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Characterizing Machinability of Microalloyed 2219 Al Alloy

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Abstract—*Being light weight alloys exhibiting high strength and reasonable ductility, 2219 Al alloys are investigated extensively in aircraft and space applications. Microalloying (i.e. < 0.1 wt.%) with elements such as Sn, In, Cd, Ag, Si, etc. is one of the strategies to achieve a higher strength to weight ratio. Higher machinability corresponds to lesser power required, improved tool life, better surface finish etc., but often a compromise in material strength. The influences of microalloying with 0.06 wt.% Cd as well as cutting parameters viz. speed, feed and depth of cut on the cutting force components have been investigated to characterize machinability of 2219 Al alloy. The cutting forces considerably increased with increasing feed and depth of cut. Cutting forces increased due to trace addition of Cd, for all the cutting parameters. Hence, microalloying imparted a lower machinability, correlated with the increased strength and hardness.*

1. INTRODUCTION

The mechanical properties of metals and its alloys can be improved by a combination of metallurgical, manufacturing and design measures, which increase the reliability and service life of the component manufactured [1]. The search for new materials with enhanced properties for industrial and structural applications has led to the development of many metallic alloys. A metallic alloy is a solid solution made of two or more metal elements or metal and non-metal elements in a metallic matrix [2]. Alloys can be a homogeneous solid solution, a heterogeneous mixture of tiny crystals, a true chemical compound, or a mixture of these. Aluminium and its alloys have high strength-to-weight ratio and other desirable properties like non-toxic, non-magnetic, high thermal and electrical conductivities, high corrosion resistance and easy to fabricate. A number of fabrication techniques have been developed to increase the mechanical strength of alloys. Among them, precipitation strengthening is the most essential techniques to increase the mechanical strength in aluminium alloys [3]. The wrought and precipitation strengthened Al-Cu (2xxx), Al-Mg-Si (6xxx) and Al-Cu-Zn-Mg (7xxx) series of alloys, were developed because of their high strength to weight ratio. The mechanical properties of the wrought Al alloys are affected by the composition, strain history and the microstructure resulting from these thermo-mechanical treatments imparted. Small additions of various alloying elements are of prime importance to modify microstructures and to improve mechanical properties of alloys. Such microalloying effects have been widely applied to various alloy systems [4]. The present research trend to develop increased strength of these materials along with reasonable toughness and low density is by the addition of trace elements (microalloying, i.e. < 0.1 wt.%) like Sn, In, Cd, Ag, *etc.* [4,5,6,7] in to the alloy matrix. Literature is available regarding the influence of several alloying elements on the structure and properties of some commercial aluminium alloys. However, investigations on the effect of microalloying on the heat treatable 2xxx series of aluminium alloys are still limited in number. The term machinability refers to the ease with which a metal can be cut permitting the removal of the material with a satisfactory finish at low cost. Materials with good machinability require little power to cut, can be cut quickly, easily obtain a good finish, and do not wear the tooling much; such materials are said to be free machining. Aluminium is much softer than steel, and the techniques to improve its machinability usually rely on making it more brittle. Alloys 2007, 2011 and 6020 have very good machinability. There is a keen interest in developing light weight alloys for aircraft applications that have a high strength to weight ratio but at the same time it is also necessary to determine optimum cutting conditions to maximize tool life and reduce cost overheads. There are many factors affecting machinability. Machinability can be based on the measure of how long a tool lasts. The surface finish is also sometimes used to measure the machinability of a material. The forces required for a tool to cut through a material are directly related to the power consumed. Therefore, tool forces are often given in units of specific energy. This leads to a rating method where higher specific energies equal lower machinability. The advantage of this method is that outside factors have little effect on the rating [8]. Hence, a clear understanding of the variation of cutting force components with cutting conditions (speed, feed, and depth of cut) helps to determine the power requirement of the process and the tool geometry. In the present work, the influences of microalloying (i.e. < 0.1 wt.%) with 0.06 wt.% Cd as well as a systematic variation of various cutting parameters viz. speed, feed and depth of cut on the cutting force components (in three mutually perpendicular directions) have been investigated to characterize machinability of 2219 Al alloy during facing operation.

