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Enhancing the Surface Finish of Aluminium Alloy A356 by Algorithmic Optimization

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ABSTRACT: To enhance the quality of machined products to reduce the machining costs and to increase the machining quality it is highly important to select most suitable machining parameters when machining is considered. Milling is one of the machining processes which deserve very high importance deciding surface finish in production industry. Obviously face milling must do very much in quality machining of many metals especially, in the case Aluminium which is used to manufacture lakhs of products in the form of alloys in automobile industry. Therefore the face milling of aluminum alloys is a matter to be investigated in both economy and quality concerns. Here an important aluminum alloy A356 which has wider applications is investigated for its cutting parameters speed, feed and depth of cut. The objective is to get the maximum best output of surface roughness by optimizing these three cutting parameters. Metaheuristic algorithms are powerful tools in providing optimum output for machining problems. They give a large saving of time and machining cost with its fast processing nature and thus it eliminates the large burden of experimental cost. There are many algorithms like GA (Genetic Algorithm), PSO (Particle Swarm Optimization), ACO (Ant Colony Optimization) etc. Out of which 'ABC' or 'Artificial Bee Colony' is one of the recently developed and found better than other techniques, inspiring foraging and dance behaviors of real honeybee colonies. This is effectively applied here for optimizing face milling parameters speed, feed, and depth of cut.

KEYWORDS: flexible manufacturing systems, Face Milling, Surface Roughness, design of experiments, ANOVA

I. INTRODUCTION

In the current industrial manufacturing environment, all industries have been attempting to apply flexible manufacturing systems (FMS) as their motto to adapt to the fast changing competitive market strategies. To enhance the quality of machined products to reduce the machining costs and to increase the machining quality, it is highly important to select most suitable machining parameters when machining is considered. Generally, machining processes are classified into turning, milling, drilling, grinding etc. Even there are further subdivisions on each like end milling, face milling etc. Materials generated by other metallurgical processes like casting, forging, extrusion and some other primary manufacturing processes need further finishing machining operations in order to attain higher finishing characteristics because surface finish and accuracy is highly important in many critical applications. Surface finish has a vital influence on important functional properties such as wear resistance and power loss due to friction in most of the engineering parts or components. The extreme finishing is obtained when the chip size approaches to nanometre range. The explorations in the fields of micromachining assert the necessity of precision machining i.e.; high surface finish and dimensional accuracy. Many automotive, defence, research, medical, aerospace, industrial components rely on this accuracy and finish. All kinds of machining operations deserve equal importance in one or another application.

II. MILLING PROCESS

Milling can be defined as a material removing operation or process, in which variety of features are created on a particular part or component by cutting away the unwanted material by using the tool called as milling cutter. It may be a single pass or a multi pass milling operation.

By feeding the work piece onto the speedy rotating cutter, material is cut away from this work piece in the form of small chips to create the intended shape. Milling is mostly used to generate parts which are not axially symmetric and have many features, such as holes, slots, pockets, similarly any other geometry can be created and even three dimensional surface contours. Parts that are created entirely through milling mostly involve components which are used in fewer quantities, mostly for prototypes. Milling can also commonly used as a following or secondary process to add or refine features on components that were fabricated using a different process. Due to the high tolerances and surface finishes that milling can offer, it is ideal for adding precision features to a part whose basic shape has already been

formed. We have only to modify that according to our necessity. Thus we need further care to be taken in it for the precise results.

Milling is again classified into face milling, end milling, chamfer milling etc. An end milling is that in which the axis of cutting tool will be parallel to the planing surface while at the same time in face milling the axis of cutting tool will be perpendicular to the surface. Chamfer milling is making peripheral cut through the edge of the work piece or a contour to create an angled surface, that surface is known as a chamfer. Among these three, face milling is of prime importance.

a) Face Milling & Surface Roughness

It is a milling operation in which the surface of the work piece is kept perpendicular to the spindle axis. Face milling primarily is used to mill the top face of the part or component. It is a type of milling operation is utilized to plane the surface of work material with improved surface texture or surface integrity.

