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INVESTIGATION OF TOOL OVERHANG LENGTH EFFECTS ON MACHINING RESPONSES DURING TURNING OPERATION

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Abstract: This paper presents an experimental investigation of tool overhang effects on machining responses on the surface roughness and chip morphology. Machining experiments were carried out on a conventional lathe machine using carbide cutting insert coated with TiC. Three levels for over-hang length was selected as the cutting variable viz. 20 to 70 mm keeping the depth of cut, feed rate and rpm constant. Through graphical and observational techniques, it was observed and concluded that the over-hang length had a significant effect on the surface roughness as well as chip behavior. These experiments led to the establishment of an optimum over-hang length value with promising result of surface finish quality and with little tool wear.
Keywords: Overhang length, Chip morphology, surface roughness, turning process

1. INTRODUCTION

In the turning process, the importance of proper selection of machining parameter is increased, as it controls the surface quality required. Several machining parameters, such as cutting speed, feed rate, work piece material, and cutting tool geometry have significant effects on the process quality. Many researchers have studied the impact of these factors. Wang S. T [1] studied the machined surface morphology based on machined feature as machining surface morphology plays an important role in the formation of surface roughness. L. G. Kong et al. [2] studied the vibration and surface roughness. Vibration of cutting process is an important factor to influence the surface roughness by analyzing the law of the variation of cutting parameters effect the amount of vibration and the surface roughness value and hence establishes the formula about vibration and surface roughness. Anayet U Patwari [3] studied the instabilities of the chip formation process during end milling of Ti6Al4V alloy and the influence of these instabilities on chatter formation to know the effects on surface morphology. Many research works has been conducted to predict the surface profile considering the different factors. S. Alam et. al [4] made a prediction model by adopting the RSM and desirability function. In study, small diameter flat end milling tool was used to achieve high rpm to facilitate the application of low values of feed and depth of cut to achieve better surface roughness. S. Tangjitsitcharoen [5] presented a surface roughness model to predict the surface roughness in the CNC turning of the carbon steel with the coated carbide tool under various cutting conditions by using the response surface analysis with the Box-Behnken design based on the experimental results. In actual turning process, the quality of the work piece is greatly influenced by the cutting parameters, tool geometry, tool material, turning process, chip formation, work piece material, tool wear and vibration during cutting. A high quality product with longer tool life may be achieved by proper selection of machining parameters and by direct monitoring of the cutting process [6]. In this study, the effects of cutting tool overhang length on the surface quality in external turning processes are investigated. The cutting tool overhang affects the surface quality, especially during the turning process, as it is known that cutting tools need to be clamped as short as possible to achieve the desired surface quality of the work piece. For the internal turning method in particular, the cutting tool should be attached with the proper length, not with the shortest distance. In this study, the effects on tool overhang length are investigated to know the surface profile behaviour with chip morphology analysis.

2. EXPERIMENTAL SET-UP

In this study, the tool overhang length has been considered as variable parameter, while keeping the depth of cut, the cutting speed and feed constant. The surface roughness of the work piece was measured and the chip size & morphology studied and analyzed. Experiments were carried out using a conventional lathe. Experimental set-up is shown in Figure-1. Cutting tool was a P10 grade-coated sintered carbide and HSS inserts (the standard DNMG150608 and PDJNR2525 type tool holders). The work pieces used in the experiments were 32 mm in diameter mild steel which is commonly preferred steel in the manufacturing industry, AISI 1050. This material contains 0.48–0.55% C, 0.17% Mn, and 0.69% Si, and has a hardness value of between 175 and 207 HV, depending on the applied heat treatment.

The tool overhang lengths were 20, 30, 40, 50, 60 and 70 mm. Depth of Cut is selected as 1.0 mm whereas the cutting speed and feed rate were selected as 530 rpm and 0.95 mm/rev, respectively.

