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EVALUATION OF COLD FORGING CHARACTERISTICS OF AL/10^{-11} SI METAL MATRIX COMPOSITES USING ANSYS 14.5

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Abstract

In this study, the mechanical properties of aluminum alloys with a 10%, 20% and 30% of differing weight percentage of nano-silicon composite has been analyzed. The aluminum alloy is the parent metal and nano-silicon are added with aluminum in the ratio of 10%, 20%, and 30%. In this present study, during the cold forging process, the simulation mechanism like ANSYS 14.5 is utilized to evaluate the impact of nano-silicon with aluminum on distortion characteristics like damage, effective strain rate and effective stress and the values have been predicted. The predicted values have been compared with the experimental findings. As a result, there has been an improvement in the damage, effective strain and stress when a rise in the weight percentage of Al/10^{-11} Si.

Keyword Head: Damage, Effective strain rate, Effective stress, ANSYS 14.5, Aluminium, Nano-silicon.

1. Introduction

Metal matrix composites were widely utilized in industries like automobiles, aircraft, and spacecraft. Because MMC possesses higher strength, higher specific stiffness, lower coefficient of thermal expansion, higher thermal conductivity, and high-temperature capability [1]. In this study, the forging parameters are optimized and measured by conducting experiments with the help of forging qualities. The predicted forging characteristics will decrease the time, and resources related to conducting experiments. The forging process of MMC was stimulated by utilizing a finite element method with the help of the stimulation process like ANSYS 14.5 [2-3].

Hillol Joardar et al [4] examined distortion characteristics of consistent cylinders of an Al alloy metal matrix composite (MMC) experiencing longitudinal compression in a UTM in accordance with dry conditions. In this study, the stir casting method was utilized to prepare the composite from LM6 aluminium alloy utilizing a particle of silicon carbide as reinforcement. The impact of % wt of SiC on hardness, microstructure, and disturbing load is analyzed. The experimental findings are eventually contrasted with the results obtained by utilizing FEM simulation. H.M.T. Khaleed et al [5] have investigated the stress distribution and the deformation of the work material in the die. They have considered AISI 1045 steel as work material and die steel (AISI D2) as die material. FEA analysis was performed on three types of work-piece geometries. Furthermore, the aspect ratios of work-piece for the cup-shaped article were optimized to attain minimum flash volume with no under filling. Chandrasekhar. P et al., [6] performed forging experiments on an alloy of LM6 aluminium and particles of SiC. The metal matrix composites were prepared with the help of a liquid stir casting procedure. Both upper bound hypothetical and experimental analyses have been prepared in accordance with the barrelling of preform vertical sides, composite interface among the friction law, and the impact of die velocity on a variety of distortion properties like energy dissipations, height reduction and forging load. Kamakoshi et al [7] stated that the powder metallurgy materials are used to make the automobile components and they have investigated and simulated the characteristics of Mo-alloyed sintered steel during the cold-forging method by FEM ie finite element method. Singh, S., et al [8] examined the distortion properties of SiCp AMC at cold conditions during the open-die forging process. The material was manufactured by the liquid stir casting technique where heated particles of SiC were blended with liquid LM6 aluminium casting alloy and molded into the silicone mould. Both experimental and upper bound hypothetical analyses were conducted supported by the finite element method with the help of DEFORM. Cristina Maria et al [9] established a prototype to simulate the ring compression test and upsetting operation. Upsetting experiments were conducted on automobile starter components and they observed the forming force, the material flow throughout a simulated phase, and the stress-strain material curve.

