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Determination Of optimum Parameters In Turning Rene 41 Superalloy

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Abstract **–** Superalloys are developed to withstand severe mechanical stresses and high temperature operation, and are widely used in aircraft and space vehicles, especially nickel-based ones, due to their high corrosion resistance. In this study, three different cutting forces and surface roughness qualities were evaluated depending on the cutting speed in the machining of Rene 41 superalloy with three different ceramic tools KYON 4300, KSY25 and KSY30. In this work, The experimental results have revealed that the feed rate had a serious effect on the cutting forces, while the effect of turning speed and type of the cutting tool on the cutting forces are relatively small. On the other hand, the most important factor influencing the surface roughness was cutting speed followed by tool type and feed rate, respectively. The presented findings can help for understanding the machinability and surface characteristics of Rene'41 during high speed turning. In the experiments, it was observed that the cutting forces decreased as the cutting speed increased.

Keywords – Machinability, Rene 41, Surface roughness, Cutting force, Superalloy

- Introduction

Nickel-based superalloys are used spacecraft, steam generators, glass industry and other heat-resistant applications [1]. With a usage rate of 50%, it is the most widely used superalloy in the production of spacecraft engines and gas turbine compartments. Nickel-based superalloys consist of the intermediate metal compound Ni3 (Al, Ta) and the solid solution strengthening elements. Inconel, Nimonic, Rene, Udimet, Pyromet are commercially used nickel alloy [2]. In conditions where high temperature, corrosion and intense wear mechanisms are present, different material groups are preferred where metals and metal alloys cannot provide the desired properties. Superalloys are at the forefront of these groups. With the development of technology; in order to obtain materials with appropriate technical properties and at an economically preferable level, it has become necessary to produce superalloys that can exhibit high performance in terms of mechanical properties and are resistant to high temperature wear and corrosion. Developments in material science have provided a significant increase in flight range in the aviation and space field. As a result of mechanical and thermal requirements, nickel, titanium, cobalt and iron-based alloys are used for parts used in aircraft engines. Nickel-based alloys are among the most preferred materials in aviation and space applications. Rene 41, a precipitation-hardening nickel-based superalloy widely used in materials exposed to significant stresses at high temperatures such as hot zone elements used in jet engines, was developed by General Electric. This alloy provides very good resistance to combustion gases up to 980 °C due to its high resistance to wear and oxidation. It is preferred as a material for turbine bodies, wheels, turbine blades, afterburner parts, bolts and fasteners in aircraft engines. Although Rene 41 has superior mechanical properties and high chemical stability at high temperatures, it is a difficult material in terms of machinability. Alloys that have been heat treated or aged in order to obtain high surface quality in machining processes are preferred. Rene 41 alloy has similar properties to Inconel 718 in terms of machinability, but its machinability properties are more difficult compared to Inconel 718 alloy [3,4]. Superalloys, unlike other alloys, produced against high mechanical stresses at high temperatures [5]. Nickel based superalloys contain 30 to 70% Ni and a significant amount of Cr (30% and above). Iron element is found in small amounts in nickel based superalloys such as Inconels, Nimonics and Hastelloy, and in about 35% in alloys such as Incoloy 901 and Inconel 706. Nickel based superalloys gain a stable internal structure and corrosion resistance in reducing environments with the high amount of nickel that forms the main matrix. The most important alloying elements in nickel based superalloys are aluminum and/or titanium. The total amount of these alloying elements does not exceed 10% atomically. These alloying elements form a two-phase internal structure called gamma (γ) and prime gamma (γ'). The γ' phase is what causes the high strength and superior creep resistance of the material at high temperatures. The strength values of many metals such as tensile strength and yield point decrease with increasing temperature. The reason for this is that the thermal activation energy coming with the increase in temperature makes it easier for dislocations to overcome obstacles. In nickel-based superalloys, the resistance to temperature is higher due to the intermetallic γ' phase it contains. In nickel-based alloys, the strength values such as tensile strength and yield point begin to decrease after exceeding 600 °C [6]. Nickel-based superalloys are among the most difficult superalloys to machine in terms of meeting quality and production requirements. The reasons for poor machinability can be listed as high thermal hardness, deformation hardening, hard carbide grain structure, high diffusion wear rate, chip adhesion, continuous chip formation and low thermal conductivity [7,8]. In conditions where high temperature, corrosion and intense wear mechanisms are present, different material groups are preferred where metals and metal alloys cannot provide the desired properties. Superalloys are at the forefront of these groups. With the development of technology; in order to obtain materials with appropriate technical properties and at an economically preferable level, it has become necessary to produce superalloys that can exhibit high performance in terms of mechanical properties and are resistant to high temperature wear and corrosion. Developments in material science have provided a significant increase in flight range in the aviation and space field. As a result of mechanical and thermal requirements, nickel, titanium, cobalt and iron-based alloys are used for parts used in aircraft engines. Nickel-based alloys are among the most preferred materials in aviation and space applications. Rene 41, a precipitation-hardening nickel-based superalloy widely used in materials exposed to significant stresses at high temperatures such as hot zone elements used in jet engines, was developed by General Electric. 