2. EXPERIMENTAL DETAILS

The base 2219 Al alloy (Alloy-*A*) was chosen to have a composition of Al–6.2%Cu–0.02%Mg (by weight). Another alloy (Alloy-*B*) corresponds to the base alloy microalloyed with 0.06 wt. % of Cd. Rectangular plates of Alloy-*A* and Alloy-*B* were obtained from aluminium ingots of commercial purity by a casting route. The details of the casting procedure have been discussed in a previous research work on microalloyed Al-Cu-Mg alloys [9]. The samples were then cut with a hacksaw to obtain samples with dimension of $15\times15\times10\ mm^3$. Finally, the sample surfaces were polished with emery papers of grit 400. The prepared samples were then subjected to homogenizing heat treatment in a muffle furnace at 510^{o}C for 10 hours to reduce chemical segregation of cast structures and to improve their workability. Finally, the samples were fixed on a mild steel cylindrical rod using adhesive and then the cylinder was held in the three jaw chuck of a metalworking lathe (MODEL: NH26). The same arrangement facilitates the holding and facing operation of the small cubic samples. Now the tool dynamometer was mounted on the carriage in place of the tool holder. The dynamometer (620B) used here was a three component piezoelectric dynamometer. It consists of three quartz plates, each of them sensitive to pressure in one of the three directions X, Y and Z. The dynamometer was connected to a force indicator (Model 652) which indicated the forces experienced in the three directions. The lathe tool dynamometer was initially set to zero reading. For each material, 48 facing operations were performed at different values of speeds, feeds and depth of cuts, as mentioned in Table 1. A total of 96 experiments were thus performed for two materials. The cutting forces were measured for each test to determine machinability.

Table 1: Different cutting parameters selected for facing operation

Sl No.	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
1	192	0.08	0.2
2	325	0.20	0.4
3	495	0.52	0.6
4	550	0.72	

3. RESULTS AND DISCUSSION

3.1 Variation of Cutting Force Components with Cutting Conditions

All the three cutting force components are plotted with the three cutting parameters experimented for both the alloys. Fig. 1 (a), (b), and (c) show the variations in cutting force F_X with cutting speed, feed and depth of cut respectively for Alloy-*A*. The results obtained revealed that the variation of cutting force components was insignificant with increase in spindle speed, up to 495 rpm. After this speed, the cutting forces increased rapidly with increase in cutting speed, at given values of feed and depth of cut. On the other hand, the cutting forces increased considerably with increase in feed and depth of cut. This slope of increase in the cutting force is however higher with increase in depth of cut, compared to increase in feed. The above variations in the cutting forces are almost identical for both the investigated alloys. Fig. 2 (a), (b), and (c) show the corresponding plots of variations in F_X for Alloy-*B*.

