Study of Machining on Surface Roughness of Engineering Plastics

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***Abstract*—Now a days plastic has been widely employed in the industrial sector. Due to the need of high dimensional accuracy and good surface finish, components of plastic for these ends should be produced by means of machining processes instead of moulding processes. The operational characteristics of machine-parts have an effect on the surface formed during machining. The surface micro geometric measuring and characterizing are mostly standardized so it is suitable to compare certain types of surfaces. Wide-ranging set of parameters is available to characterize the surface texture. These plastics can be produced powder or granule products, semi-finished products (bars, pipes, plates etc.) finished product respectively which depend on basically their further processing methods. Among the important group of engineering plastics, we have carried out cutting experiments with Cast polyamide 6, Acrylic, and UHMWPE materials. The cutting process, within this using turning at machining plastic for nowadays has got great importance and is mainly sole in repair technology. The spreading of engineering plastics cut compelled the tool manufacturers to develop tools suitable machining plastics, too.**

Keywords—plastics, machining, surface roughness, regression analysis, machine tool

I. INTRODUCTION

Nowadays plastic has been widely employed in the industrial sector. The use of plastic with superior characteristics has increased in several sections such as equipment of precision, electronics and optics. Due to the need of high dimensional accuracy and good surface finish, components of plastic for these ends should be produced by means of machining processes instead of moulding processes. In many cases, [10] the plastic-machining now in use are simply the result of know-how gained from previous experience. In addition, most machining methods depend on the use of existing machines and tools developed for the fabricator of wood and metals, and little has been done to develop cutting equipment or methods especially suited to plastics. According to Kulkarni [4], the deformation and fractures in metals occur along crystalline planes; in plastics, the fracture can happen among amorphous and crystalline areas. Carr and Feger [11] describe the theory of viscoelasticity of the polymer by the way that the material responds to a disturbance. Thus, it has been rather difficult to machine all plastics successfully, owing to the many kinds and grades of plastics available and the lack of a basic understanding of their inherent machinability. There are several different methods of roughness measurement in use today. In this article we will talk about only two of the many methods of roughness measurement, how to convert between these two methods and how to avoid the problems caused by the inevitable use of more than one roughness measurement. The primary goal of our research work is to evaluate and to analyse the parameters of surface roughness of engineering plastics machined by turning. Further important task is to work out the requirements of suitable surface planning of expected operational behavior of surfaces produced during machining plastic parts. The most important viewpoint was that the experiments results should be useful for engineering practice too. The connection between the surface micro geometry and the technological data at cutting of engineering plastics now a days are not yet revealed properly.

We have selected some thermoplastics types among the engineering plastics as test material which fulfill decisive role in engineering application to discover function-relations with empirical relations taking into account the effect of must influencing factors too by examining the Brammertz-formula.

($R = C \times x1v \times x2f \times x3a$) function-relation with experiment planning method, in which the parameters selected is Ra (average roughness) and the Rz (unevenness height), the set out factors are the cutting speed (v), the feeding (f) and depth of cut(a).

II. EXPERIMENTS

A. Materials

Nylon 6 or polycaprolactam is a polymer developed by Paul Schlack at IG Farben to reproduce the properties of nylon 6, without violating the patent on its production. Unlike most other nylons, nylon 6 is not a condensation polymer, but instead is formed by ring-opening polymerization. Its competition with nylon 6 and the example it set have also shaped the economics of the synthetic fiber industry. It was given the trademark Perlon in 1952. It is a semi crystalline polyamide.

Acrylic is used for products that contain a substance derived from acrylic acid or a related compound. Most often, it is used to describe a clear, glass-like plastic known as poly (methyl) methacrylate (PMMA). PMMA, also called acrylic glass, has properties that make it a better choice for many products that might otherwise be made of glass. There are two basic types: extruded and cast.

Extruded acrylic is made through a process in which the liquid plastic is pushed through rollers, which press it into sheets as it cools. This is a comparatively inexpensive process, but the resulting sheets are softer than cast acrylic, can scratch easier, and may contain impurities. Extruded acrylic is still generally considered to be good quality, and is usually the more common type made available.

