Multiobjective Optimization of process parameters of CNC turning on AA6082/Sic MMC using Genetic Algorithm

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Abstract - *Machining of composites is an advanced and important topic in current research field of manufacturing technology. In the present study Aluminium 6082/ Silicon Carbide (Al/SiC) composites are fabricated using stir casting methodology and the effect of machining parameters i.e., cutting speed, feed, and depth of cut on CNC turning was investigated. The objectives of the present study is to minimize the surface roughness and maximize the material removal rate using multi-objective optimization. The study establishes a mathematical relationship between three process parameters on the responses. Regression equation is used to represent relationship between input and output variables and Genetic Algorithm is chosen to optimize the process parameters.*

***Key Words*: Al6082/Sic. Metal Matrix composites, CNC Turning, Genetic Algorithm, Multiobjective optimization.**

1. INTRODUCTION

In order to meet the needs and requirements of engineering applications, metal matrix composites are chosen in which strong ceramic fillers such as zirconia, alumina, silicon carbide (SiC) were added to the metal matrix such as aluminum, magnesium or titanium and its alloys, enhances the strength, stiffness and wear resistance compared to unreinforced alloys [1]. Besides, MMCs also have some outstanding properties like low density, high modulus, high thermal conductivity and low thermal expansion which make them find increasing applications in automobile, aerospace, electronics and medical industries. The properties of the particle reinforced metal matrix composites produced by this way are influenced to a large extent by type, size and weight of fraction of the reinforcing particles and their distribution in the cast matrix [2].

An enduring problem with MMCs is that they are difficult to machine [3] to a better surface quality due to their low plasticity, non-uniformity and high abrasive nature of the ceramic reinforcement, which causes rapid tool wear rate and excessive machining induced defects [4]. These difficulties associated with the machining of MMCs need to be minimized foe extensive applications.

In the present world scenario, optimization is of utmost importance for organizations and researchers to meet the growing demand for improved product quality along with lesser production costs and faster rates of production [5]. it has been observed that optimization of single response proves unbeneficial to manufacturing firm. Optimizing a single response may yield positively in some aspects but it may adversely affects in other aspects [6], however, the problem can be evoked if multiple objective are optimized simultaneously [7].

In the present investigation an attempt is made is made to study and optimize the machining parameters on surface roughness, material removal rate in CNC turning of Al/SiC composites. Speed, Feed rate and Depth of Cut are chosen as the influencing parameters and a full factorial design of experiments was carried out to collect the experimental data and to analyse the effect of these parameters on surface roughness and material removal rate. Genetic Algorithm is chosen for Multi-objective optimization.

2. EXPERIMENTAL DETAILS:

2.1 Preparation of Composite:

Aluminium 6082 alloy and Silicon carbide (150 μ) was selected as the matrix and reinforcement respectively. Al6082 possesses good formability, weldability, machinability and corrosion resistance, with good strength compared to other grades of aluminium alloys. Its nominal chemical composition is shown in Table 1.

Table -1: Chemical composition of Al6082

Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
Composition	0.7 – 1.3	0.0 – 0.5	0/0 – 0.1	0.4 -- 1.0	0.6 – 1.2	0.0 – 0.2	0.0 -- 0.1	0.0 – 0.25	Bal

First, the matrix is fed into the crucible and melted using stir casting furnace as shown in Fig.1, and then the 5 wt.% of silicon carbide is added to the melt and stirred at constant speed of 300 rpm for homogenized mixture. The melt was degassed using hexachloroethane to remove the entrapped gases before stirring. The melt is poured into the preheated cylindrical metallic mold of size Ø 25 mm x 90 mm shown in Fig.2 and Fig.3 respectively.

Fig -1: Stir Casting Furnace

Fig -2: Cylindrical mold

Fig -3: Cylindrical specimens after casting.

After casting, the composites rods are prepared of size Ø 20 mm x 75 mm length for the experiments.

2.2 Cutting conditions:

The cutting tool selected for machining of metal matrix composites was HSS steel. The experiments were carried with three factors at three levels each as shown in Table 2. The experiments were performed on the MTAB - MAX PLUS CNC turning centre in dry machining condition.

Table -2: Machining parameters and levels

S. No.	Process parameters	Levels			
		1	2	3	Units
1	Speed	1400	1600	1800	RPM
2	Feed	0.08	0.14	0.2	mm/rev
3	Depth of Cut	0.4	0.6	0.8	mm

Surface roughness is measured by using the mitutuyo handheld talysurf instrument, and the material removal rate is measured using the formula as shown in Eq. (1).

$$MRR = (V_i - V_f) / t …….. (1)$$

Where V_i = initial volume of the workpiece
V_f = final volume of the workpiece
t = machining time (min)

2.3 Design of Experiments:

In order to investigate the influence of machining parameters on surface roughness and material removal rate, Full factorial design is chosen for design of experiments, due to its capability to check the interactions among all the factors and all levels. The design of experiments and the responses i.e., surface roughness, material removal rate is shown in Table 3. The machined specimens are shown in the Fig. 4.

Fig -4: After Machining

Table -3: DOE and Responses.

