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OPTIMIZATION OF MILLING PARAMETERS FOR HDPE PLASTIC USING GENETIC ALGORITHM

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Abstract: **In this project work applied Genetic algorithm optimization technique to determine best machining parameters for milling process of HDPE(High density polyethylene) using CNC milling machine where the surface roughness and material removal rate is considered and High speed steel tool is used as cutting tool. Three machining parameters; spindle speed, feed rate and depth of cut are investigated at three levels, low, medium, and high for each parameter. The experiments were conducted based on L27 Orthogonal array. It has been noticed the influence of the spindle speed, feed rate and depth of cut on Material removal rate and Surface roughness on milling process. The regression analysis is developed by using MINITAB 17. Genetic algorithm (in MATLAB R2017a) is used for optimization of responses to indicate that the significance of these process parameters.**

Keywords: **CNC Milling, Genetic algorithm, High density polyethylene, MINITAB17, MATLAB R2017a.**

I INTRODUCTION

Plastics have been widely used in various applica tions in the manufacturing sector in the present days. Plastics are organic materials produced with macro molecules composed atom of chains. They are made of essential synthetic crude materials called monomers, which are mainly separated from petrochemical ventures. Across several sections such as precision equipment, electronics, optics and mechanical components such as bearings, gears, pump parts, bushings, valve parts etc., the use of plastic with greater characteristics has been increased. Because of the need of high dimensional exactness and better surface completion segments of plastics ought to be created by methods for machining forms as opposed to embellishment forms.

In the manufacture of plastic components, injecti on, extrusion orcompression molding methods ar e generally applied. The procedures that are customarily utilized in the creation of segments in plastics don't offer the exactness required by the applications.

When the aim is to produce high dimensional pre cision plastic components, the machining process is applied as the final procedure. During machini ng, the plastics reaction depends mainly on the m echanical, thermal and rheological properties.

The plastics response during machining depends primarily on the mechanical, warm and rheological properties. The specific machining characteristics the material to be used should therefore be assessed in any evaluation of the machining attributes. During the machining mechanism, heat is triggered by deformation and friction between the chip as well as tool & between tool and job portion.

Milling is one of the activities that employ a multi-point cutting tool called a cutter to generate smooth, contoured and helical surfaces. The Milling is a machining activity that feeds a work piece with numerous cutting edges through a revolving cylindrical tool. The rotation alliance of the tool is vertical to the feed vein. In the production of a high quality product, surface finishing of any machining process is very vital. It gives high impact to the efficiency and confidence of the client as well as the company's trustworthiness. The surface harshness was observed to be harmed by various issues regarding material characteristics, rate of feed, harshness of job, cutting speed, cutting time, cutting edge angles, reliability of machine tools and many more.

