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Study and Comparison of Surface Roughness between Experimental and Analytical Data of Forged Al-Tib_2 Composite

Hemavathy.S[1], C.N.Chandrappa[2], Swathi M B[3], Shaila d Hosmani[4]

Research Scholar, Department of Mechancial Engineering, M.S.Ramaiah Institute of Technology, Bangalore, Karnataka, India.[1]

Professor & Head, Department of Mechanical Engineering, Acharya Institute of Technology, Bangalore, Karnataka, India.[2]

Assistant Professor, Department of Mechanical Engineering, Acharya Institute of Technology, Bangalore, Karnataka, India.[3]

Associate Professor, Department of Mechanical Engineering, R R Institute of Technology, Bangalore, Karnataka, India.[4]

ABSTRACT: Aluminium composites are very rapidly replacing engineering metals and alloys because of its lightweight and high strength in Aerospace and Bio-medical applications etc. In the present work Al-TiB_2 composite is fabricated by In-situ technique. The intensive study and comparison of surface roughness of Aluminium TiB_2 composite is carried out. The material is subjected for turning operation to study the surface roughness.

This study focuses on developing an empirical model for prediction of surface roughness on forged, forged-heat treated composite. The working parameters considered in the model are, speed, feed, depth of cut, and tool nose radius. The test results show that the value of surface roughness is low at high cutting speed and comparatively high at low cutting speed. Surface roughness increases with increase in feed and depth of cut. However it decreases with increasing tool nose radius and surface roughness increases as wt. % of TiB2 increases in aluminium.

The value of surface roughness predicted this model compares verified/ with experimental results. Results so obtained from experimentation and statistical test results demonstrate that the model developed in this study have a satisfactory compatibility in both model construction and verification.

KEYWORDS: Al-TiB_2, composites, empirical model, surface roughness

I. INTRODUCTION

Many of the applications in the world today require materials with unusual combinations of properties that cannot be met by the conventional monolithic materials. This is especially true for materials that are needed for high technology areas such as jet engines, airframes, space shuttles, deep-sea submersibles, hypersonic spacecrafts etc. There is a need of materials having lightweight and high strength, offering a unique combination of properties and to find an extensive application in structural, aerospace and automotive industries. A new class of materials called "composite material" has ushered a new era in material development. Particulate reinforced Al-metal matrix composite is one of the important composites among the metal matrix composites, which have reinforcement particles in aluminum matrix, which are harder such as tungsten carbide, but they pose many problems in machining. The aluminum alloy reinforced with discontinuous reinforcements is rapidly replacing conventional materials in various automotive, aerospace and

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automobile industries [1]. But machining MMCs is one of the major problems, which limits the spectrum of engineering application [2].

From some early conventional turning tests on MMCs [3, 4], it is found that the tool wear is excessive and surface finish is very poor when carbide tip tools are used for machining. The hard reinforcement particles of MMC, which intermittently come in contact to the hard surface, are acting as small cutting edges like those of a grinding wheel on the cutting tool edge which in due course is worn out by abrasion and resulting in the formation of poor surface finish during turning [5].

Al-TiB_2 composite being a new material not much data is available on machining the same and it require to optimize the cutting parameters in order to have a good surface finish, which is one of the important criteria in aerospace application. Hence machinability study on this material has been carried out. Finally developing a mathematical model using data mining technique, which is commonly referred as nonlinear- regression analysis. The mathematical model is transformed to software, which can predict optimum cutting parameters for surface roughness and vice versa. Further actual machining has been carried out to ascertain the feasibility of predictor. Also the same procedure of developing a surface roughness model for Al-TiB_2 composite is carried out after the material is subjected to forging and forged-heat treatment processes and the results are compared among forged, forged-heat treated process.

II. EXPERIMENTAL RESULTS

The matrix alloy chosen for this work is A2024 Al-Cu-Mg alloy. It is one of the high strength alloys that render favorably heat treatment.

Reinforcement:

TiB_2 as reinforcement has been synthesized with chemicals by initiating an exothermic reaction.

Chemical Reactants:

Titanium boride was been synthesized in the matrix as reinforcement by addition of the reaction mixture into the molten matrix alloy.

The reactants used were;

(i) Titanium di oxide (TiO_2) particles
(ii) Cryolite ($Na_3 AlF_6$, i.e. Sodium hexafluro aluminates) particles
(iii) Potassium tetra fluoro borate (KBF_4)

Exothermic reaction takes place due to the heat in the alloy, with the formation of TiB_2.