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These tools are intensively preferred in continuous chip removal operations such as turning and drilling. With the development of cutting tool technology, some ceramic tool materials (Al2O3–TiC), Si3N4 silicon nitride-based ceramics and whisker-reinforced aluminum oxide ceramics (containing 25% SiCw) are used more than carbide tools in the machining of nickel-based superalloys [11,12]. Nickel-based superalloys are among the most difficult superalloys to machine in terms of meeting quality and production requirements. The reasons for poor machinability can be listed as high thermal hardness, deformation hardening, hard carbide grain structure, high diffusion wear rate, chip adhesion, continuous chip formation and low thermal conductivity [7,8]. Short tool life and hardness of the workpiece are the two most important factors in the machinability of nickel-based superalloys. During the machining process, stress changes may occur on the surface and this causes the mechanical and chemical properties (such as stress-corrosion) of the processed material to change. Therefore, preserving the surface integrity of the processed part is of great importance. In the machining of nickel-based superalloys, very low tool life is encountered. In order to obtain sufficient tool life, parameters such as machining method, tool material, tool geometry, cutting speed, feed rate, depth of cut should be selected appropriately [13]. All these reasons necessitate the examination of the machinability. Cemented carbide tools are widely used in the machining of nickel-based superalloys. These tools are intensively preferred in continuous chip removal operations such as turning and drilling. With the development of cutting tool technology, some ceramic tool materials (Al2O3–TiC), Si3N4 silicon nitride-based ceramics and whisker-reinforced aluminum oxide ceramics (containing 25% SiCw) are used more than carbide tools [14,15]. When literature studies are examined, Inconel 718 is a more preferred material with an average usage value of 75% in the aviation and space field and 50% in jet engines in terms of machining properties [16]. When literature studies are examined, Inconel 718 is a more preferred material with an average usage value of 75% in the aviation and space field and 50% in jet engines in terms of machining properties [17]. In recent years, the use of Rene 41 superalloy has increased significantly and a good understanding of its processing properties is necessary to create effective production methods. In the study conducted by Tali et al., during machining of Rene 41 material were examined. Cutting and feed rate were used as variable parameters in the experiments. As a result; They stated that the feed rate is a major factor in surface roughness and that high feed rate values cause a decrease in surface quality. They predicted that the cutting speed is an effective factor in determining the surface roughness and that there is a possibility of a decrease in surface quality with the increase in cutting speed. They emphasized that the wear mechanism of the cutting tool is directly proportional to the increase in cutting and feed speed [18,19]. When literature studies are examined, Inconel 718 is a more preferred material with an average usage value of 75% in the aviation and space field and 50% in jet engines in terms of machining properties [20]. In recent years, the use of Rene 41 superalloy has increased significantly and a good understanding of its processing properties is necessary to create effective production methods. In the study conducted by Tali et al., surface roughness and tool wear during turning of Rene 41 material were examined. Cutting and feed rate were used as variable parameters in the experiments. As a result; It was stated that feed rate is a major factor in surface roughness and that high feed rate values cause a decrease in surface quality. They predicted that the cutting speed is an effective factor in determining the surface roughness and that there is a possibility of a decrease in surface quality with the increase in cutting speed. They emphasized that the wear mechanism of the cutting tool is directly proportional to the increase in cutting and feed speed [21]. As a result of the literature review, it is seen that the studies on the microstructure, wear resistance and welding properties of Rene 41 material are investigated more intensively [22-23]. As a result of the literature review, it is seen that studies on the properties of Rene 41 material such as microstructure, wear resistance, weldability are investigated more intensively [24-25]. It was determined that there are very few studies on the machinability of Rene 41 superalloy. In this study, the surface quality of the workpiece, cutting force and wear behavior of the cutting tool are investigated in the turning process of Rene 41 superalloy. Since it is the parameter affecting the machinability behavior of the material and the tool life [26].

