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Experimental Analysis of Surface Roughness and Machinability Parameters of Al base Alloys with Material Additives (Fe-Si)

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Abstract

Machining operations plays the key role in the manufacturing industry since the industrial revolution. Manufacturing industries strive to achieve minimum cost of production with a maximum production rate. Machinability is one of the important parameter that is related to all phases of manufacturing. Machinability is influenced by a number of variables, such as the inherent properties or characteristics of the work materials, cutting tool material, tool geometry, the nature of tool engagement with the work, cutting conditions, type of cutting, cutting fluid, and machine tool rigidity and its capacity. Tool life is affected by machinability of the material at different speeds and temperatures. Worldwide research is going on to improve the machinability of the existing materials or to develop new materials with similar properties and improved machinability. Present work is carried out to improve the machinability of an aluminium based alloy (Al-Fe-Si) with an aim to optimize the effecting parameters. The surface roughness and machinability of the material with variation of ferrous percentage is tested and the results are produced.

Keywords: Machinability, surface roughness, Al-Fe-Si alloy.

INTRODUCTION

Traditional machining operations such as turning, milling, boring, tapping, sawing etc. are easily performed on aluminum and its alloys. The machines that are used can be the same as for use with steel, however optimum machining conditions such as rotational speeds and feed rates can only be achieved on machines designed for machining aluminum alloys. Many aluminum applications are undergoing a reduction in weight as strength and durability of aluminum is improved by alloying. Research in many areas of aluminum technology, such as advanced alloys, rapid solidification, composites and corrosion resistance, is aimed at keeping aluminum material competitive in traditional as well as new applications.

LITERATURE REVIEW

Aluminum alloys such as Al-Si, Al-Cu-Si and Al-Mg-Zn alloys are widely used in aerospace and other engineering industries due to their light weight and high strength to weight ratio. Al-TM (TM - transition metal) Systems have the potential for high temperature applications. Among the Al-TM system, Al-Fe-Si, Systems have altered considerable interest due to its high strength at room as well as at elevated temperature. Iron increases the hardness and decreases the ductility**[Pathak et al., 2006]**.Grain refinement of the casting yields several benefits. A fine grain size results in mechanical properties that are uniform throughout the material. Also, as the grain size decrease, the distribution of secondary phases and porosity is on a finer scale, and machinablity is improved .Therefore V is added to these alloys for its grain refining effects**.[K.L.Sahoo et al.,2000].** Iron is a common impurity in aluminium and it leads to the formation of complex intermetallic phases during solidification, and how these phases can adversely affect mechanical properties, especially ductility, and also lead to the formation of excessive shrinkage porosity defects in castings. Although iron is highly soluble in liquid aluminium and its alloys, it has very little solubility in the solid, and so it tends to combine with other elements to form intermetallic phase particles of various types. The differing shapes of these iron intermetallics are in part responsible for the impact of iron on castability and mechanical properties. It is consistently reported that as Fe levels increase, porosity increases & the ductility of Al-Si based alloys decreases [John A. Taylor 2004].The major factors which are highly responsible for the surface roughness are feed rate and tool size. The work piece had the most surface roughness when the feed rate was high in combination with the highest depth of cut and the lowest spindle speed but it was not consistent with the system response. The combination for achieving this type of surface finish is best when the spindle speed is running at its highest i.e.,2800 rpm, depth of cut was adjusted to its maximum value of 0.075 in with a low feed rate of 10 in/min provided the least roughness amongst all given samples. The tool size of 0.5 inches in diameter used for this experiment did not show much variability in the surface roughness when compared to the tool size of 0.25 inches dia. The 0.25 inch tool size did give the highest and thelowest surface roughness when in combination with the other three parameters[R. Noorani, 2009].

EXPERIMENTAL PROCEDURE

The compositions of different alloys and different modification treatment are given in the Table 1 & Table 2.

Table 1: Compositions of the alloys prepared

Alloy Designation	Chemical composition (wt. %)		
	Fe	Si	Al
S1	1	1	Balance
S2	2	1	Balance

Table 2. Different sample size

Sample no.	Al	Fe	Si	
Sample A	Requirement of materials Si = 53 g, Fe = 53 g, Al = 4.9 kg.	Total Fe required (1/100) x 5000 = 50 g. Wt. of Fe (5% loss) = 1.05x50=52.5 g.	*Wt. of Si required = (1/100) x 5000 = 50 g.* Wt. of Si(5% loss) = 1.05x50=52.5 g.	Al-1Fe-1Si
Sample B	Requirement of materials Si = 53 g, Fe=105 g, Al = 4850 g.	Total Fe required (2/100) x 5000 = 100 g. Wt. of Fe required including 5% loss = 1.05x100=105 g.	Wt. of Si required = (1/100) x 5000 = 50 g. Wt. of Si required including 5% loss = 1.05x50=52.5 g.	Al-2Fe-1Si