Cell cast acrylic tends to be of higher quality than extruded, but it's also more expensive. In cell casting, single sheets are made by pressing the liquid plastic between pieces of a mold, often made of glass, which is then taken through a gradual heating process. The resulting sheet is stronger than extruded acrylic.

Ultra-high-molecular-weight polyethylene (UHMWPE, UHMW) is a subset of the thermoplastic polyethylene. Also known as high-modulus polyethylene, (HMPE), or high-performance polyethylene (HPPE), it has extremely long chains, with a molecular weight usually between 2 and 6 million. The longer chain serves to transfer load more effectively to the polymer backbone by strengthening inter-molecular interactions. These results in a very tough material, with the highest impact strength of any thermoplastic presently made.

B. Selected Specimen description

POLY AMIDE-6	30mm dia. Length 400mm
ACRYLIC	30mm dia. Length 400mm
UHMWPE	30mm dia. Length 400mm+

C. Methods

2.1 Engineering plastics machining by cutting: The primary forming of plastics is the hot-forming (injection-moulding, extruding, etc.). However as a secondary process the cutting gets also important role, especially at such parts with accurate, complicated shape. Some reference to cutting circumstances of various plastics can be found in the technical literature. Studying the literatures referred it can be established that every company producing or selling plastic ,semi-finished product suggests cutting data within very wide range for cutting certain plastics.

1. The following conditions influence the cutting of plastics generally:

2. The dimensional change of certain plastics caused by temperature is ten times higher than the metals.

3. The most suitable is using fine-grain tip for turning with using accordingly great relief angle.

4. The work piece supported accordingly restricts the tool inclination.

5. Optimum result can be expected only by collective and proper choosing of champing, tool material, edge geometry and of cutting data.

2.2 The cutting experiment : We have carried out the cutting on a centre lathe of 2hp motor inside the institute. The machine-tool was well conformed to my experiments, its condition can be still qualified excellent. After running different data combinations there was always possibility to collect chips respectively to prevent sudden events (for example: chip stuck, tool barbing, etc.

2.3 Parameters selected for turning: We have selected the cutting data combinations of certain experimental settings as well as the turning tools used taking into account the technical literature suggestions. We have carried out turning operations in two phases .

During the first phase we performed the turning operation at constant speed and constant depth of cut varying the feed rates so that to analyze only the dependency of the feed rate on the microstructure.

While during the second phase we varied all the three parameters (speed, feed, depth of cut) for each turning operation so that to analyze the dependency of all the three parameters on the microstructure.

2.4 Turning tools : In selecting the turning tools i have taken the technical literature suggestions into account. Based on this I have selected the k10 carbide of YG6X grade tool applied to cutting experiments among the available.

2.5 Surface roughness measurements: We have submitted the work pieces cut to preliminary examination to a laboratory for testing surface roughness parameters of each specimen machined during each phase. We have carried out the 2D-la and 3Dal roughness examinations of machined surfaces with Olympus LEXT OLS4000 3D Confocal Laser Microscope.

2.6 Regression analysis: We have planned and carried out the examination with the experiment-planning method which is often used to examine the effects of cutting parameters. We have modeled with linear functions the values measured of the direction height characteristics (Ra, Rz) of roughness profile at the surfaces machined.

During the first phase analysis we modeled the regression equation depending only on single parameter (i.e. feed) and we modeled the regression equation making it dependent on three parameters (i.e. speed, feed, and depth of cut)

The characteristics (parameters) of surface roughness and the cutting data (factor) set can be described with the following function:

$$R = C \times X1V \times X2f \times X3a\ [\mu m]$$

Where C= constant and X1, X2, X3 = coefficient of speed, feed, depth respectively

We have completed the regression function examinations and evaluating the results with the Minitab15 statistical software. We have determined the coefficient of the dependent models, the standard deviation (s), and the value of determinant coefficient showing the correlation (R2) with the help of program.

2.7 1st phase Regression analysis: During the first phase of the turning, the velocity (480 rpm) 45.23m/s and depth (1mm) were kept constant at while the feed rates were altered during each machining 0.107, 0.112, 0.127 mm/rev.