- Materials and Method
- *Material*

A Rene 41 superalloy, which is widely applied in industry, was used in our experiments. Samples with dimensions of Ø2’’ × 15’’ mm were used. Regarding the chemical composition and mechanical properties, these are given in Tables 1 and 2., cutting parameters and levels are shown in Table 3 . Due to their high hardness, these materials are very difficult to machine, which makes them suitable for high temperature applications such as aerospace, automotive and aircraft fields.

Table 1. Chemical composition of material Rene 41

C	**Mn**	**Si**	**S**	**Cr**	**Ni**	**Co**	**Mo**	**Fe**	**Zr**	**Ti**
0,062	0,01	0,05	0,001	18,53	53,86	10,52	9,53	2,37	0,03	3,24
Al	**B**	**Pb**	**Bi**	**Se**						
1,53	0,006	<0,0001	0,00001	<0,0001						

Table 2. Mechanical properties of the Rene 41 specimens

Cnd.	Temp.(F)	UTS (ksi)	YS (%) (ksi)	Stress (ksi)	Life (Hrs)	% El.	% R.A.
M	RT (LONG)	208,0	150,0			26,0	31,0
M	1500(LONG)	152,5	128,5			14,0	15,5
M	1700(LONG)			97,5	35,2	34,0	

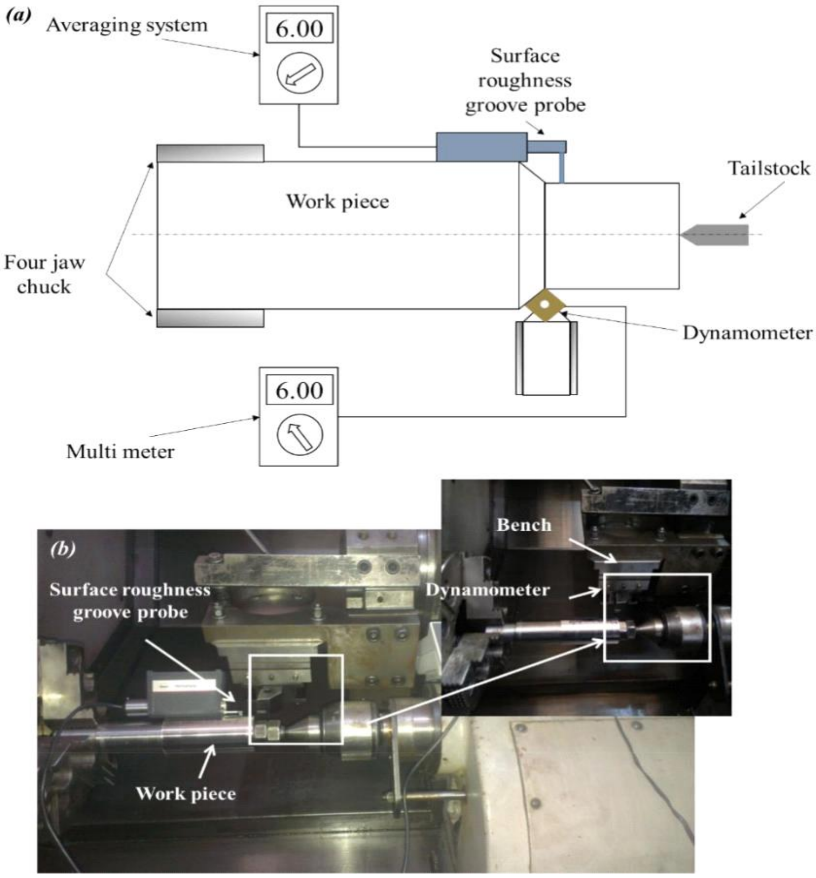

Fig. 1. Dinamometer measuring system with CNC lathe.

- *Machine Tool and Measuring Devices*

In the experiments tests JOHNFORD T35 industrial type CNC lathe used (Figure 1). Kistler brand 9257B dynamometer was used under dry cutting process to measure three orthogonal cutting forces (Fx, Fy, Fz).

This allows the direct and continuous recording of the three cutting forces and their simultaneous graphical visualization by dinamometer measuring system with CNC lathe (Figure 1). The "MahrPerthometer M1" surface roughness measuring device was used for surface roughness measurements.