II LITERATURE REVIEW

J.L.C.Salles, Gonclaves, Ultra high molecular weight polyethylene was tested on the superficially finish to scrutinize the cutting action of surface harshness. In turning surface harshness, the influence of cutting speed and feed rate was observed. The surface completion was tried by assessing the normal surface unpleasantness and the surface picture investigation, assessing the activity on the device utilized and recognizing the impact of parameters superficially finish of thermoplastic material [1]. M.Alauddin, M.A.El Baradie, gave a survey on plastics and their machining by ordinary strategies like Drilling, Milling, and Grinding. In Milling Cutting paces ought to never fall beneath 300m/min and the surface completion will improve with better feeds independent of the profundity of cuts utilized. Clarified general thought regarding machining of plastics and the possibility of grinding, milling, drilling of thermosets and thermo plastics [2]. S.Husin,S.Said, J.Abdul Shukor,Ab.Kadir; Applied Taguchi strategy to discover machining parameters for polypropylene pocket processing utilizing a CNC processing machine where surface unpleasantness is considered and fast steel embeds are utilized as cutting apparatus. Experiments were conducted using L9 Orthogonal array, taking into account spindle speed, feed rate and cut depth as parameters for machining. Slots were built for observing surface roughness on the work piece content of Polypropylene. The optimum parameters obtained were the cutting speed of 4138rpm, the feed rate of 1241mm / min and the cutting depth of 0.5 mm and the corresponding surface roughness of 0.5999µm [3]. Milan.D Selvam, A.K.Shaik Dawood, applied Taguchi strategy and GA for limiting surface unpleasantness in machining steel. The investigations did in a FANUC arrangement CNC Vertical machining focus. The analyses were led dependent on Taguchi L9 OA. The machining parameters considered were number of passes, profundity of cut, spindle speed, rate of feed. The procedure of improvement is done utilizing Genetic algorithm streamlining instrument in MATLAB. The impact of machining on surface harshness is assessed and the ideal cutting conditions for limiting the surface unpleasantness is speed 1999rpm, feed rate 497.7mm/min, profundity of cut is 0.1162mm, number of passes is 3. The affirmation tests has been directed at ideal degrees of machining and the deviation between anticipated worth and affirmation test is 4.625% [4]. Kannan.S, Baskar.N; carried out investigation on machining of Aluminum using Tungsten carbide inserts on CNC Milling machine to measure the material evacuation rate and surface harshness considering machining variables as profundity of cut, feed rate and spindle speed. Utilizing the RSM (Response Surface Methodology) technique for analyze the parameter contribution with ANOVA technique and build the model with regression analysis. The combined objective function is formulated based on the empherical equations of surface roughness and material removal rate. The best parameter values are spindle speed 1917rpm, feed rate 1600mm/min, and profundity of cut is 1.49mm and the corresponding material removal rate is 88580 mm3/min, surface roughness is 1.8µm. For better surface completion the most extreme degree of cutting pace with least degree of feed and profundity of cut is prescribed [5]. M.Tolouelrad and I.M.Bidhendi, on the optimization of machining parameters for milling operation. Identification of relationship between machining variables and responses are important for manufacturing industries [6]. D.Bajic, B.Lela, D.Zivkovic Modelling of machined surface roughness and optimization of cutting parameters in face milling, A set of investigations were conducted in the Design of Experiments to evaluate the impact of cutting factors such as feed rate, depth of cut and cutting speed on surface harshness in face milling operation [7], Juan C Campos Rubio1, Tulio H Panzera2 and Fabrizio Scarpa3 Machining behaviour of threehigh-performance engineering plastics such as Ultra high molecular weight polyethylene, Polyacetal, Polyoxymethylene has been observed effects of Drilling parameters [8]. M. Sindhusha, N. Naga Krishna; studied on influence of Milling parameters on surface roughness of Nylon material using Taguchi method by varying the parameters such as spindle speed, feed rate and depth of cut. Experiments are conducted on CNC Vertical milling machine by considering machining parameters and evaluated the surface roughness values. L9 Orthogonal array was used to conduct the experiments. Design of experiments is done using Taguchi technique in Minitab software [9]. Vasanth Kumar. R, B. M. Preetham; examined the role of machining parameters on surface harshness for different engineering materials such as Acrylic and Polyamide. The tests are led on turning machine. It has been seen that the cutting pace slightly affects the surface unpleasantness. [10].

III MATERIALS AND METHODOLOGY

WORK PIECE MATERIAL

HDPE (High Density Polyethylene) is identified for conducting experiments, as they most extensively used material in industries. Size of the work piece material is 75x75x10 mm as shown in figure. HDPE is a low cost liner

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structured thermo plastic extracted either from natural gas refining or crude oil catalytic fracking into gasoline. It is used for making Pump parts, Valve parts, Bushings, Bearings, Washers. It is now most frequently used plastic since its cost is low while it gives material properties that are pertinent for some modern industrial applications.