2.8 2nd phase Regression analysis : During the second phase of the turning; the velocity, Feed rate, and depth of cut, each parameter were varied during machining and the Ra and Rz values were recorded with the help of TALLY SURF available in the college material testing laboratory.

Velocity (V) = m/sec

Feed rate (f) =mm/rev

Depth of cut (a) = mm

Ra = µm

III. RESULTS & DISCUSSION

From the Regression analysis, we observed that the relation co-efficient (R2) is comparatively low (57-68%). The p-value of the coefficient of feed for each material was observed to be lesser than the selected level (0.05). Hence the regression equation developed states a statistically significant and hence we can strongly reject the null hypothesis

In case of all the three selected materials, the regression analysis shows the correlation of the two equations of Ra and Rz lies between (57-68%). The observed p-value of the co-efficient of feed is lesser than the selected level (0.05). The observed p-values in all three cases lie between 0.041-0.050. Hence we can strongly reject the null hypothesis and can say that change in roughness of all three materials is brought up by the change in feed rate to some extent or the roughness is dependent on the feed rate.

A. Effects of feed rates on surface roughness (Ra & Rz)

3.1 1st Phase - Scattered plots of Ra & Rz versus speed, feed, & depth :

1) PolyAmide-6 (speed=480rpm, depth=1mm constant)

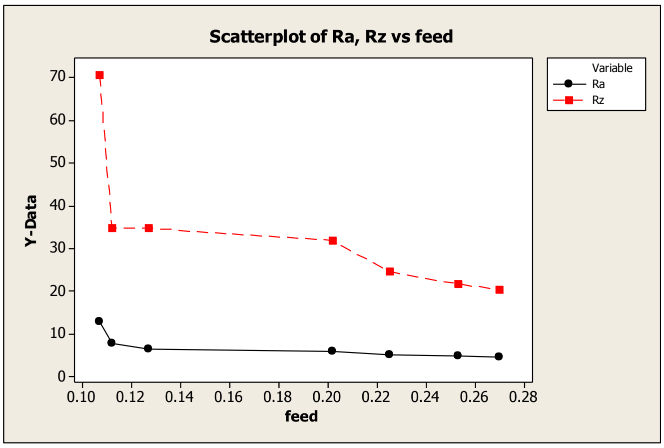

Fig. .1 Scatter plot of Ra , Rz vs feed

2) UHMWPE (speed=480rpm, depth=1mm constant)

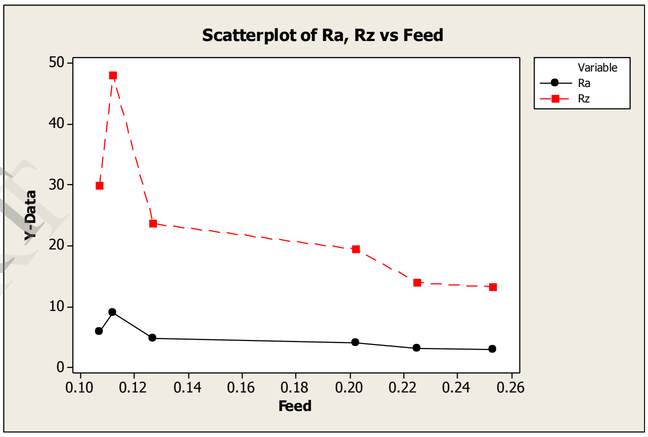

Fig. .2 Scatter plot of Ra , Rz vs feed

3) Acrylic (speed=480rpm, depth=1mm constant)