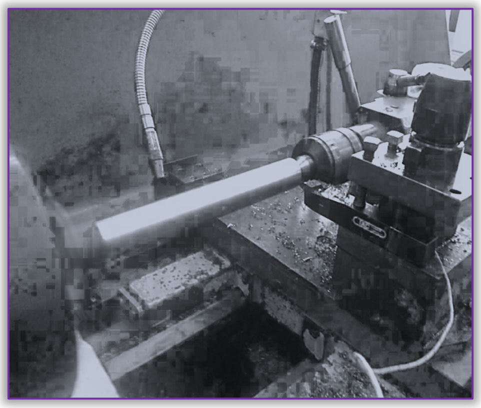


Figure 1: Experimental set-up used in this study

a) b)

Figure 2. Photograph of instruments used for chip analysis.
a) Polishing wheel, b) optical microscope

3. MEASUREMENT TECHNIQUE FOR SURFACE PROFILE AND CHIP MORPHOLOGY

In this study, measuring surface roughness and surface profile a portable stylus-type profilometer has been used. The Mitutoyo SURFTEST SJ-210, a contact profilometer, was used in this study as shown in Figure 3 (i) to measure the surface roughness of the machined surface. The chips formed during turning were mainly investigated and it has been found that at some specific cutting conditions chip formation presents extreme cases of secondary and primary chip serration.

Firstly, the chip at different cutting conditions were collected, labeled and kept accordingly. Then each chip was mounted using a mixture of resin and hardener. In the study, for the analysis of chip polishing wheel and optical microscope was used to process the collected chip for analysis. The equipment used in this study in shown in Figure 2. The mixture was stirred for about one minute and left to solidify. The solidified mixture is called mounting. The next step is to grind the mounting surface in order to reveal the chip to the surface. Various grade of abrasive paper are used starting with grade 240 followed by 400, 800 and 1200. In order to remove the scratches on the surfaces, the mounting is then polished using alumina solution starting from grain size 6.0 μ, followed by 1.0 μ, 0.3 μ and 0.01μ. As a safety precaution, before polishing; the mounting as shown in figure 3 (ii) is viewed under the microscope to ensure that the chip is visible on the surface. Finally, nitol is applied to the surface to reveal the grain boundaries of the ferrite and pearlite. Then the mounting is ready to be viewed under the microscope to capture the structure of the chip.

a) b)

Figure 3.(a) Measurement of the Surface Roughness;
(b) Preparation of chip for analysis

4. RESULTS AND DISCUSSION

Effects of overhang length on surface roughness

From the charts a comparative idea about surface roughness at each cutting conditions in different cutting environment can be obtained. As shown in the figure 4 surface quality at different overhang length keeping the feed, depth of cut and rpm same is presented.

From the graph, it is seen that the lowest roughness value (direct implication of the best quality) falls between the over-hang lengths 40 mm and 45 more or less. This implies that for the job diameter the best over-hang length for obtaining the better quality will be approximately 40 mm. The minimum surface

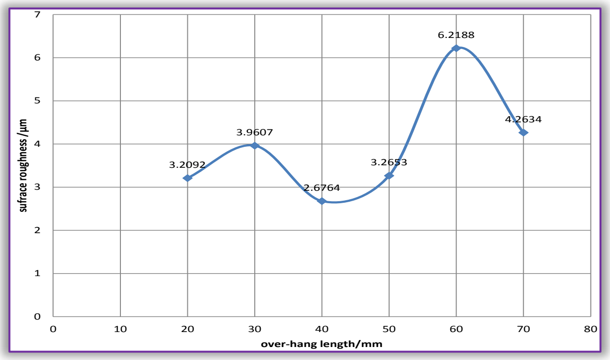


Figure 4. Effect of Overhang length on Surface Roughness

roughness at 40 mm overhang length is 2.6764 micro-m whereas as 60 mm overhang length the surface roughness is measured 6.2166 micro-m.

Variation of Chip structure with change in over-hang length:

After turning, sample of some of the chips for each experiment were collected, analyzed and observed. By observing the different chips at different overhang length the following observations is made. From the figures as shown in Figure 5, it has been observed that there is marked variation in the structure, shape and sizes of the chips obtained at different over-hang length.