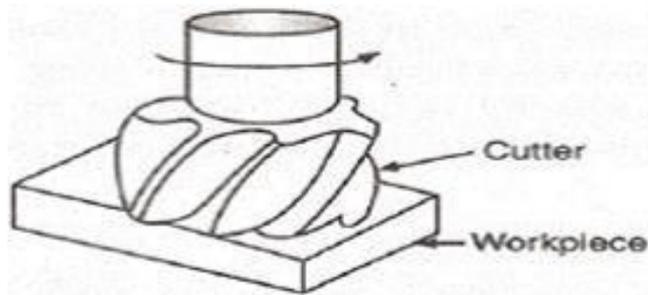


Figure 2.1 Face milling operation

Face milling is most common method of milling used extensively to create plane surfaces with desired properties. One peculiar use of face milling is the production of sealed surfaces which have numerous applications. The two factors essential for its functionality are surface quality and edge shape. Non compliance with any of the foretold qualities may eventually lead to the failure of a component during usage.

b) Surface roughness (Ra)

The surface roughness is a most essential quality concern in machining of metals and is defined as the 'irregularities existing on the surface of any material'. It may result from either a previous metallurgical operations like casting, forging, extrusion or due to pre-machining of the material. It becomes influential in the case of two mating or sealing surfaces.

III. MATERIAL CHOSEN FOR MILLING A356

The alloy using for the proposed experiments is A356, a wide range of materials can be experimented and have done previously like hardened steel AISI H13, Ti-6Al-4V, or Aluminum 7075-t6, Al SiC metal matrix composite materials etc but A356 has some specialities to be selected as the experimenting material. That properties are related to the content that we added to base material.

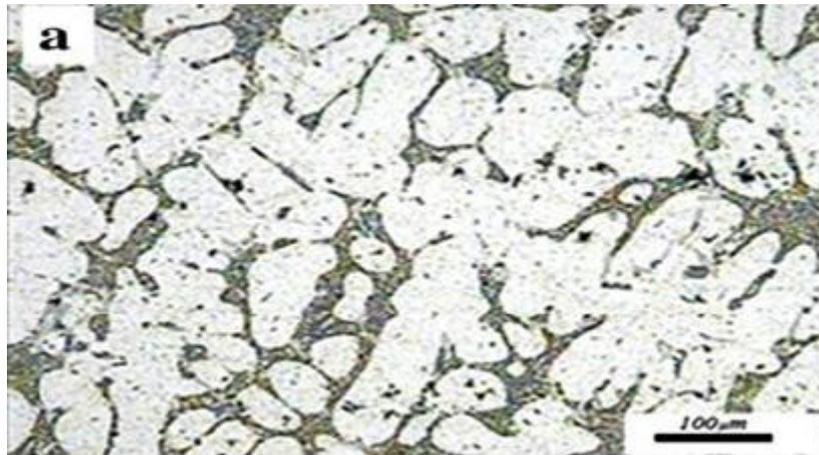


Figure 3.1:Optical micrograph of A356 alloy

There are some certain applications for A356, which is widely applied in aircraft pump components, automobile transmission cases, aircraft fittings and control parts, water-cooled cylinder blocks the general chemical composition of A356 is given in the Table 1.1

Table 3.1: Chemical composition of A356

Designation	A356 (%)
Silicon (Si)	6.5-7.5
Iron (Fe)	0.20 max
Copper(Cu)	0.20 max
Manganese (Mn)	0.10 max
Magnesium (Mg)	0.25-0.45
Nickel (Ni)	-
Zinc (Zn)	0.10 max
Tin (Sn)	-
Lead (Pb)	0.05 max
Titanium (Ti)	0.20 max
Aluminum (Al)	balance

Other applications where excellent castability, good weldability, pressure tightness, and good resistance to corrosion are required. Also in aircraft structures, engine control elements, nuclear power installations and other applications where high-strength permanent mould or investment castings are required. A356 is probably one of the most popular alloys applied for semi-solid metal (SSM) forming. This is due to its high fluidity.