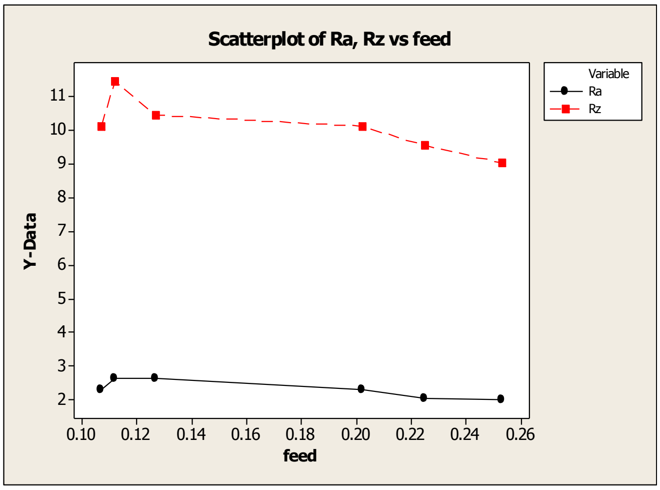

Fig. .3 Scatter plot of Ra , Rz vs feed

Once the machining was completed, we submitted the machined specimen in the lab for measuring the surface parameters. With the help of a software, its surface parameters were recorded which is tabulated above. After plotting the scattered plot of the Ra & Rz Vs Feed as shown in fig . 3, 4, 5, we observed that:

Feed rate directly affect the surface roughness. The plot shows that the small variation in feed affects the Ra value to a low strength while it causes great variation in the Rz value.

The plot also revealed the fact that machining with high feed rate at constant speed and depth cause low Ra and Rz values while machining with low feed increases the Ra and Rz.

3.2 2nd Phase- Scattered plots of Ra & Rz versus speed, feed, & depth :