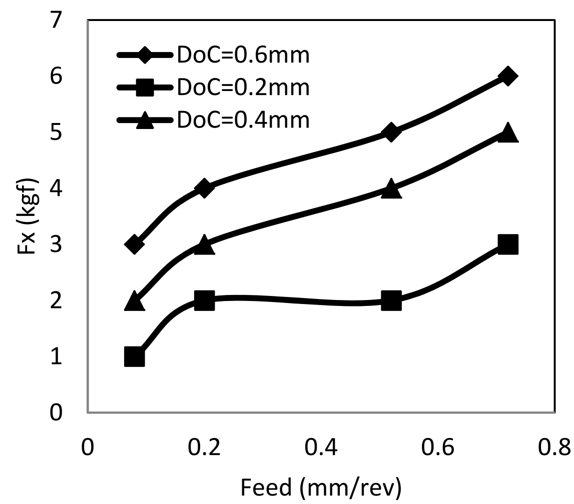

Fig. 1(b) Variation of F_X vs. Feed for Alloy-*A* at Speed 495 rpm

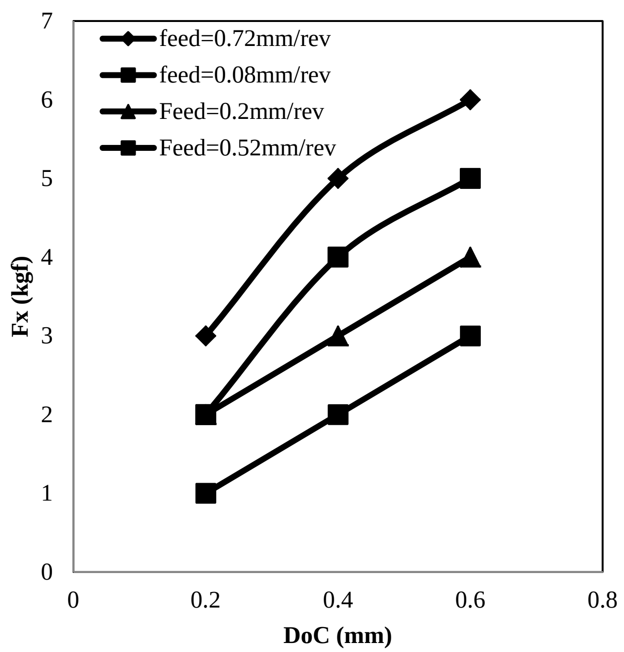

Fig. 1(c) Variation of F_X vs. DoC for Alloy-*A* at Speed 495 rpm

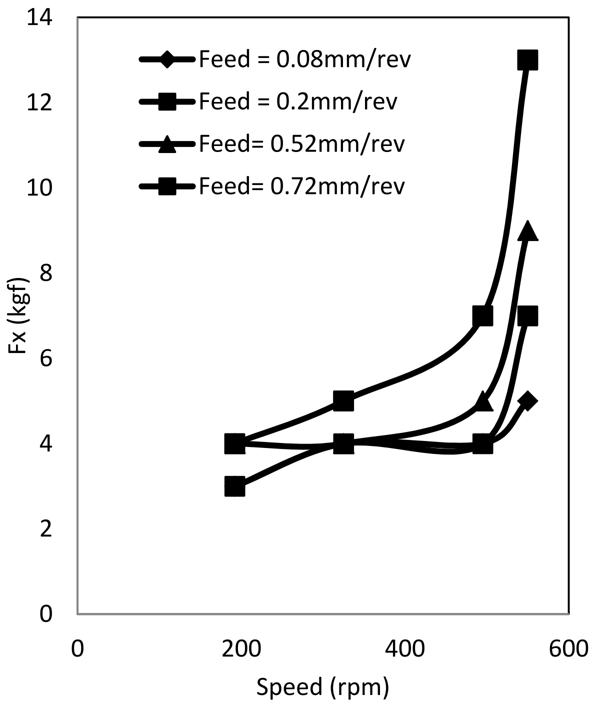

Fig. 2(a) Variation of F_X vs. Speed for Alloy-*B* at Depth of Cut 0.6mm

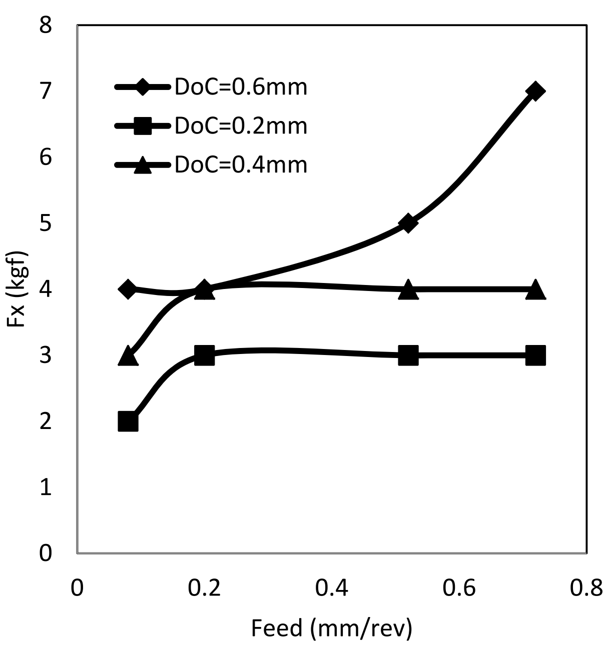

Fig. 2(b) Variation of F_X vs. Feed for Alloy-*B* at Speed 495 rpm

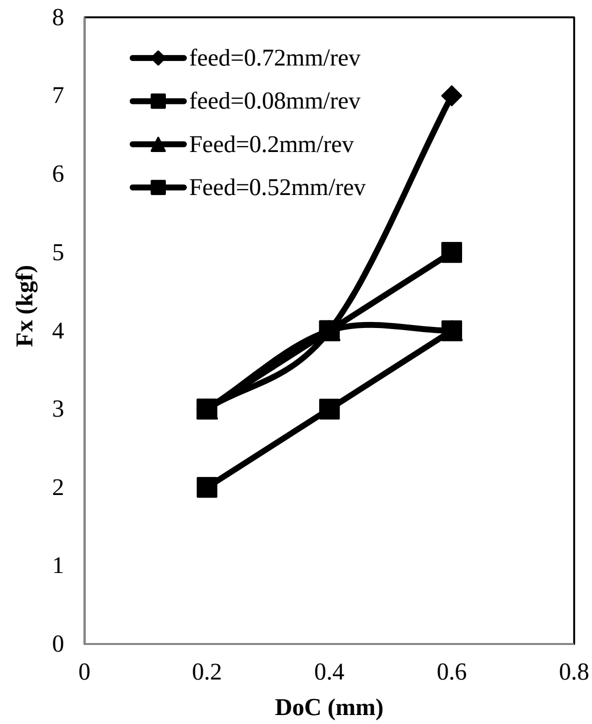

Fig. 2(c) Variation of F_X vs. Doc for Alloy-*B* at Speed 495rpm

3.2. Influence of Trace Addition of Cd on the Machinability of 2219 Al Alloy

It was observed that the cutting forces for Alloy-*B* are considerably higher than the corresponding values for Alloy-*A*, at given values of speed, feed and depth of cut. In other words, all the three components of cutting forces of the 2219 Al alloy were observed to increase due to trace addition of 0.06 wt.% of Cd, for almost all the experimented cutting parameters. Hence, if machinability is evaluated with cutting force as the criteria, microalloying imparted a lower machinability to the 2219 Al alloy. Because higher cutting force leads to the higher power required and lower tool life. In another research work conducted parallelly, it has been observed that there is a considerable increase in strength and hardness of the 2219 Al alloy, due to addition of 0.06 wt.% of Cd. Hence the increase in cutting force may be attributed to the increase in strength / hardness of the base alloy due to microalloying with Cd. The similar increase in strength and hardness, as well as cutting force of this alloy was also observed after adding trace contents of Sn [10]. Thus it is evident that although the mechanical property (strength / hardness) of 2219 Al alloy improved due to trace addition of Cd, there is a considerable loss in machinability, which may considerably affect the manufacturing of this alloy. Therefore, the alloy should be microalloyed only with a clear objective of either higher hardness or machinability, as per the specific requirement. Further investigations with systematic variation in the microalloying composition may shed light to achieve an optimum combination of strength and machinability. Moreover, an optimum cutting combination of speed, feed and depth of cut should be carefully chosen based on the generated cutting force.