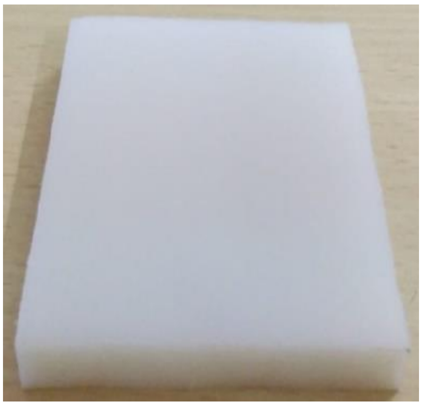

Fig 1 High density polyethylene

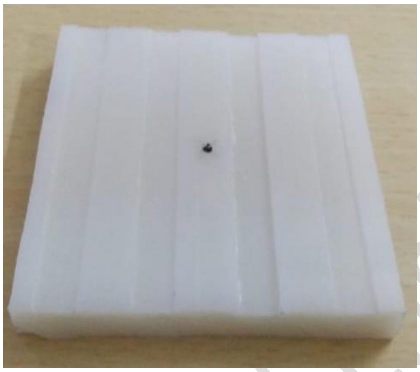

Fig 2 Slots produced on the work piece

TOOL MATERIAL

The selected tool material for this experiment is HSS (High Speed Steel). This tool material is fundamentally high carbon steel, to which the unique alloying materials have been applied in greater volumes to improve hardness, toughness and wear resistance properties. This tool material can possess its hardness up to 600°C and so can be operated at much higher cutting speeds, hence the name "High speed steel". The size of the tool is a crucial factor in evaluating the material expulsion rate. For this experiment the tool diameter considered as 6mm is appeared in below fig 3.

Fig 3 High speed steel end mill cutter

EXPERIMENTAL DETAILS

The experiments were comprised employing orthogonal array utilizing DOE (Design of experiments).DOE is capable of working on which we can display and breakdown effect of particular procedural variables generally referred to as response variables. There are numerous sorts that can be found within DOE. Amongst the most frequently recognized is the concept of orthogonal array. Among this investigation the surface ruggedness and suppression rate of High density polyethylene material was anticipated and customized by taking, rate of feed, spindle speed and cutting depth variables. The rate of feed, spindle speed and cutting depth of three levels are considered. For this analysis L_{27} orthogonal array was chosen. The response was recorded and further analyzed from the tests conducted as per L27 OA experimentation. The real cutting variables utilized for each trial preliminary and the comparing estimations of estimated MRR and Surface harshness acquired. The range and levels of machining parameters appeared in table 1.

Machining Parameters	Units	Ranges		
		Level 1	Level 2	Level 3
Spindle Speed	rpm	1000	1200	1400
Feed rate	mm/min	150	175	200
Depth of cut	mm	0.6	0.8	1.0

Table 1 Ranges and levels of input parameters

Machine Specifications

MTAB XL MILL THREE AXIS VERTICAL CNC MILLING MACHINE was used for conducting the experiments and it is shown in below figure 4

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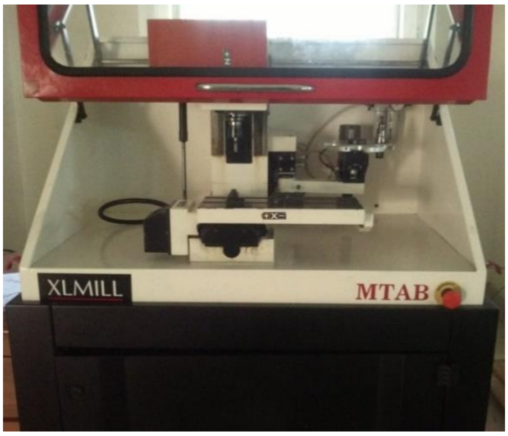

Fig 4: MTAB XL MILL CNC MILLING MACHINE

Specifications	Units	XL MILLS
movements		
X-axis	Mm	225
Y-axis	Mm	150
Z-axis	Mm	115
Space between table top and spindle nose	Mm	70-185
Table		
Table dimensions	Mm	360 *132
Spindle		
Spindle monitor capacity	HP	0.5
Programmable spindle speed	Rpm	150-4000
Spindle nose taper	-	BT 30
Accuracy		
Positioning accuracy	Mm	0.010
Repeatability	Mm	±0.005
Feed rate		
Rapid traverse X Y Z axis	m/min	1.2
Programmable feed rate X Y Z axis	Mm/min	0-1200
ATC Unit		
Tool storage capacity	Pcs	6
Maximum tool length	Mm	40
Maximum tool diameter	Mm	16

