

Analysis of Surface Roughness and Waviness During Diamond Turning of Polycarbonate



Engineering

KEYWORDS : crumb rubber, utilization, compressive strength, low cost, sustainable

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ABSTRACT

Plastics are very common materials that can be diamond turned and widely used in optics and our ultra precise applications. Surface texture parameters (Roughness and waviness) are very important considerations in these applications. In this experiment single point diamond turning is done on polycarbonate for about 200Kms length of machining. Surface roughness and waviness are plotted against machining time after certain no. of cycles. After machining 9Kms, surface roughness value was less than 15nms. With increase in machining time Ra values was increasing. Machining was stopped when roughness value crossed 70nm. Waviness also increased with machining time. Waviness was below 1 μm up to 7 Kms. Further machining resulted in increased waviness. As polycarbonate is plastic, linear trend is seen in both roughness and waviness.

INTRODUCTION

Tool wear is one of the major effecting parameter that causes changes in the surface roughness and waviness. Gradual wear or chipping on the cutting tip may lead to affect the roughness values. [1-2] machining environment (temperature, humidity etc) and cutting conditions have important role in ultra precise processes, so these factors are to be controlled. [3]. Generally, MQL (minimum quantity lubrication) turning has better surface roughness compared with wet turning, as cutting forces are similar in wet and MQL turning. If only surface roughness and cutting force are main requirement, switching from wet turning to MQL turning could affect environmental and economical advantages[4]. Studies have been performed to see the effect of work piece hardness and vibrations between tool work piece interface on the roughness of machined work piece[5-6]. A study to develop the artificial neuro network to online access the surface texture was done, which was more effective and efficient for Ra measurements in turning operations [7]. Figure1 shows the surface texture elaborating surface roughness. Further researches were carried out to see the effects of machining parameters on the surface roughness during

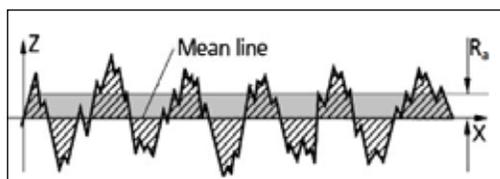


Figure 1 : surface roughness denoted as Ra

Machining of stainless steel, tool feed rate is most effecting parameter among the all parameters [8]

Surface roughness of aluminium alloy is less than that of aluminium alloy composites during turning also resulting in more tool wear during turning of Al alloy composites as compared to Al alloys [9]. In this study single point diamond turning operation for the experimental analysis of surface roughness and waviness of plastic with increase in machining time. A diamond tool is employed having HSS shank. Roughness and waviness of the work piece after required number of cycles is calculated. Also optimum machining parameters have been obtained e.g. spindle speed, tool feed rate, Depth of cut. Dry machining is carried out as tool work piece interface temperature is not so high.

EXPERIMENTAL SET-UP

• Equipment and metrology

In this experiment, Taylor Hobson nanoform – 250 for diamond turning was used. LVDT and dial gauge are used for proper tool positioning and work piece centering. Achievable accuracy in this set up is about 10nm.

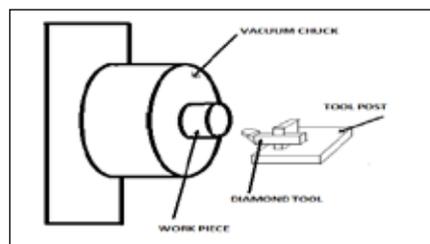


Figure 2 : SPDT set up

Diamond turning set up is shown in fig. 2. Machine has T-base configured hydrostatic bearing slides which helps to control Slide movements in X and z directions in nm and an aerostatic bearing work piece spindle Work piece is held in vacuum chuck and tool is mounted on tool post. Chip extractor is also used (not shown in fig.) for proper machining. Taylor Hobson PGI talysurf series -2 for metrology purpose was used. Figure3 shows the profiler set up (maximum travel of 120 mm). Stylus tip is placed on the surface at required pressure and moved over the machined surface. Values for roughness and waviness are measured

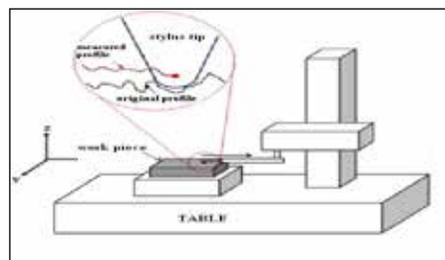


Figure 3 : Contact type profilometer set up

Source:www.googleimages.com/contacttypemechanicalprofilometer.

• Cutting tool and work material

A polycarbonate work piece having diameter 44mm and 12mm thickness is used for experimental analysis. Rockwell hardness of polycarbonate is M70. This material is selected because of its wide range of applications in optics, automotive, camera, com-

munication, electric and electronic parts. As polycarbonate is a soft material, Tool wear was very small even after machining for large lengths. A single point diamond tool (single crystal) having tool nose radius 0.5mm , 0° rake angle and 10° clearance angle is employed . Diamond crystal has 8000knoop hardness.

