TURNING OPERATION OF NICKEL BASED SUPERALLOY RENE 41

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Abstract- In the present work, the turning operation of superalloy Rene 41 was investigated in terms of surface quality of workpiece and wear behavior of cutting tool. In the experimental stage of this study, cutting speed and feed rate were used as the variable parameters and their influences were investigated using main effects plots in a full factorial experimental design. The results showed that surface roughness is mainly dependent on feed rate which results in a poor surface finish at high values. Although cutting speed is not a determining factor for surface roughness, surface quality is more prone to reduce as cutting speed increases. On the other side, the wear mechanism of cutting tool accelerates using elevated cutting speeds and feed rates.

Keywords- Turning; nickel based superalloy; surface roughness; wear.

I. INTRODUCTION

Aerospace applications provide an increase in flight range due to improvements in materials science for jet engines (Figure 1). In general, nickel, titanium, cobalt and iron based alloys are employed for the components of aero-engine systems depending on mechanical and thermal requirements. Nickel based alloys are the most preferred materials for aerospace applications. Rene 41 is a kind of precipitation hardening nickel based superalloy developed by General Electric and widely utilized for severely stressed high temperature applications such as hot section components in jet engines (Figure 1). Rene 41 is a highly corrosion and oxidation resistant material and therefore, it provides very good resistance to jet engine combustion gases up to 980°C. In aero-engines, this alloy is employed for afterburner parts, turbine casings (Figure 2), wheels, buckets, bolts and fasteners. Although this advanced alloy contributes to improvement in aerospace applications, it exhibits poor manufacturing properties due to their superior mechanical and chemical properties especially at elevated temperatures. The alloys with fully treated or partially aged condition are recommended for better surface finish in machining operations. Although Rene 41 has processing characteristics similar to Inconel 718, the machining behavior of this alloy is more difficult in comparison to alloy 718. In general, the studies in literature investigate the machining characteristics of Inconel 718 which is more popular due to the average utilization of 75wt% in aerospace applications and 50wt% in modern jet engines [1]. However, utilization of Rene 41 has been greatly increased in recent years which means that the machining behavior of this alloy is required to be properly understood for high efficient manufacturing operations. This work investigates the turning operation of Rene 41 in terms of surface quality of workpiece and wear behavior of cutting tool. In the study, cutting speed and feed rate were used as the variable parameters and their influences were investigated using main effects plots in a full factorial experimental design.

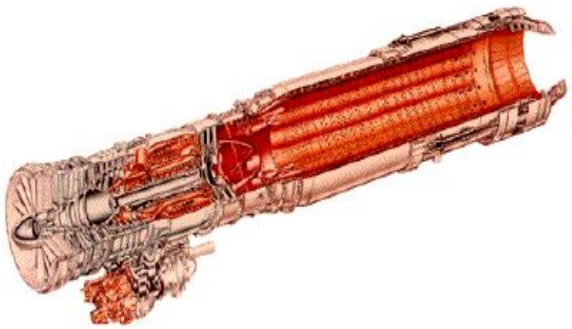


Figure 1. J85 Turbojet Engine with Afterburner [8]

II. EXPERIMENTAL DETAILS

In the present study, a cylindrical bar made of Rene 41 was used as the workpiece. The machining operation was performed using a vertical CNC machine (You Ji, YV-1000ATC)(Figure 3). Two input parameters such as cutting speed and feed rate were varied to investigate their effects on the surface roughness of workpiece and wear behavior of cutting tools. Table 1 shows the full factorial experimental design in this study. The cutting depth of 0.2 mm was fixed in the experiments. After completing the experiments, surface roughness of the workpiece for each run was measured ten times from different regions on the surface using a Taylor-Hobson Surtronic 3P surface profilometer. The wear tracks on the inserts were visualized using a Mitutoyo Quick

Scope microscope and wear measurements were performed in accordance with ISO-3685 standard.



Figure 2. A typical gas turbine casing [9]



Figure 3. CNC machine YV 1000 ATC [10]

Table 1. Full factorial design of experiments

Run	Cutting speed (m/min)	Feed rate (mm/rev)
1	180	0.15
2	180	0.20
3	180	0.25
4	240	0.15
5	240	0.20
6	240	0.25