4. CONCLUSION

The experimental results revealed that for both the investigated alloys, the cutting force components were almost constant with increase in cutting speed while considerably increased with increase in feed and depth of cut. Moreover, all the three components of cutting forces of the 2219 Al alloy were observed to increase due to trace addition of 0.06 wt.% of Cd, for almost all the experimented cutting parameters. Hence, microalloying imparted a lower machinability to the investigated 2219 Al Alloy system.

REFERENCE

[1] G.E. Dieter, Engineering Design: A materials and Processing Approach, 2nd Edition McGraw-Hill Books Company, Japan, 1988, P-315.

[2] Callister W.D., "Material Science and Engineering: An Introduction", *John Wiley & Sons*, 4th Edition, 1997

[3] Callister W.D. Jr., "Material Science and Engineering: An Introduction", *John Wiley & Sons*, 4th Edition, 1997

[4] Sercombe, T.B., and Schaffer, G.B., "On the use of trace additions of Sn to enhance sintered 2xxx series Al powder alloys", *Material Science and Engineering*, 1999.

[5] Schaffer, G.B., Huo, S.H., Drennan, J. And Auchterlonie, G.J., "The effect of trace elements on the sintering of an Al–Zn–Mg–Cu alloy", *Acta Materialia*, 49, 2001, pp. 2671-2678.

[6] Silcock, J.M., and Flower, H.M., "Comments on a comparison of early and recent work on the effect of trace additions of Cd, In, or Sn on nucleation and growth of in Al-Cu Alloys", *Scripta materalia*, 2002.

[7] Ocenasek, V., and Slamova, M., "Resistance to recrystalization due to Sc and Zr addition to Al–Mg alloys", *Materials characterization* , 47, 2001, pp. 157-162.

[8] Schneider, George, "Machinability of Metals," *American Machinist*, December, 2009 pp. 9.

[9] Banerjee, S., Robi, P.S., and Srinavasan, A., "Prediction of hot deformation behavior of Al–5.9%Cu–0.5%Mg alloys with trace additions of Sn", *Journal of Material Science*, 47, 929-948, 2011.

[10] Roy, A., Bayan, G.J., "Investigating the Influence of Rolling and Age-Hardening Treatment on the Hardness Properties and Cutting Force Based Machinability of Microalloyed 2219 Al Alloys", M.Tech thesis, Tezpur University, 2014.

[11] Elagin, V.I., "Ways of developing high-strength and high-temperature structural Aluminium alloys in the 21st century", *Metal Science and Heat Treatment*, 2007.