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The simulated results were compared with simulated results and the results corroborate each other, and the developed model was suitable to simulate the forging operation. Morokuma, Yuki, et al., [10] examined the impact of sintering time on the densification characteristics and plastic distortion during the cold-forging process. A cold forging process of Mo-alloyed sintered steel was modeled by a FEM analysis in accordance with the density difference in the process. From the experimental results, it was observed that there is large local distortion and consequently the extreme metal element expands with rising sintering time even though the variation in the actual stress-exact strain illustrations is insignificant. Ayer [11] conducted forming experiments on an alloy of copper and aluminium, and the deformation loads were predicted when the discs were formed using DEFORM- 3D and Artificial Neural Network. The results were compared with experimental results, and both the results have good agreement with each other. Height to diameter ratio, displacement of the punch and forming percentage of samples were all considered as parameters in this investigation. L.Ceschini et al., [12] evaluated the impact of the hot forging process on the tensile and microstructure characteristics of an MMC based on the Al alloys AA2618 strengthened with 20 vol.% of particles of alumina (Al2O3p). SEM analyses of the fracture surfaces of the flexible samples demonstrated significantly comparable to the morphological characteristics for the forged and as-cast composites, both at high and room temperature. The method of damage was primarily decohesion at the matrix–particle interface. Hanamantraygouda et al [13] examined the impact of cold forging on the mechanical characteristics of Al-SiC composite material at various weight percentages of SiC in aluminium. Different characteristics like effective strain, stress, damage, and velocity, were calculated with the help of DEFORM-3D and they noted that the highest effective stress, velocity, damage, strain reduction at 60% of forging cycle with 6 % of SiC with aluminium. Wu, Kun, et al.,[14] prepared 10% volume SiCp/AZ91 magnesium matrix composites with the help of a stir casting technique. The results demonstrated that the particles were polished throughout forging. The particle refinement and consistent grain distribution triggered an evident rise in the work strengthening rate in the as-extruded composite while in a tensile distortion at ambient temperature. From the literature, it was discovered that no sufficient study was performed on the Al/10^{-11} Si metal matrix.

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In this study, an effort has been carried out to assess the impact of differing weight percentage of nano-silicon with aluminium alloy on the mechanical properties. The experimental findings have been compared with the simulation results.

2. Experimental Method

2.1 Materials and Method

The composite for this research was made from Al alloy utilizing a particle of nano-silicon as reinforcement. Initially, the Al alloy was molten in a resistance oven and then 3 wt% of Mg has been added to the liquid metal. This was due to the fact that magnesium is well-known to favor the establishment of a powerful adhesion among the reinforcing particles and the matrix by reducing the wetting angle (surface energy). A Supplement of pure magnesium also improves the flexibility of melted aluminium. Heated nano-silicon particles at 900˚C - 950˚C of temperature in differing weight fractions (10 wt% - 30 wt%) was then adding it to the melted liquid and the mixture was instinctively stimulated at an 850^{o}C temperature by an impeller at a stirring rate for approximately 500 rpm - 600 rpm. The melted liquid was drenched at an 845^{o}Ctemperature into nano-silicon silt moulds for the preparedness of the test experiments. Table 1 lists a composition of Al alloy.

Table 1: Chemical composition

Components	Fe	Cu	Mg	Si	Mn	Ni	Zn	Pb	Ti	Al	Sb
%	11-14	0.2	0.2	0.7	0.6	0.2	0.2	0.2	0.3	Remaining	0.06

Specimens of aluminium alloy and nano-silicon metal matrix composite have been fabricated to examine the cold forging qualities with the help of ANSYS 14.5. A 10%, 20% and 30% of the weight percentage of nano-silicon has been added with aluminium alloy and three samples were made respectively.

2.2 Finite Element Modelling

Finite element modeling of the cold forging process in accordance with the lubricated condition has been performed by utilizing the simulation process like ANSYS 14.5. The Lagrangian formulation was used. The frictional coefficient necessary for the modeling was

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achieved from the ring compression test. The workpiece with a diameter of 200mm and a height of 230mm was prepared. The material constitutive equation was adopted as:

$$\sigma = K\varepsilon^{n} \qquad (1)$$

Where n is the strain hardening index, σ is the effective stress, ε is the effective strain, K is the stress coefficient, K and n were both decided from compression tests. In this research, mesh distribution in the FEM technique has a great significance not only for susceptible FEM findings but additionally to save computation time and the information storage space. Due to this purpose, optimal mesh distribution has been applied to the model. The ambient temperature was chosen as room temperature for the more realistic experiments and punch velocity has been defined as 5 mm/sec. Fundamentals Conventions in this FEA Analysis: shear friction factor: 0.06, Node, relative mesh type (dies): 35000, relative mesh type (work): 35000, workpiece material, work material type: plastic, isotropic, tool material: carbide insert, coolant utilized, atmosphere temperature, convection coefficient: 0.02 W/m2K, heat transfer coefficient, number of modeling steps, step increment to save 25. In the material selection, three types of flow stress are defined with respect to the addition of 10%, 20% and 30% Nano-silicon with Aluminium respectively.

