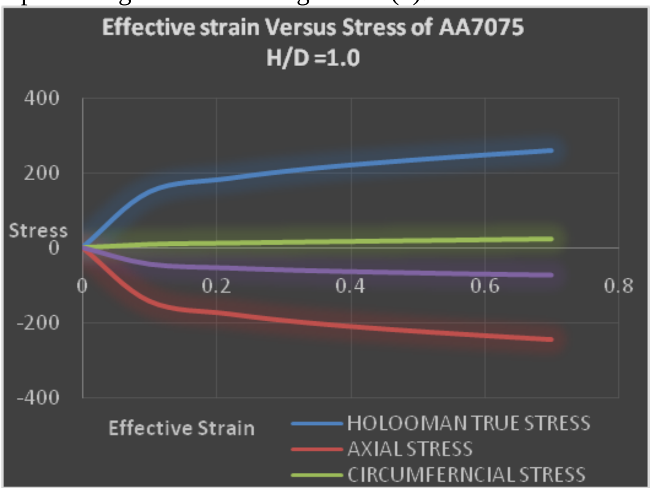

Fig 1.10 Effective strain Versus Stress of AA7075 with H/D =1.0

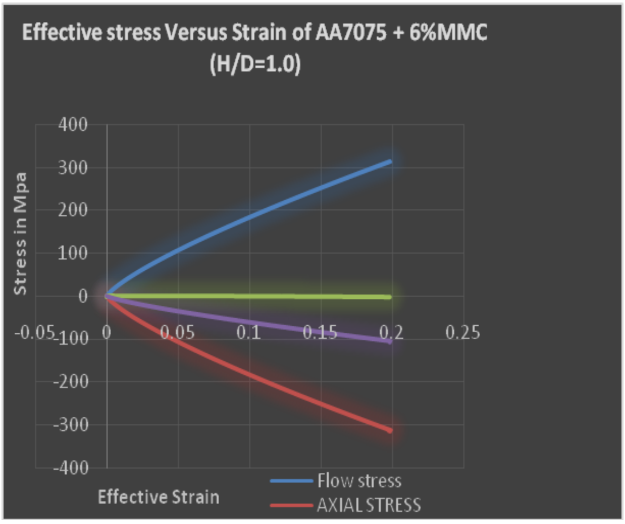

Fig 1.11 Effective Stress Versus strain of AA7075+ 6% MMC (H/D=1.0)

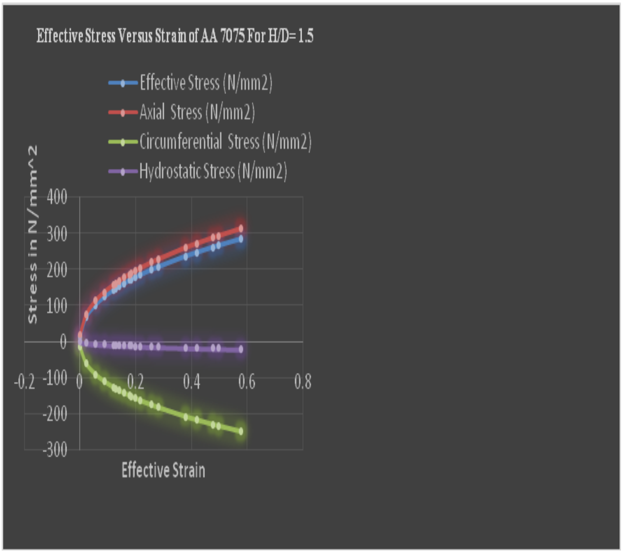

Fig 1.12 Effective strain Versus Stress of AA7075 (H/D=1.5)

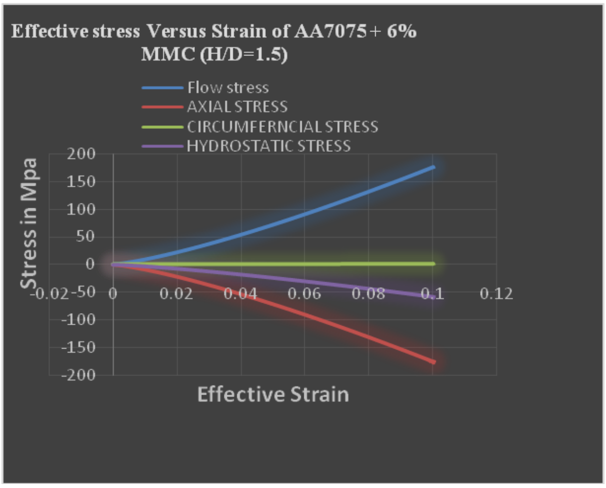

Fig 1.13 Effective strain Versus Stress of AA7075 + 6%MMC (H/D=1.5)

Table 1.1 : Effective strain Versus Stress of AA7075 and Composites for H/D=1.0 and H/D=1.5

Compo site	Geometrical shape	Max Flow strain	Max Flow stress	Max Axial Stress	Max Circumferential Stress	Hydro Static Stress
AA7075 6%	H/D=1.0	0.198	336.22	-337.7	-3.02	-111.56
	H/D=1.5	0.099	174.99	-174.59	-0.79	-57.93
AA7075 9%	H/D=1.0	0.20564	350.6758	-349.03	-3.2689	-117.433
	H/D=1.5	0.12801	248.9485	-248.22	-1.444	-82.2594
AA7075 12%	H/D=1.0	0.19472	390.55	-388.81	-3.44	-130.75
	H/D=1.5	0.1255	389.379	-388.26	-2.21	-128.68
AA7075 Pure form	H/D=1.0	0.175	280.21	-300.6	-2.24	-120.65
	HD=1.5	0.099	174.99	-174.59	-0.79	-65.93

The Fig 1.10 to Fig 1.13 shows the graph drawn between effective strain on x- axis and axial, circumferential, flow and hydrostatic stresses are taken along Y-axis for different aspect ratios of base alloy and reinforced composites. The Table 1.1 represents the Effective stresses Versus Strain of AA7075 and Composites for H/D values of 1.0 & 1.5.

VI. CONCLUSIONS

(1).The quad metal matrix composite was prepared successfully using stir casting route for AA7075 reinforced with silicon carbide, fly ash and graphite particles under vortex method.
(2).cylindrical samples of different aspect ratios as H/D= 1.0 and H/D= 1.5 are fabricated successfully using CNC machine, for base AA7075 and reinforced composites.
(3).The compression tests have been carried out by computer controlled universal testing machine, the load and displacement data generated is utilised for analysing the material properties of deformed samples
(4). The results are found by the fracture theory equations and discussed.
(5). The strength coefficient (K) and the strain hardening exponent (n) are found increased with the increased content of reinforcement.
(6). The axial stress are found high initially, that is at the beginning of the deformation and reduced gradually as the fracture initiates. The hydro static stresses are observed high for the samples with lower aspect ratio, compared to the higher aspect ratio samples of pure AA7075 and its reinforced composites.

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