Preparation of alloy :

The experimental alloys were prepared in an electric heating furnace in a clay bonded graphite crucible under the cover of Na-free flux. First crucible was preheated to about 600^0C. For alloy preparation, Pure Al and Fe were used. At around 600^0C, weighted quantity of 99.9% pure aluminium and 99.9% pure silicon metallic was charged. (Compositions are given in wt.% unless otherwise mentioned). Just after melting, the molten alloy was covered with a sodium free flux (2% of melt). After melting, sufficient time was given for complete homogenization of the melt. The melt was frequently agitated with a graphite rod for complete mixing. The melt was then degassed with hexachloroethane. Degasser was wrapped in aluminium foil and plunged into the melt. After degassing the melt was cast in different moulds. The object is to vary the cooling rates.

Pouring of melt at different moulds :

After complete homogenization at desired temperature the melt was poured in different mould to prepare different samples. There were five samples prepared which were poured in (a) 12 mm diameter permanent mould, (b) 25 mm thickness permanent (steel) flat mould, (c) 75 mm diameter permanent mould.The pouring temperature was maintained approximately at 880^0C. The fluidity of the melt at this temperature was sufficient for casting test pieces. In all the cases, the mould was preheated approximately up to 1500^0C to drive off the moisture.

Result analysis :

Mechanical properties of both samples of Al alloys are discussed in detail. The hardness of the samples that cast in permanent mould is given in the Table 3.

Table 3. Vickers's hardness of as cast samples:

Hardness (VHN)	
Alloy	Permanent mould
Al-1Fe-1Si	35
Al-2Fe-1Si	41

From the table, it is clear that hardness is increases as iron content increases. Table 3 shows the ultimate tensile strength (UTS), percentage elongation and percentage reduction in area (RA) as cast samples.

Table 4. Mechanical properties of as cast alloys:

Cast alloy	UTS (MPa)	% elongation	% RA
Al-1Fe-1Si	37	5	4
Al-2Fe-1Si	45	4	3

From the table, it is clear that as iron percentage increases, UTS sharply increases but percentage elongation decreases. During tensile testing, the massive iron bearing phases also adversely affect effective feeding in the casting resulting in micro pores. Thus the mechanical properties deteriorate. To avoiding this defect, hot rolling will be done.

Machinability of aluminum alloys

Different samples have been made for machinability test of the alloys. The samples were cut in eight pieces from the cast piece 170X75X20mm. The dimension of the samples used for milling operation is 40X18X8mm. For milling operation 16mm diameter HSS tool were used. The machining set up used for milling operation is shown below. The samples were machined under different parameter. Now the specimens are ready for surface measurement which will be carried out during major project work.

Surface roughness measurement of Al-1Fe-1Si & Al-2Fe-1Si alloys

From the experiment it has been shown that the surface roughness is a function of cutting parameters, composition and alloy conditions. [Dwivedi-2002] The effect of depth of cut, cutting speed and feed rate on arithmetic mean roughness Ra(centre-line average) and maximum peak to valley height roughness Rz values of milling Al alloy with HSS are presented in Figure1 to Figure 3 respectively.

Figure 1 shows the influence of depth of cut on the surface roughness height Ra and Rz during machining of Al alloy without use of coolant. From the depth of cut versus surface finish graph, it can be observed that the graph plotted between depth of cut and surface finish is not following the trend in increasing order but it is abruptly changing alternately and it goes up. It may be due to some fault. Initially at 0.25mm depth of cut, the surface roughness is low, at 0.50 mm depth of cut there is good surface finish and again as depth of cut increases alternately the quality of surface finish also changing. Therefore, it may be recommended that the machining should be done either at 0.75 m/min cutting speed or 1.25 m/min cutting speed for best surface finish.

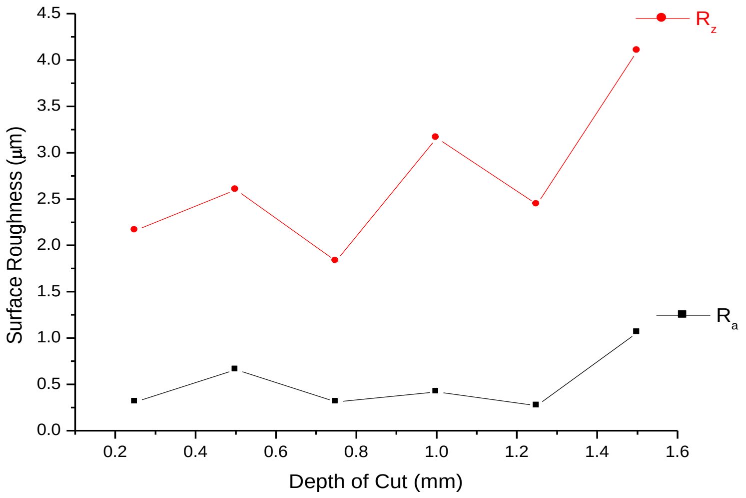

Fig.1 (a). Effect of depth of cut on surface roughness height for f=0.5mm/rev and v=75m/min of Al-1Fe-1Si alloy.