S.No	Speed (rpm)	FEED (mm/rev)	DEPTH OF CUT (mm)	Ra (μ)	MRR (mm^3/min)
1.	1400	0.08	0.4	1.28	1606.6
2.	1400	0.08	0.6	1.18	3451.7
3.	1400	0.08	0.8	1.22	5268.4
4.	1400	0.14	0.4	1.12	3108.2
5.	1400	0.14	0.6	1.26	6195.8
6.	1400	0.14	0.8	1.69	9288.1
7.	1400	0.20	0.4	2.04	4308.1
8.	1400	0.20	0.6	2.28	9220.9
9.	1400	0.20	0.8	2.92	13739.0
10.	1600	0.08	0.4	1.01	1927.5
11.	1600	0.08	0.6	1.80	4039.1
12.	1600	0.08	0.8	1.04	6069.0
13.	1600	0.14	0.4	1.62	3490.1
14.	1600	0.14	0.6	1.58	7332.8
15.	1600	0.14	0.8	1.56	10417.7
16.	1600	0.20	0.4	1.76	5057.3
17.	1600	0.20	0.6	2.05	9734.5
18.	1600	0.20	0.8	2.23	15808.6
19.	1800	0.08	0.4	1.04	2137.3
20.	1800	0.08	0.6	1.12	4644.4
21.	1800	0.08	0.8	1.00	6792.0
22.	1800	0.14	0.4	1.63	4151.0
23.	1800	0.14	0.6	1.76	9087.2
24.	1800	0.14	0.8	1.62	11910.3
25.	1800	0.20	0.4	1.89	5841.4
26.	1800	0.20	0.6	1.96	11251.2
27.	1800	0.20	0.8	2.38	17361.4

3. MULTI OBJECTIVE OPTIMIZATION

3.1 Regression model:

The correlation between the machining parameters and responses i.e., roughness, MRR were formulated using a regression model. The mathematical models were shown in Eq's (2) and (3)

'Ra' = 0.372 - 0.000164 * SPEED + 8.17 * FEED + 0.631* DEPTH OF CUT… (2)

'MRR' = -18541 + 4.72 * SPEED + 52209 * FEED + 18063 * DEPTH OF CUT.. (3)

3.2 Genetic algorithm

To perform multi-objective optimization, combine multiple objectives to one objective. Then, a single objective optimization algorithm can be used to obtain the solution. Combine Eq's (2) & (3) to Eq (4) as shown below

'MOBJ' = 0.372 - 0.000164 * SPEED + 8.17 * FEED + 0.631* DEPTH OF CUT + (- (-18541 + 4.72 * SPEED + 52209 * FEED + 18063 * DEPTH OF CUT)) …. (4)

The developed mathematical model is solved with the genetic algorithm code to obtain the pareto optimal solutions for the objective function

4. RESULTS & DISCUSSION

4.1 Pareto Optimal solutions

After performing Genetic algorithm to the fitness function, pareto optimal solutions are obtained as shown below in the table 4.

Table -4: Pareto optimal solutions

S. No	Ra	MRR	Speed	Feed	Depth of Cut
1	0.986	1301.485	1785.312	0.080	0.401
2	1.203	7139.517	1789.710	0.082	0.716
3	1.084	4076.142	1785.700	0.080	0.554
4	0.986	1301.485	1785.312	0.080	0.401
5	1.810	11767.835	1793.810	0.153	0.768
6	1.271	8252.108	1789.967	0.087	0.764
7	1.119	4813.295	1789.807	0.082	0.589
8	1.441	9626.372	1794.064	0.106	0.783
9	1.192	6075.649	1793.924	0.087	0.643
10	2.216	14839.201	1798.648	0.200	0.800
11	1.665	10291.567	1793.540	0.138	0.729
12	1.134	5534.586	1792.210	0.080	0.632
13	2.069	13695.301	1794.047	0.183	0.787
14	1.711	11117.224	1792.007	0.141	0.767
15	1.538	10272.605	1793.064	0.118	0.785
16	2.009	12713.312	1794.141	0.179	0.744
17	1.380	8859.115	1786.316	0.101	0.760
18	2.179	4301.717	1791.392	0.197	0.781

5. CONFIRMATION RUN:

After determining the Pareto optimal combination of parameters, the MRR and Surface roughness are verified by conducting the confirmation experiments. The confirmation test is carried out with the any set of optimal parameter combinations, listed in Table 6.5 and the results are tabulated in Table 6.6, and the error is 0.03 for Ra and 0.07 for MRR. It is clear that the MRR and SR increased greatly with the optimal parameters.

Table 6.6 Confirmation test results

Parameter	Level	Optimal/Predicted		Experimental		Error (%)	
		Ra	MRR	Ra	MRR	Ra	MRR
Speed	1792.007	1.71	11133.06	1.68	11124.32	0.03	0.07
Feed	0.141						
Depth of Cut	0.767						

6. Conclusions:

Speed found to be the most significant factors influencing all responses investigated for both the experiment sets.

Pareto Optimal solutions give the best quality with rapid machining.

Confirmation test gave the least error and confirms the optimal parameter combination set.

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