PolyAmide-6

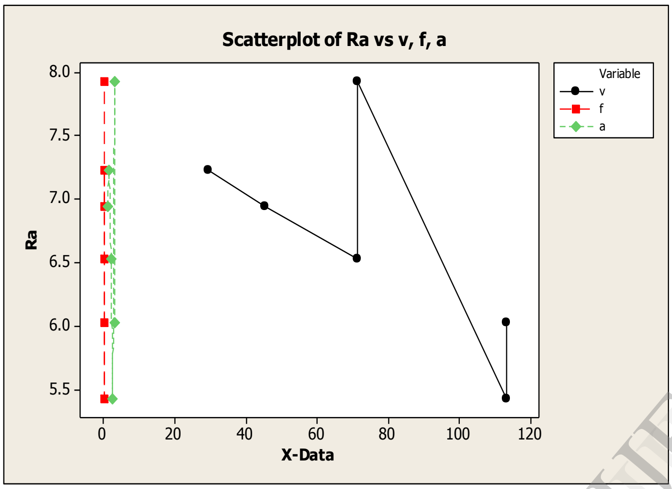

Fig .4 Scatter plot of Ra vs v, f, a

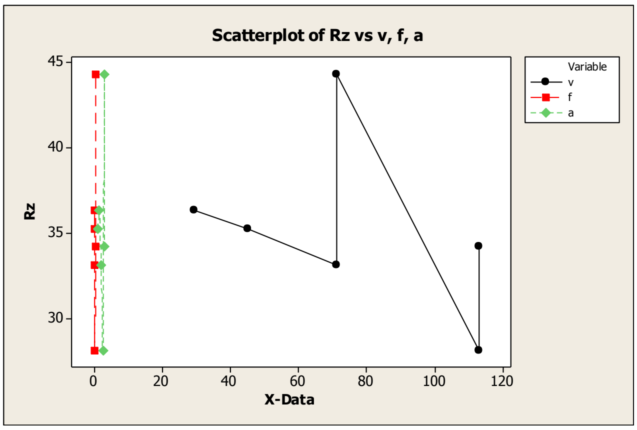

Fig .5 Scatter plot of Rz vs v, f, a

Acrylic

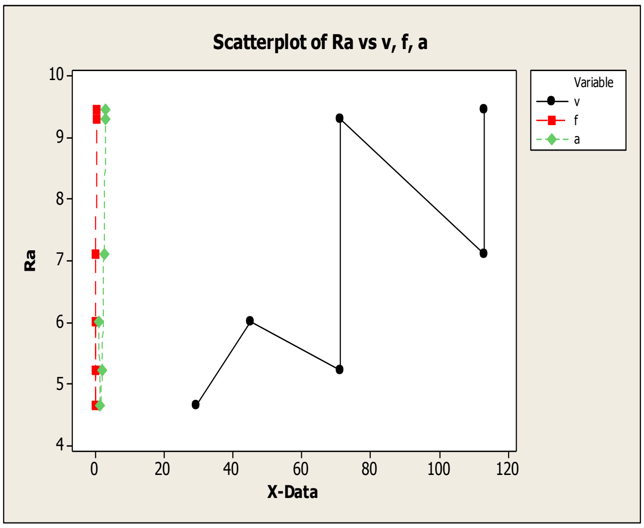

Fig .86 Scatter plot of Ra vs v, f, a

From the scatter plots as shown in fig .6, 7, 8, 9, it is observed that the graphical behavior in the change in Ra and Rz for all the three selected materials is similar to much extent. This is due to the fact that the change in Rz is a function of Ra. The case observed was that the Rz values are well in the multiplication ratio in the range of 4-5 times.

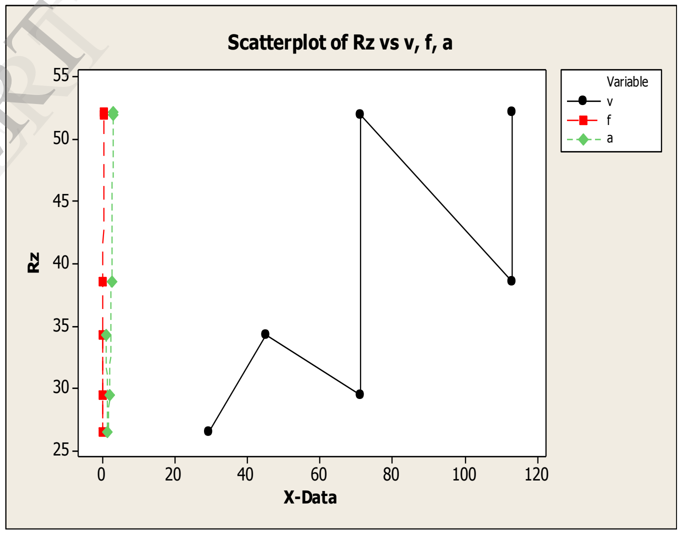

Fig .97 Scatter plot of Rz vs v, f, a

The result from the scatter plots was the fact that the cutting speed does not seems to have much influence on the surface roughness.

B. Discussion :

1. The second phase regression analysis of Ra and Rz relation with speed, feed, depth, shows a high co-relation coefficient (92-99%).

2.The regression analysis shows that though the standard deviation(s) were high enough, the p-value of the coefficient of all the three parameters for all the three materials were well below the selected level. Hence we can strongly reject the null hypothesis and obey the alternate hypothesis that the change in roughness is significantly brought up the change in the selected independent parameters (speed, feed, and depth.).

3. The regression analysis also shows the p-values of the independent parameters are well below the selected level (0.05). Hence we strongly reject the null hypothesis and proved the alternate hypothesis to be true in the cases to a maximum possible level so far.

4. From the graph it can be seen that while the speed were kept constant for two trials and only the depth of cut and the feed rates were varied, there is drastic change in the roughness value.

5. The scattered plot graphs of all the 3 specimen show that the feed rate and the depth of cut are the parameters strongly affecting the roughness while the speed do not have much contributions.

6. Important result was observed from the scattered plot of Ra and Rz versus Feed. The surface roughness value tends to be decreasing at higher feed rates (>0.270mm/rev) at constant speed of 480rpm and constant depth of cut 1mm.

IV. CONCLUSION

We have drawn up a complex cutting plan applying to three-type engineering plastics which gave possibility to examine the behavior of the individual materials during turning with peculiar consideration to the micro geometry of surface texture.

From the turning experiments carried out with single-point tool having regular edge geometry that the height directional micro geometric characteristics (Ra, Rz) of the surface machined the $29.13 \le vc \le 113$m/min cutting speed influences only in minimum way in the experimental range applied by me. This is contradictory with experiences at cutting steels. The conclusion is valid for the three engineering thermoplastics (PA 6, UHMWPE, and ACRYLIC) used in the experiment.

We have proved that the cutting speed has a slight effect onto the surface roughness examined in the experimental range determined by us. This differs basically from the experiences at cutting steels and metals.

The experimental results show into that direction that the cutting data-combinations can be still made more exact relating to the surface roughness at the semi-finished products of engineering plastics examined

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