Table 2 Machine specifications

Measurement of responses

The machining is observed to complete the machining operation on work piece material. The rate of extraction of material from the machining is referred to as material clearing rate and is measured in g/min. The surface brutality analyzer MITUTOYO SURFTEST SJ201 is utilized to gauge the surface harshness of machined work piece and is measured in µm. The surface harshness and Material evacuation rate values are calculated and tabulated in the below table 3.

Exp. no	Spindle Speed (rpm)	Feed rate (mm/min)	Depth of cut (mm)	Material removal rate (g/min)	Surface Roughness Ra(µm)
1	1000	150	0.6	1.4298	0.67
2	1000	150	0.8	1.0854	0.83
3	1000	150	1	1.6662	0.84
4	1000	175	0.6	1.6482	0.79
5	1000	175	0.8	1.374	0.58
6	1000	175	1	1.4148	0.69
7	1000	200	0.6	1.6548	0.71
8	1000	200	0.8	1.6896	0.74
9	1000	200	1	1.6158	0.81
10	1200	150	0.6	0.69	0.7
11	1200	150	0.8	1.0704	0.5
12	1200	150	1	1.7718	0.73
13	1200	175	0.6	0.8664	0.46
14	1200	175	0.8	0.849	0.4
15	1200	175	1	1.875	0.76
16	1200	200	0.6	1.4276	0.62
17	1200	200	0.8	1.4238	0.83
18	1200	200	1	1.44	0.52
19	1400	150	0.6	0.7308	0.43
20	1400	150	0.8	1.4454	0.74
21	1400	150	1	1.7874	0.84
22	1400	175	0.6	1.4232	0.79
23	1400	175	0.8	1.6698	0.79
24	1400	175	1	1.713	0.81
25	1400	200	0.6	1.5482	0.67
26	1400	200	0.8	1.6042	0.76
27	1400	200	1	1.8947	0.69

Table 3 Experimental design using L27 Orthogonal array and their responses

Mathematical modeling

Mathematical modelling is a better statistical approach used to test the response effects for various input parameter combinations. This method of data evaluation helps to find optimal cutting conditions in theoretical decision making. Regression Analysis can be used to extract the mathematical model and is done in MINITAB 17.Analysis of Regression produces a formula for defining the statistical relationship between explanatory variables and responses. Multiple linear regressions are a mathematical technique for estimating the connection among one dependent variable and two or several explanatory variables in a linear equation.

The mathematical models of Material removal rate and Surface harshness for this work is deduced are shown in below equations

$$MRR = -0.436 - 0.000001 * S + 0.00617 * F + 1.001 * D$$

SR Ra = 0.551 – 0.000086*S - 0.00004*F + 0.289*D

Where S is spindle speed in rpm, F is feed rate in mm/min, D is depth of cut in mm.

OPTIMIZATION

Optimization is indeed the strategy to effectively acquire a viable solution from the key sources available in system. To acquire practical estimations of Material repulsion rate and Surface unpleasantness from noteworthy parameters profundity of cut, feed rate and spindle speed a methodology of streamlining Genetic Algorithm is applied.