3. Results and Discussions

The simulated values after forging aluminium with 10%, 20%, 30% of nano-silicon at a 0.1MN, 0.2MN and 0.3MN of loads have been compared with the experimental findings. During the modeling, Lagrangian step-by-step type is utilized, and in step controls, a preliminary step has been allocated as 1, increment: 1 step, and the overall number of steps: 75. Here, the workpiece is considered as a slave and for both dies. This analysis is comprised of post-processor, simulation, and preprocessor. After the database generation, the simulation began, all the inputs and assumptions are specified in the pre-processor,

The outputs are detected in the post-processor. The post-processor contains a simulation engine that will save the findings of all steps. The entire forging process modeling is conducted in 75 steps. Figure 1(a-d), Figure 2(a-d) and Figure 3(a-d), demonstrate the effective stress, strain damage and tool velocity identified throughout forging simulation of three specimens, where it is noted that the extreme effective stress is detected for the specimen of 30% nano-silicon with aluminium. It is noted that the effective stress value increases when there is an improvement in the percentage content of nano-silicon with aluminium alloy. The effective stress of Al–10wt%10^{-11} Si, and Al–20wt%10^{-11} Si and Al-30wt%10^{-11} Si composites are 80 Mpa, 70 Mpa and 75 Mpa respectively. The effective strain detected for Al–10wt%10^{-11} Si, and Al–20wt%10^{-11} Si and Al–30wt%10^{-11} Si composites are 0.40, 0.27 and 0.37 respectively. By adding 30wt% of 10^{-11} Si with aluminium, the effective strain is increased which may be due to decrease of the ductility. It is observed that, maximum strain is seen towards the outer portion of the sample. Further, it is observed that, the effective strain reduces when adding the 20%wt10^{-11} Si with aluminium. The maximum damage is observed in the middle portion of the sample which is about 0.067, 0.050 and 0.042 for Al–10wt%10^{-11} Si, and Al–20wt%10^{-11} Si and Al–30wt%10^{-11} Si composites respectively. The cracks are initiated and propagated which causes damage. Further, it is observed that the deformation load governs the velocity of the particle in the forging. The outer regions are subjected to higher velocity than inner regions. In Figures 1 to 3, the blue colors show low velocity and red colours shows the highest velocity at the outer surface. By adding a weight percentage of nano-silicon, the velocity of the particle slightly increases, therefore it is observed that the effective stress and strain are high for aluminium with 30%10^{-11} Si. The velocity of the particle is very low inside samples as there is a bond between the two different atoms.

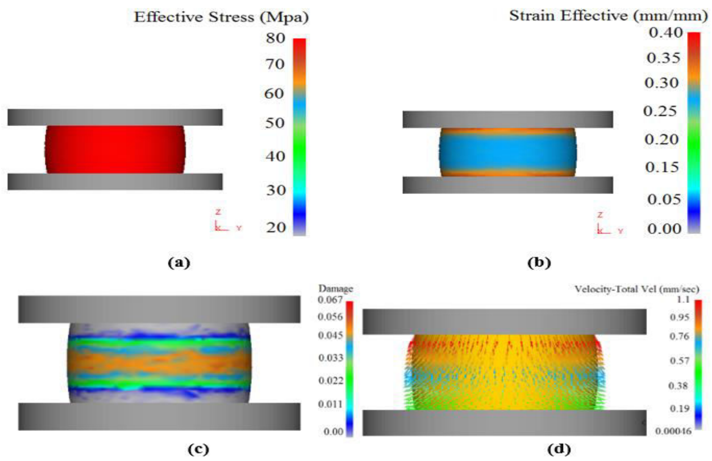

Figure 1 (a) Effective Stress, (b) Effective strain, (c) Damage and (d) Velocity Along deformation at load 0.02MN for Al & 30% 10^{-11} Si.