2.2 Apparatus

Melting unit:-

The details of composite preparation and processing parameters are presented. The melting unit depicted in Fig.1 was an electric resistance-heating furnace of 4kw heating capacity, with a controller to monitor the temperature with in $\pm 2^0$ C accuracy. The furnace has a chromel - alumel thermocouple and digital indicator and is capable of melting 5kg of metal. The furnace can attain a maximum temperature 1200^0 C. The melt temperature was maintained at 810^0 C.

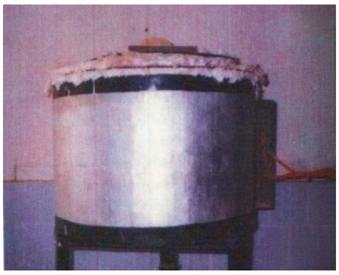

Fig.1 Melting Furnace

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Property measurements

Fig.2 shows, the software is developed by using visual basic programming language for predicting surface roughness for given cutting parameters and vice versa. Using the prediction models obtained by regression analysis both before and after the heat treatment, the models are utilized separately in the development of the software to get surface roughness predictor for each 'before heat treatment and after heat treatment' conditions.

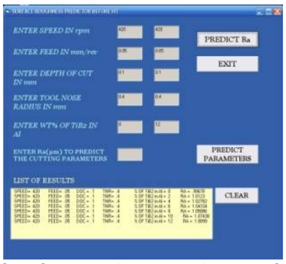

Fig.2 Window of surface roughness predictor software

III. RESULTS AND DISCUSSIONS

Composite materials with various weight percentages of TiB_2 were prepared as per the procedure given in previous chapter and subjected to different processing conditions. In this section, in-situ composites were subjected to machinability studies under as cast state, where surface roughness is determined experimentally and compared the same with the analytical results obtained by a computer program. Then this material is subjected to heat treatment and the surface roughness is determined experimentally and analytical method. In this section, the effect of cutting parameter like speed, feed, depth of cut and tool nose radius on surface roughness by prediction and experimental are presented and discussed.

Comparison of experimental and predicted Ra when cutting speed is varied

From the Fig 3,it is observed that the Ra values decreases as the speed increase as against predicted constant Ra value. The maximum error between experimental and the predicted surface roughness is 0.983µm and the maximum relative percentage error is 14.66.

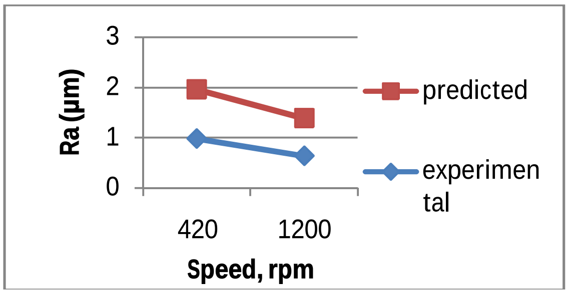

Fig.3 Comparison of experimental and predicted Ra when cuttingspeed is varied

Comparison of experimental and predicted Ra when cutting feed is varied

From the Fig.4, it is observed that the experimental and the predicted surface roughness are very close. The experimental and the predicted surface roughness increases as feed increases. It is observed that the maximum error between the experimental surface roughness and predicted surface roughness is 1.11µm and maximum relative percentage error is 11.71.

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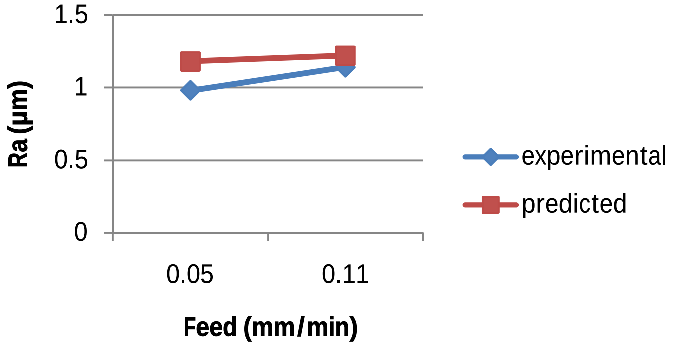

Fig. 4 Comparison of experimental and predicted Ra when cutting feed is varied

Comparison of experimental and predicted Ra when cutting depth of cut is varied

In the Fig.5, experimental surface roughness is less compared to predicted surface roughness. It is observed that the maximum error between the experimental surface roughness and predicted surface roughness is 0.983µm and maximum relative percentage error is 0.305.The variation in the figure shows that experimental and predicted values decreasing as depth of cut increases so it concludes that the mixing of TiB_2 particles and while turning operation the tool surface will be improper, in that case the variations occur.