- From the photos, it has been noticed that chips for overhang-length 20 mm, uncoiled and highly discontinuous.
- Chips from tool over-hangs 30 mm and 50 mm had similar structures but different sizes. The chips for tool over hang length 50 appeared a little bigger in size.
- Chips from tool over-hangs 40 mm and 60 mm had slightly similar structures; however, the sizes seemed different. The chips also looked curly but the chip at 40 mm looks more stable than chip formed at 60mm.
- The chips from the tool over-hang length 70 mm appeared highly disorganized and disorderly curled. This most have resulted from the vigorous acoustic and mechanical vibrations developed in the tool during operation, leading to high temperatures at the tool tip which led to high internal stress.

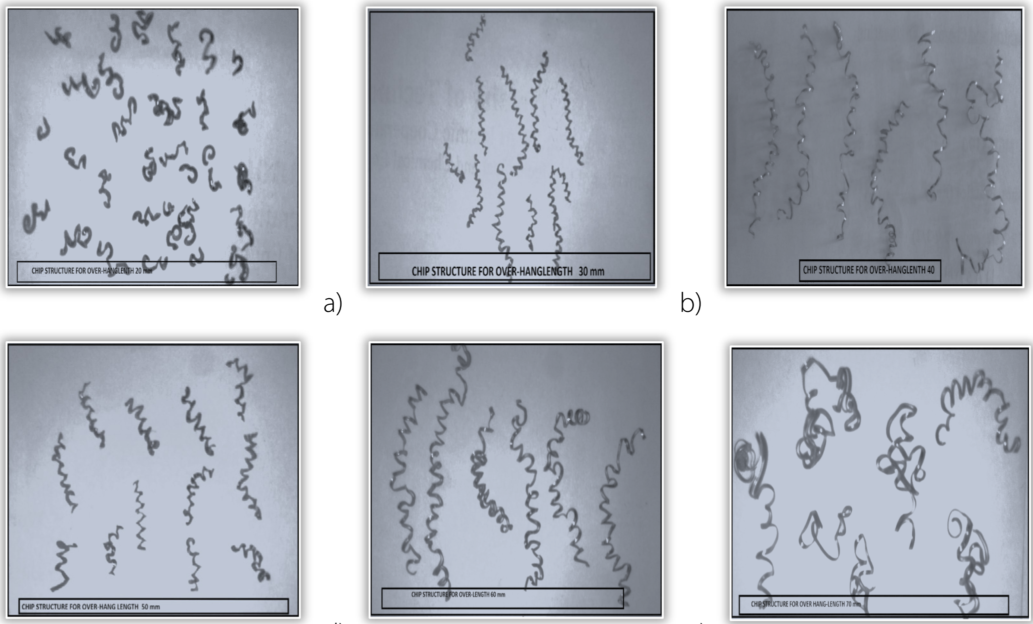


Figure 5: chip structure (a); for over-hang length 20 mm. (b); over-hang length 30 mm. (c) over-hang length 40 mm. (d); over-hang length 50 mm. (e); over-hang length 60mm. (f) over-hang length 70 mm

Tooth formation

Figure 6 below shows a schematic view of the chip showing where the chips were sectioned (along the line A-A) to be observed under the microscope as shown in Figure 6. This sectioning is done in order to observe more clearly the chip serration. The lengthwise cross-section view of the chips under optical microscope is shown in Figure 7.

The chip formation mechanism depends on the variation of several cutting parameters and particularly cutting speed. From Figure 7, it is clearly visible that the tooth of serrated chip is larger in case of unstable overhang length but in case of stable overhang length at 40 mm it appears that chip is less serrated and stable. This phenomenon is a clear indication of change in vibration characteristic of the system in different condition.