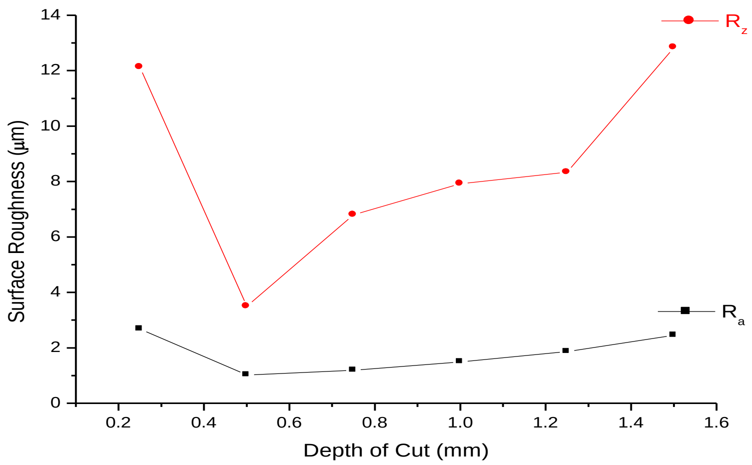

Fig.1(b). Effect of depth of cut on surface roughness height for f=0.5mm/rev and v=75m/min of Al-2Fe-1Si alloy

Fig 2 shows the influence of feed rate on surface roughness characteristics i.e; R_a and R_z during milling of Al-alloys without use of coolant. The milling operations were performed considering 75m/min constant cutting speed and 0.5 mm depth of cut. The test results show that the value of both surface roughness heights R_a and R_z are increasing as feed rate increases.

From the graph, it has been seen that the best surface finish has been observed at 0.25mm/rev feed when iron % is 2 in alloy.

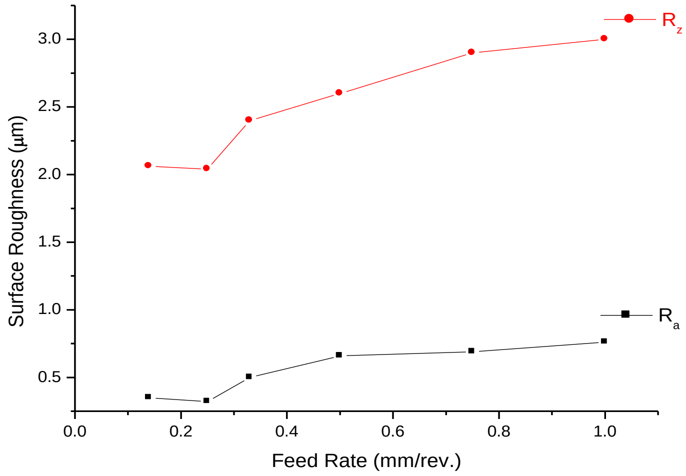

Fig.2 (a). Effect of feed rate on surface roughness height for v=75m/min and a_p=0.5mm of Al-1Fe-1Si alloy.

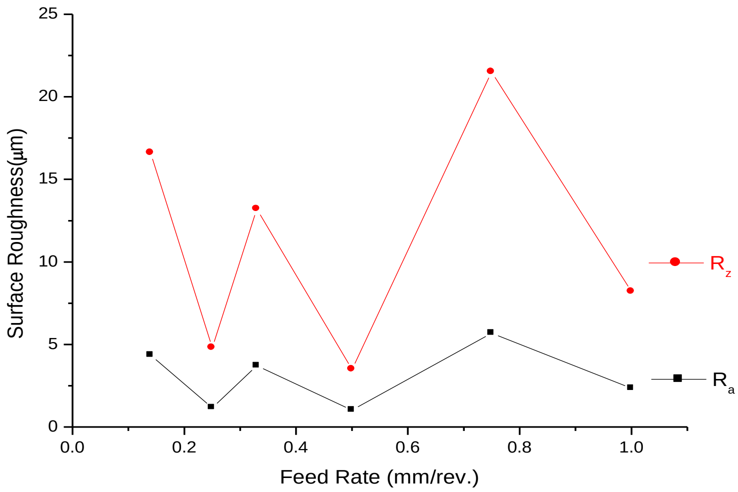

Fig.2(b). Effect of feed rate on surface roughness height for v=75m/min and a_p=0.5mm of Al-2Fe-1Si alloy

Fig 3 shows the influence of cutting speed on surface roughness characteristics i.e; R_a and R_z during milling of Al-alloys without use of coolant. The milling operations were performed considering 0.5mm/rev constant feed and 0.5 mm depth of cut. The test results show that the value of both surface roughness heights R_a and R_z are low at high cutting speed and comparatively high at low cutting speed. The best surface finish has been shown at 150m/min.