**TABLE - 1
CUTTING CONDITIONS FOR ANALYSIS**

s.no	Machining parameter	level
1	Spindle speed	2000RPM
2	Depth of cut	15μm
3	Tool feed rate	1μm/rev

With these cutting conditions, values for Surface roughness and waviness are measured after certain number of cycle

RESULTS AND DISCUSSION

• **Effect on surface roughness with machining time**

In figure 6. It is seen that Surface roughness is increasing with machining time. Initially for machining time up to 100 minutes, surface roughness was less than 20nm (refer figure 4). It was varying from 9 nm to 15nm. As the machining time increased, surface roughness value jumped above 30nm.Fig.4&5 are showing surface roughness patterns within 100 minutes and after 1400 minutes of machining

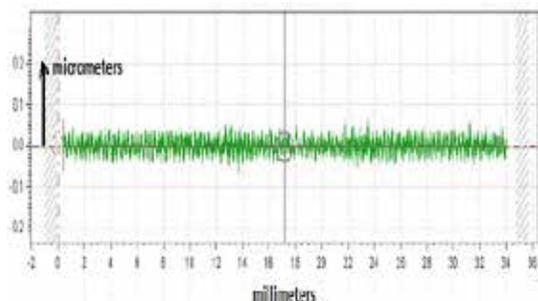


Figure 4: Ra-12.7nm, within 100 minutes of machining

After machining time near 200 minutes, it was near 40nm .After that with increase in machining time roughness values started varying between limits 39nm to 56nm.

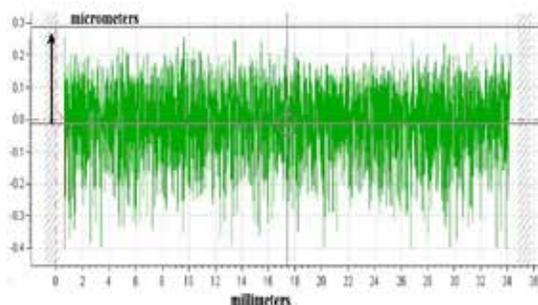


Figure 5: Ra-75.8nm, after 1400 minutes of machining

This trend is followed up to 1100 minutes of machining. Roughness value increased to 60nm up to 1200 minutes. Then after

further machined resulted in surface roughness value above 70nm (refer figure 5).

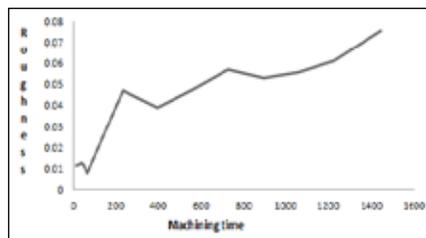


Figure 6: variation of roughness with time

• **Effect on surface waviness with machining time**

In Figure 7. A similar trend is seen in surface waviness variation with machining time. Initially for 40-50 minutes of machining, waviness was varying below 1μm.After that a sudden growth is seen in waviness value, it was near 1.2μm. After that waviness was nearly constant , Its value varied between 1.2μm-1.4μm. This trend was up to 1100 machining minutes .Further machining resulted in sharp increase in waviness values near about 1.9μm .waviness analysis can be divided into three regions (a) waviness value varying within 1μm(up to 50mins). (b) Constant waviness region (from 50-1100min). (c) Region in which waviness value lies between 1.4-1.9μm (1100-1440mins).

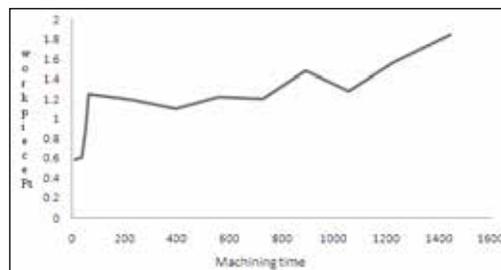


Figure 7: variation of waviness with time

• **Reasons for increase in surface roughness and waviness**

Major reason for increase in roughness values is tool wear. When machined with cutting edge having wear

on it, its worn out edge is projected on the machined surface resulting in degraded roughness. Cutting forces also affect the roughness, as cutting forces increases causes increase in roughness. Vibrations and noise can affect roughness value in precise machining. So, these are the main factors for increase in surface roughness.

CONCLUSIONS

1. Polycarbonate can be machined around100 minutes for very fine roughness, around 220 minutes for roughness near 40nm.
2. 220-1200minutes can be used for roughing operations as roughness value is varying between 40-60nm
3. After 1200 minutes, roughness value crosses 60nm and is rejected from view of ultra precise applications. It causes sub surface damage which increases machining cost and time wastage.
4. Surface waviness increases at very fast rate up to 50 minutes and it remains nearly constant for long time.
5. After machining for 1200 minutes, surface waviness again increases at high rate.

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