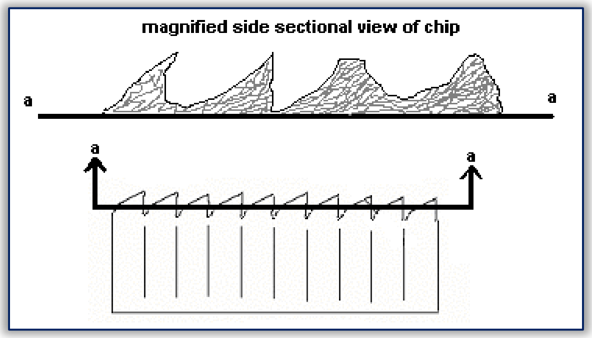
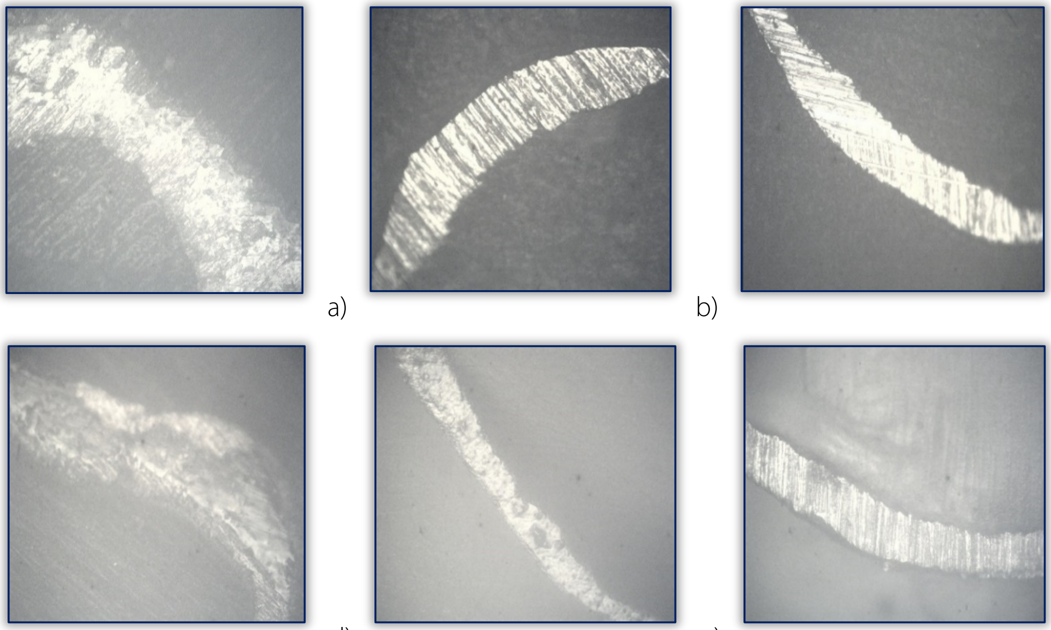


Figure 6. Section of chip formed at different cutting conditions [3]

These chips are formed by a localization of deformation and catastrophic shear resulting from the increase in hardness and brittleness of the material. Thus, the mechanism of the generation of these chips is based on the initiation of a crack followed by a slip. However, the change of the mechanism of chip formation is associated with the appearance of the shear instability. This instability originates from a competition between thermal softening and dynamic hardening of the machined material. This mechanism can be expressed by laws of the material behavior that takes into account the sensitivity to the strain rate, the strain hardening, and the thermal softening.



a) b) c)

d) e) f)

Figure 7. Microscopic view of the chip morphology (a); for over-hang length 20mm. (b); over-hang length 30mm. (c) over-hang length 40mm. (d); over-hang length 50mm. (e); over-hang length 60mm. (over-hang length 70mm

5. CONCLUSIONS

For recent industrial development and continuous progress, it is essential to determine a way to increase speed and feed rate to further increase productivity. But increasing speed and feed rates lead to problems such as tool wear, tool life reduction, and reduced surface quality among other problems. As a result, it is necessary to develop a new system or new approaches which fulfill this requirement. In this experiment, the effects on overhang length on surface roughness, chip morphology has been investigated to determine the suitability of over-hang length with coated carbide inserts so that with the proper selection of the overhang length the productivity will increase with the increased process parameters.

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ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665