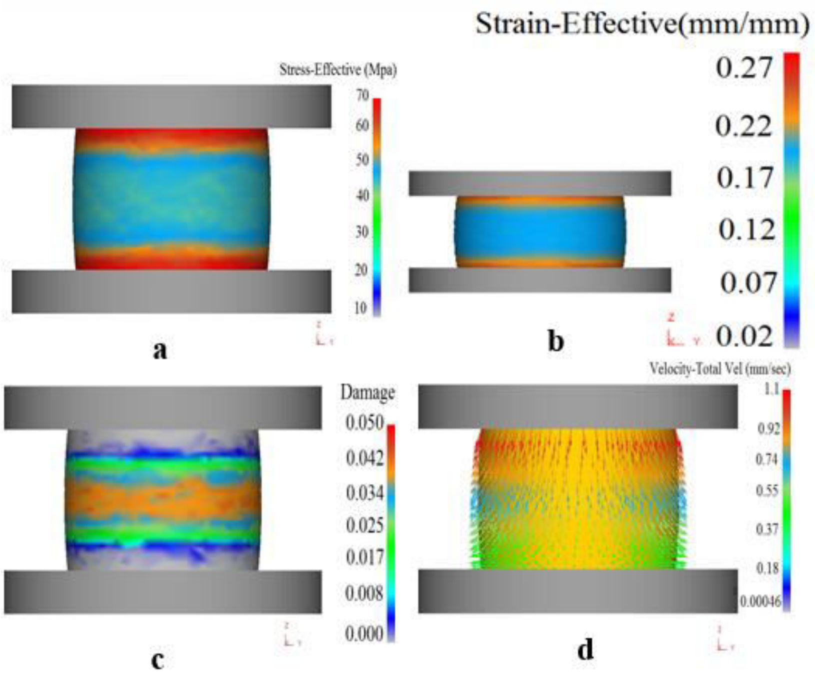

Figure 2 (a) Effective Stress,(b) Effective strain, (c) Damage at load 0.02MN for Al & 20% 10^{-11} Si

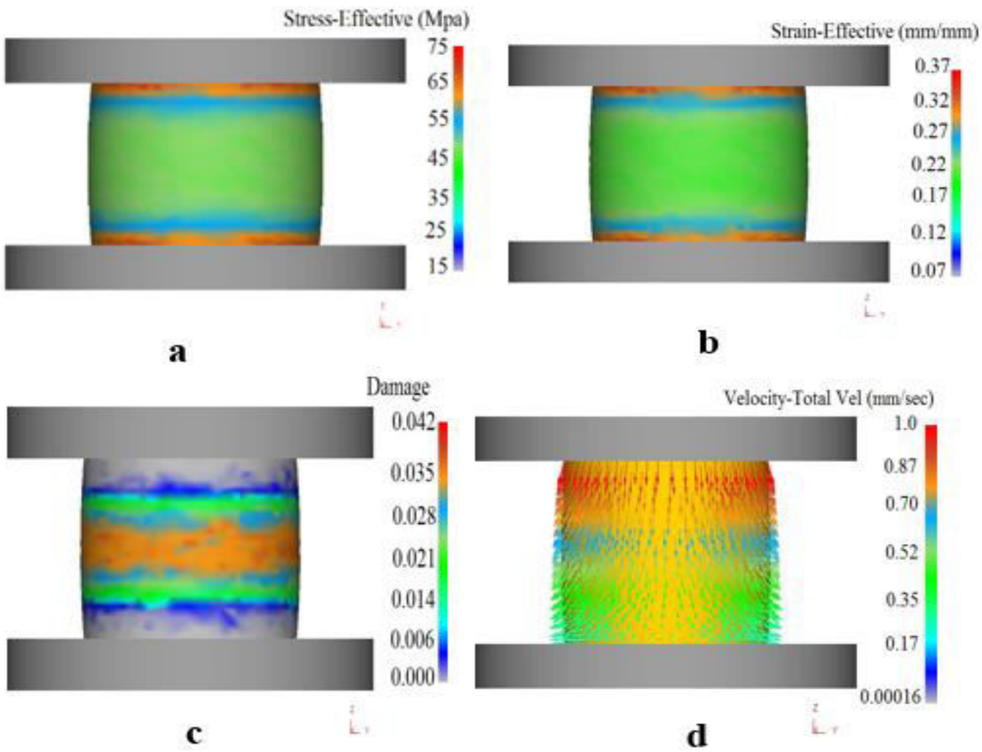

Figure 3 (a-d) (a) Effective Stress,(b) Effective strain, (c) Damage , (d) Velocity -Tool at load 0.02MN for Al & 10% 10^{-11} Si

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4. Conclusion

Evaluation of cold forging of aluminium with a 0%, 20% and 30% of weight percentage were conducted to assess the effective strain, stress, velocity and damage of tool. The following findings have been examined.