1V GENETIC ALGORITHM

A genetic algorithm is a deterministic quest that is enlivened by the hypothesis of normal development of Charles Darwin. This algorithm exemplifies evolution mechanism in which the predominant desirable participants are picked for replication in order to achieve future offspring. By binary encoding the cutting parameters are represented as genes to apply Genetic algorithm to enhance the machining variables. A group of genes is well organized to creation of alleles, which are used to achieve the intrinsic mechanism of GA. In a genetic algorithm five steps are called Initial population, fitness function, selection, crossover and mutation. The procedure starts with a gathering of people which is called populace. Every individual is described by a lot of factors known as qualities. Qualities are joined into a string to shape chromosome. The fitness feature dictates of an individual ability to compete with other competitors. It provides each individual with a fitness score. Premised on the fitness ratings two pairs of individuals are picked. High fitness individual are more likely to be picked for reproduction. Hybrid is the activity to trade some piece of two chromosomes to produce new prosperity. Mutation is incorporated on crossover to give a faint arbitrariness to the new clusters. The encoded cutting conditions are decoded from the chromosomes to determine each individual or chromosome and use to predict the quality of machining performance. Objective function is a necessary feature in the genetic algorithm virtualization process and collection of next generation in genetic algorithm. Adequate results of cutting conditions are acquired after a series of evaluations by assessing values of the subjective functions between all individuals. The Genetic algorithm variables are forced on the GA improvement strategy together with important target objectives and set of machining imperatives to guarantee ideal cutting conditions. The procedure of enhancement is completed using GA tool in MATLAB 2017a.

Genetic Algorithm conditions and parameter constraints

Population type	Double vector
Population size	50
Number of variables	3
Initial size	1000, 150,0.6
Final range	1400, 200, 1
Selection function	Tournament selection
Crossover function	Two point crossover
Crossover fraction	0.8
Mutation function	Constraint dependent
Mutation rate	0.1
Migration	Forward
Total number of iterations	400
Level of display	Iterative

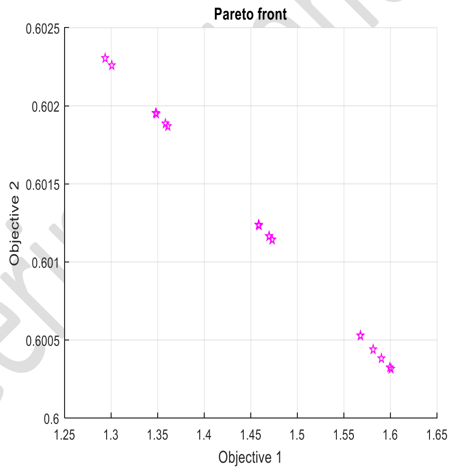

Fig 4 Plot of objective 1 VS objective 2

From the Fig 4 Material evacuation rate and Surface unpleasantness value is found out as 1.600587g/min and 0.600314µm.

V RESULTS

Optimum machining parameters

From the mathematical computation the ideal arrangement of machining variables came to find, it is given in underneath table4.

Spindle speed (rpm)	Feed rate (mm/min)	Depth of cut (mm)
1356.26	199.77	0.6

Table 4 Optimum machining parameters

Affirmation experiment for Genetic algorithm

The validation experiment have done at ideal degrees of machining parameters and the outcome was found as appeared in the below table 5.

Parameters	Experimental values	Predicted values	Error (%)
Material removal rate(g/min)	1.600587	1.525	4.68
Surface roughness (µm)	0.600314	0.58	3.38

Table 5 Results for Genetic Algorithm

The contrast between the anticipated value and the affirmation test value for Material evacuation rate is 4.68% and for the Surface unpleasantness is 3.38%.

CONCLUSION

The influences of spindle speed, depth of cut and feed rate have been studied. The experiment was carried out on High density polyethylene thermoplastic material and collected data has been analyzed using Genetic Algorithm. Mechanical properties (like toughness, rigidity, stiffness) of some polymers are like metals. So these types of polymers can replace metals. Also when contrast to metal goods, the cost and weight of plastic products are also lower. Plastic machining is preferred to achieve high dimensional precision and desired surface roughness of plastic components.

In reality, the investigation of plastic machining reveals that machining on plastics is not exclusive to all. It is therefore important to assess the impact of machining parameters individually for different plastic materials. In the field of machining, numerous examinations are completed on distinct metallic materials. Literature on machining of metals and alloys are readily ubiquitous. There are very limited researches on plastic machining. Therefore, literature is substantially less in this field. Therefore, plastic machining furthermore needs to be explored extensively.

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