a) A356 in Automotive Industry

Aluminum alloy A356 is most widely used in automotive industry. Common components found in an engine include pistons, timing chains, camshafts, rocker arms, and other various parts. When fully stripped of all attachments, the core of the engine can be seen: the cylinder block. Numerous forces from pistons, crankshafts etc, are acting upon it. The cylinder block (popularly known as the engine block) is the strongest component of an engine that provides much of the housing for the hundreds of parts found in a modern engine. Since it is also a relatively large component, it constitutes 20-25% of the total weight of an engine. Thus there is much preference in reducing the block’s weight. Many early engine blocks were manufactured from cast iron alloys primarily due to its high strength and low cost. But, as engine designs became highly complicated, the weight of the engine (and the vehicle) had increased. Consequently, the desire among manufacturers to use lighter alloys that were as strong as cast irons arose. One such material that was being used as a substitute was aluminum alloys. Used sparingly in the 1930’s (due to problems with durability), aluminum alloy use in engine blocks increased during the 1960’s and 1970’s as a way to increase fuel efficiency and performance. Together, these two metals were used exclusively to fabricate engine blocks. There is certain required material properties for an engine block to meet the functional requirements listed above; the engineering material(s) used to manufacture the product must possess high strength, modulus of elasticity, abrasion resistance, and corrosion resistance. High strength is a particular concern in diesel engines, since compression ratios are normally 17.0:1 or higher (compared to about 10.0:1 for conventional engines).

IV. DESIGN OF EXPERIMENTS

Planning, Problem definition, Objective Definition, Modeling of experimental plan, Screening, Optimization, Verification, Factorial designs are the steps in design of experiments.

Table 4.1: Parameters and levels

Machining parameters	Unit	Levels (3)		
Speed	Rpm	1000	1400	2000
Feed	Mm/min	1000	1100	1600
Depth of cut	Mm	.5	1	1.5

Both run order and standard run order is given. This is to reduce the occurrence of likelihood that the results will be affected by the confounding variables and other sources of biases that are generally present in all kinds of observational studies. There may be problems related to machining like that of machine, tools, coolant etc.

V. RESULT & CONCLUSION

ANOVA is expressed mainly in terms of two values, the ‘f’ statistic or ‘p’ statistic. Here we can observe the ‘f’ value or ‘Fisher’ statistic for the first two parameters speed and feed is sufficiently high implies their high impact on the output response. Because as ‘f’ value deviates larger from the zero the greater will be its influence on the output. Obviously low value of ‘depth of cut’ indicates it has not to do much with the ‘roughness value’. In other words ‘f’ statistic can be defined as the ratio of variability within the group to the variability between the groups. At the same time ‘p’ value works as the inverse of ‘f’ in a way. The zero value of the first two parameters indicates their definite role in the output at the same time, the third parameter value which is higher than zero depicts that it is almost independent in determining the output. This shows the variation of roughness value ‘Ra’ as one of the three parameters change. The ‘Minitab 16’ generates a linear regression relation plotting the ‘surface roughness’ in terms of



the input parameters speed, feed and the depth of cut given as x, y and z respectively. The relationship obtained and is given as,

$$Ra = .00482x + .00604y - 1.13z - 1.10$$

Conventionally, getting the optimum results for most of the machining problems is almost impossible, especially within a short span of time. But by employing some heuristic based methods it is possible to get near optimal solution within reasonable time. Even though they may not give the optimal solution, the time taken to get the results is too small when we consider the error in the solutions. This study focuses on application of heuristic algorithm ABC (Artificial Bee Colony) to get a near optimum result

Table 5.1: Results of ANOVA

Source	f	p
Speed	49.65	0.00
Feed	23.38	0.00
Depth of cut	2.32	.124

Table 5.2: Design of Experiments

Standard Order	Run Order	Speed (rpm)	Feed (mm/min)	Depth of cut (mm)
1	17	1000	1000	0.5
2	6	1400	1000	0.5
3	25	2000	1000	0.5
4	20	1000	1100	0.5
5	3	1400	1100	0.5
6	24	2000	1100	0.5
7	13	1000	1600	0.5
8	21	1400	1600	0.5
9	22	2000	1600	0.5
10	5	1000	1000	1
11	18	1400	1000	1
12	27	2000	1000	1
13	8	1000	1100	1
14	14	1400	1100	1
15	2	2000	1100	1
16	4	1000	1600	1
17	1	1400	1600	1
18	9	2000	1600	1



19	19	1000	1000	1.5
20	7	1400	1000	1.5
21	23	2000	1000	1.5
22	10	1000	1100	1.5
23	16	1400	1100	1.5
24	15	2000	1100	1.5
25	11	1000	1600	1.5
26	26	1400	1600	1.5
27	12	2000	1600	1.5

Table 5.3: Comparison of Roughness value

Method	Experimentation	Regression Model	ABC Algorithm
Lowest Roughness Value	8.1714 μm	8.060 μm	8.010 μm
Corresponding Parameters	x = 1000, y = 1000 z = 1.5	x = 1000 y = 1000 z = 1.5	x = 1003.8 y = 1112.1 z = 1.4860

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