- The effective strain, stress, velocity and damage of the tool were all improved by adding 30wt%10^{-11} Si.
- When the velocity of the particulate matter is high at the external surface of the specimens, the effective strain, stress, and damage are also high.

References

[1] Lee, Hyo S., et al. "The fabrication process and mechanical properties of SiCp/Al–Si metal matrix composites for automobile air-conditioner compressor pistons." Journal of Materials Processing Technology 113.1-3 (2001): 202-208.

[2] Cavaliere, P., and E. Evangelista. "Isothermal forging of metal matrix composites: Recrystallization behaviour by means of deformation efficiency." Composites Science and Technology 66.2 (2006): 357-362.

[3] Shabani, Mohammadmehdi, et al. "Microstructural and sliding wear behavior of SiC-particle reinforced copper matrix composites fabricated by sintering and sinter-forging processes." Journal of Materials Research and Technology 5.1 (2016): 5-12.

[4] Joardar, Hillol, Goutam Sutradhar, and Nitai Sundar Das. "FEM simulation and experimental validation of cold forging behavior of LM6 base metal matrix composites." Journal of Minerals and Materials Characterization and Engineering 11.10 (2012): 989-994.

[5] H.M.T. Khaleed, M.F.Addas, M.A.Mujeebu, Abdullah A. Al-Rashed, Irfan Anjum Badruddin, G.A. Quadir, Salman Ahmed N.J, T.M. Yunus khan, Sarfaraz Kamangar, Flash-less Cold Forging of Cup-shaped Object and Stress Analysis of Forging Die using FEM Simulation and Experiment, Australian Journal of Basic and Applied Sciences, 8,24,2014, 401-410.

[6] Chandrasekhar, P., Sudipta Chand, and Saranjit Singh. "Investigation of dynamic effects during cold upset-forging of Silicon Carbide particulate reinforced Aluminium metal matrix composite preforms." Materials Today: Proceedings 5.9 (2018): 20201-20209.

[7] Y Kamakoshi1, S Nishida, K Kanbe and I Shohji, Finite element method analysis of cold forging for deformation and densification of Mo alloyed sintered steel, IOP Conf. Series: Materials Science and Engineering 257, 2017.

[8] Singh, S., et al. "Investigations into Deformation Characteristics during Open-Die Forging of SiCp Reinforced Aluminium Metal Matrix Composites."

[9] Cristina Maria Oliveira Lima Roque Sérgio Tonini Button,Application of the Finite Element Method In Cold Forging Processes, J. of the Braz. Soc. Mechanical Sciences, Vol. XXII, No 2, pp. 189-202, 2000.

[10] Morokuma, Yuki, et al. "Plastic Deformation Simulation of Sintered Ferrous Material in Cold-Forging Process." Materials Science Forum. Vol. 941. Trans Tech Publications Ltd, 2018.

[11] Numericka analiza, za.predvidanje, nastalog, opterecenja, I eksperimentalna, provjera sabijanja, bimetalnog, diska, A Numerical study for prediction of forming load and experimental verification of bimetallic disc upsetting, doi.org/10.17559/TV-20160130154750.

[12] Ceschini, L., G. Minak, and A. Morri. "Forging of the AA2618/20 vol.% Al2O3p composite: Effects on microstructure and tensile properties." Composites Science and Technology 69.11-12 (2009): 1783-1789.

[13] Hanamantraygouda.M.B, Dr.B.P.Shivakumar, S B Halesh,P N Siddappa, Chethan D, Prashant.S.H, Numerical Analysis of Cold Forging Effect on Mechanical Properties of Al/Sic Metal Matrix Composites, Journal of Mechanical and Civil Engineering,14, 1, 2017, PP 26-35.

[14] Wu, Kun, et al. "Microstructure and mechanical properties of SiCp/AZ91 composite

deformed through a combination of forging and extrusion process." Materials & Design 31.8 (2010): 3929-3932.