III. RESULTS AND DISCUSSION

In the evaluation of the experimental results, main effects plots were used to observe the influence of the input parameters on each output. Figure 4 shows the main effects plot for surface roughness of workpiece. It is seen that surface roughness of workpiece is not heavily dependent on cutting speed since the mean of data is quite close each other for each level of cutting speed. However, there is a very slight increase in surface roughness when cutting speed is enhanced in the operation. On the other hand, feed rate has a significant impact on surface roughness that the surface profile of workpiece becomes rougher as feed rate is increased in the turning operation [2]. This phenomenon stems from the geometrical characteristics of machining. The amplitude of surface profile gets larger using higher feed rates which means that surface roughness increases due to higher difference in the location of peak and valley points of each cycle [3]. Figure 5 shows the main effects plot considering the wear behavior of cutting tools for each input parameter. It is obvious that cutting speed negatively influences the wear rate of cutting tool in the operation. This is directly related to the interaction of workpiece and cutting tool surface where crucial conditions are seen in this zone [4], [5]. The increase in cutting speed causes elevated cutting temperature in the cutting zone and therefore, wear resistance of cutting zone deteriorates due to degradation of cutting tool. In particular, Rene 41 has very low thermal conductivity which stops the generated heat dissipating from the cutting zone [6], [7]. In addition to thermal effect which accelerates the adhesive wear, cutting speed enhances the chip flow rate on the surface of cutting tool and therefore, abrasive wear prevails the failure mode of cutting tool. Considering the influence of feed rate on the wear rate on cutting tool, it can be mentioned that wear rate continuously rises by increasing feed rate in the operation. This can be attributed to enhanced cutting forces act on cutting tool which grow the friction at the contact surface of cutting tool and chip [8], [9]. Figure 6 shows the wear tracks on the cutting tools for different feed rates in the turning operations. It is seen that high feed rates result in a quick wear deformation on cutting tools and consequently, the service life of tool drastically reduces which enhances the expenses in manufacturing. The tool life criterion is a maximum notch wear of 600 µm in according to the ISO-3685 standard and the mean of notch wear values are 683 and 1376 µm for the cutting tools at the feed rate of 0.15 and 0.25 mm/rev when the cutting speed is 240 m/min. In this light, it is possible to state that the cutting tools completed their service life for both feed rates however, lower feed rates extends the utilization period of cutting tools. Beside the wear mechanism, tool breakage is common type of failure at the excessive feed rates due to drastic jump in cutting forces.

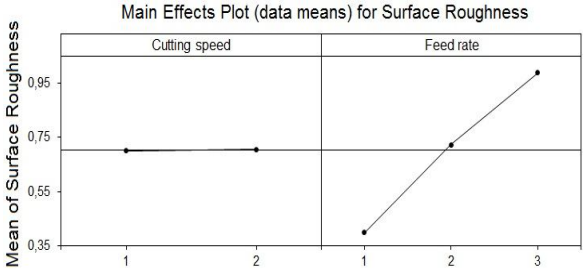


Figure 4. Main effects plot for surface roughness of workpiece

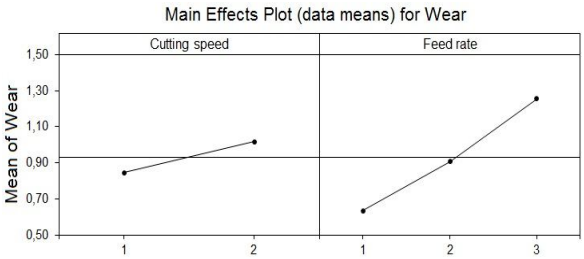
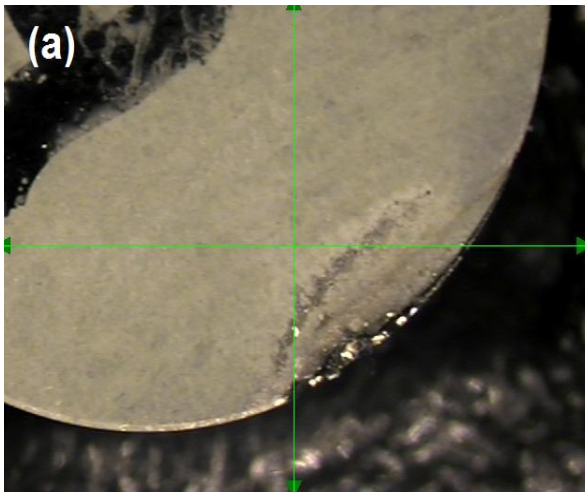


Figure 5. Main effects plot for wear on cutting tool

CONCLUSIONS

In the present work, the turning operation of superalloy Rene 41 was investigated in terms of surface quality of workpiece and wear behavior of cutting tool. In the experimental stage of this study, cutting speed and feed rate were used as the variable parameters and their influences were investigated using main effects plots in a full factorial experimental design. The results showed that surface roughness is mainly dependent on feed rate which results in a poor surface finish at high values. Although cutting speed is not a determining factor for surface roughness, surface quality is more prone to reduce as cutting speed increases. On the other side, the wear mechanism of cutting tool accelerates using elevated cutting speeds and feed rates.



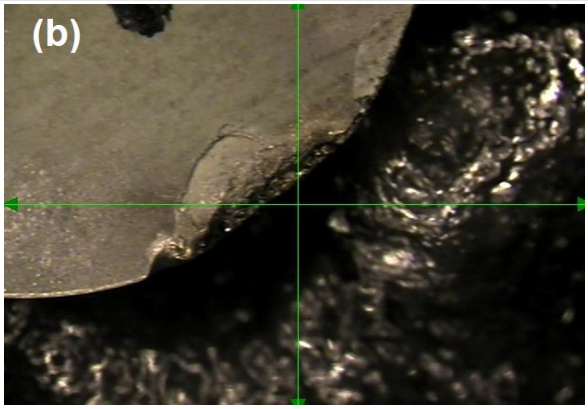


Figure 6. Wear tracks on the cutting tools at the feed rate of (a) 0.15 and (b) 0.25 mm/rev (cutting speed: 240 m/min)

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