Some times during milling, it can be observed that the value of surface roughness height is abruptly higher than the trend value.The abrupt irregularity in the values of surface roughness heights may be due to the presence of the hard phase of alloys on the machined surface during milling and ploughing on the machined surface which may generate grooves on the machined surface.

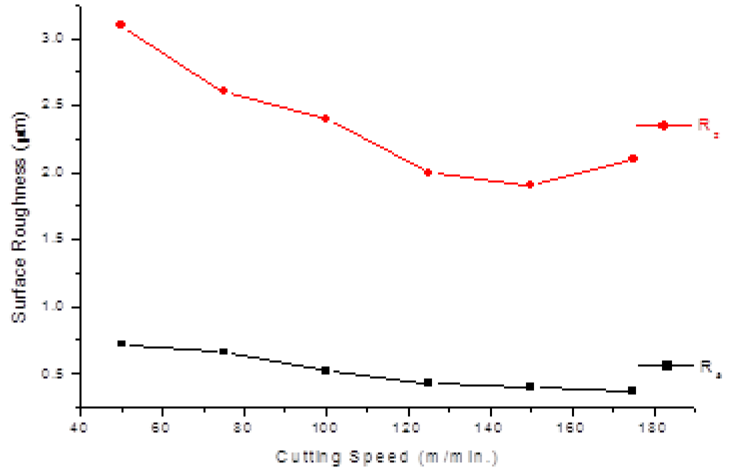

Fig.3 (a). Effect of cutting speed on surface roughness height for f=0.5mm/rev and a_p=0.5mm of Al-1Fe-1Si alloy

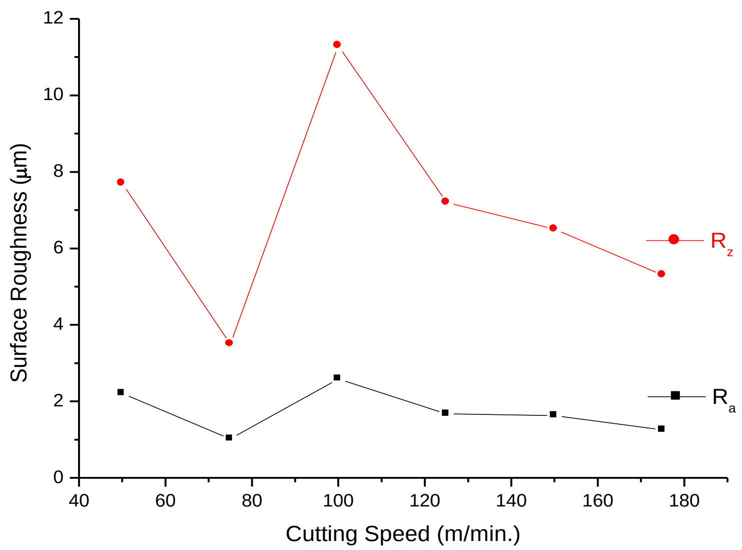

Fig.3 (b). Effect of cutting speed on surface roughness height for f=0.5mm/rev and a_p=0.5mm of Al-2Fe-1Si alloy.

DISCUSSION

Al-Fe-Si alloys, which has the potential to use in elevated temperature applications. Al-Fe-Si alloys are generally produced through rapid solidification process, which exhibit comparable better mechanical properties to conventional cast aluminium alloys. The improved performance of these alloys at elevated temperature have made them strong candidates for a variety of future aerospace applications such as aircraft fuselage, missile fins and winglets, rocket motor cases, and various gas turbine engine components. Al-Fe-Si alloys produced through RSP route is also a cost intensive.

The entire experimental programmed may be grouped under the following heads:-

1. Preparation of Al-Transition metal alloys of different composition.
2. Casting the alloys in various moulds.
3. Determination of properties of the as cast alloys.
4. Chips formation of alloys.
5. Surface roughness measurement of alloys to determine mahinability.

CONCLUSION

In present work the Hardness & UTS of alloys increases as iron content increases & Ductility decreases as % of iron increases. As per appearance of chip formation it may be conclude that machinability of alloys increases with increasing spindle speed and machinability is poor as depth of cut and feed rate increases. Decrease in feed and an increase in cutting speed improve the surface finish. High speed, low feed rate and low depth of cut are recommended for better surface finish. The surface finish is poor as Fe content increases from 1% to 2% in all the conditions. The surface roughness of the workpiece was mostly affected by cutting speed. The optimum surface roughness in the machining of Al alloy was obtained at a cutting speed from 125 to 175m/min.

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