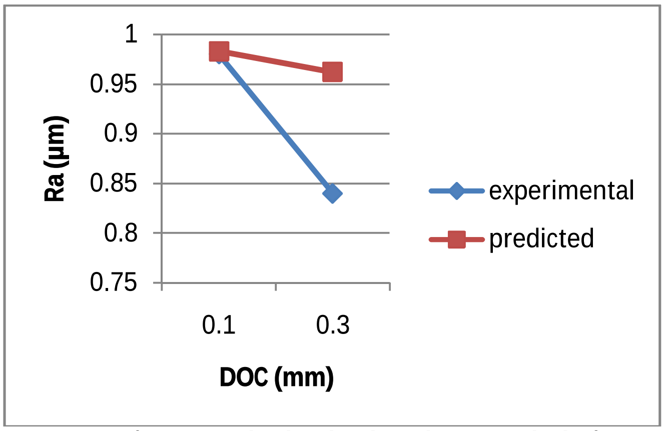

Fig. 5 Comparison of experimental and predicted Ra when cutting depth of cut is varied

Comparison of experimental and predicted Ra when cutting tool nose radius is varied

From Fig.6, it can be considered that the experimental surface roughness decreases as the tool nose radius increases as against predicted surface roughness. It is observed that the maximum error between the experimental surface roughness and predicted surface roughness is 0.395 µm and maximum relative percentage error is 0.041.

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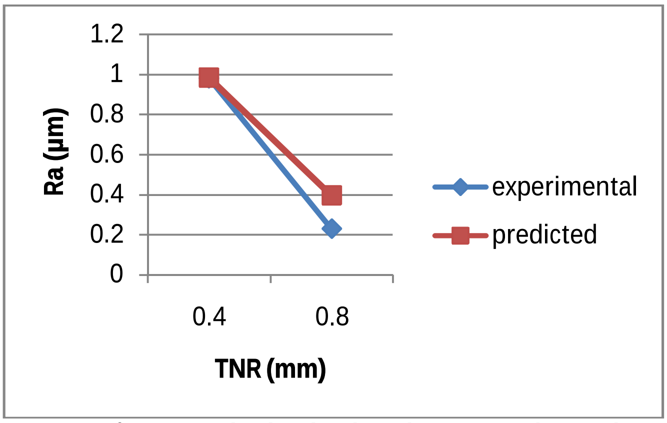

Fig.6 Comparison of experimental and predicted Ra when cutting tool nose radius is varied

Comparison of experimental and predicted Ra when cutting % of TiB_2 is varied

From the Fig.7 shows that Ra values are higher than predicted values at 2% TiB_2. It is observed that the maximum error between the experimental surface roughness and predicted surface roughness is 0.42 µm and maximum relative percentage error is 45.

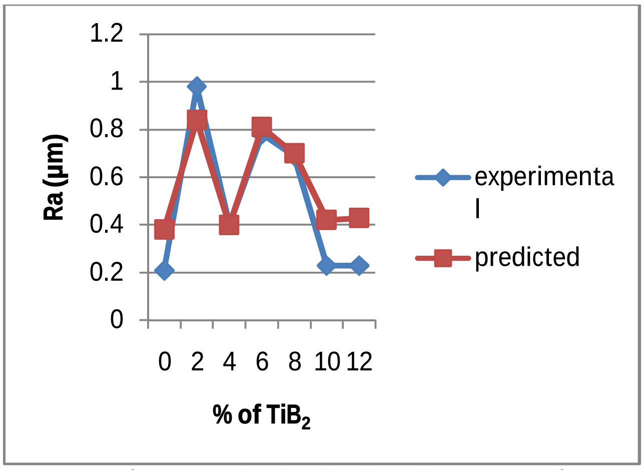

Fig.7 Comparison of experimental and predicted Ra when cutting % of TiB_2 is varied

IV. CONCLUSION

Surface roughness is low at low wt. % of TiB_2 in aluminium and comparatively high at higher % of TiB_2 in aluminium. However maximum value of surface roughness is observed with 2% TiB_2 composition. The trend of surface roughness predicted by model is similar to the trend obtained by experimental values. However marginal deviations are observed from prediction which may be due to the model prediction accuracy.Hardness of the forged- heat treated under different wt% of TiB_2 composite increases than the forged Al-TiB_2 composite. Irrespective of the percentage composition of TiB_2, surface roughness values increase after forged-heat treatment.In many cases it was observed that forged-heat treated composite had higher surface roughness value whereas forged Al-TiB_2 composite showed comparatively lesser values.

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