Table 3. Cutting parameters and levels

Control parameters	**Units**	**Levels**		
		1	2	3
Cutting tool	(A)	KY4300	KYS30	KYS25
Cutting speed (m/min.)	(B)	200	230	260
Feed rate (mm/rev.)	(C)	0,100	0,125	0,150
Depth of Cut (mm) constant	(D)	1,6	1,6	1,6

- *Cutting Parameters and Cutting Tool*

Regarding the processing parameters, cutting speeds were 200, 230, and 260 m/min, cutting depth was fixed at 1,2 mm, feed rate was 0.10, 0.125 and 0.150 mm/rev at 120 mm cutting length. These parameters were selected considering the ISO 3685 standard recommended by the manufacturers. During the cutting process, processing tests were performed with three different ceramic tools KYON 4300, KSY25 and KSY30. It was made using 1.2 mm cutting depth, 40° approach angle and PCLNR 2525 M12 type tool holder. Each measurement was repeated five times and averaged for analysis.

- *Results*

In this study, the cutting force values obtained as a result of the experiments depending on the cutting speed are given in Figure 2. When Figure 2 is examined, a force formation is observed according to the cutting theory. While the radial force Fr is formed as the lowest force component, the feed force Ff is formed as approximately three times the force Fr. The main cutting force according to Fr is measured as approximately five times. This situation may change depending on the chip section.When the cutting speed is changed from 230 m/min to 260 m/min, an increase of 15% is observed in Fr, 18% in Ff and 6% in Fc. The excessive increase in temperature with the increase in cutting speed caused the cutting forces to increase.

- DISCUSSION

As the temprature on the cutting tool increases, the surface roughness of the machined part also increases. This situation is more common in materials with high hardness [18-19]. Figure 2 shows the cutting forces graph and Figure 3 surfage roughness depending on the cutting speed. It has been determined that cutting forces decreases depending on the cutting speed, but in surface roughness is different. This situation can be explained by the fact that the temperature generated in the cutting zone due to the cutting speed causes cutting forces increases. If we need to interpret all the graphs in terms of machinability, it is seen that Rene 41 material can be machined between 200 and 260 m/min cutting speed. It is seen that the high cutting resistance of superalloys prevents the use of high cutting speeds in these materials.

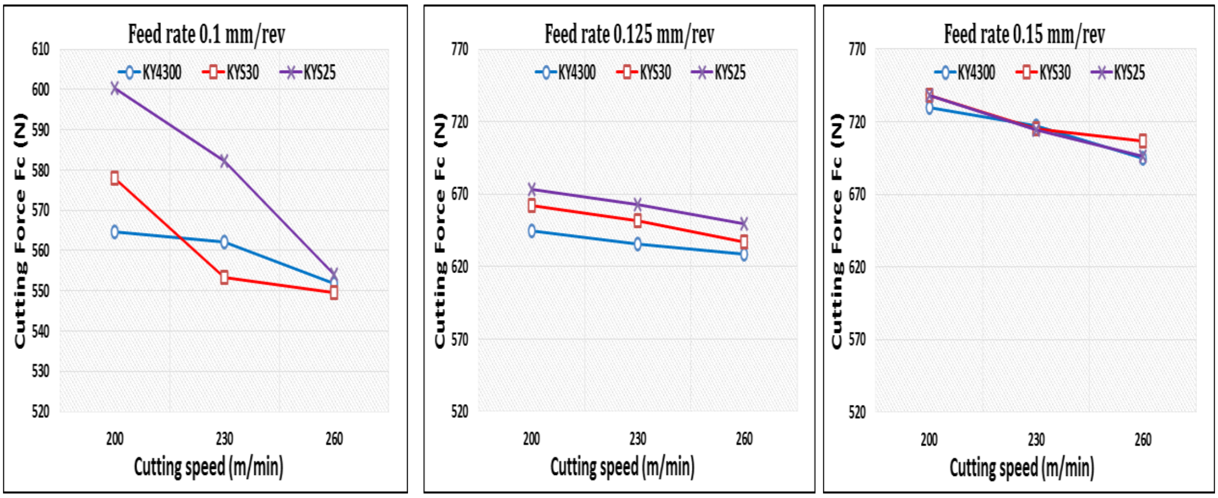

Fig. 2. Change of cutting forces depending on cutting speed in the machining of Rene 41

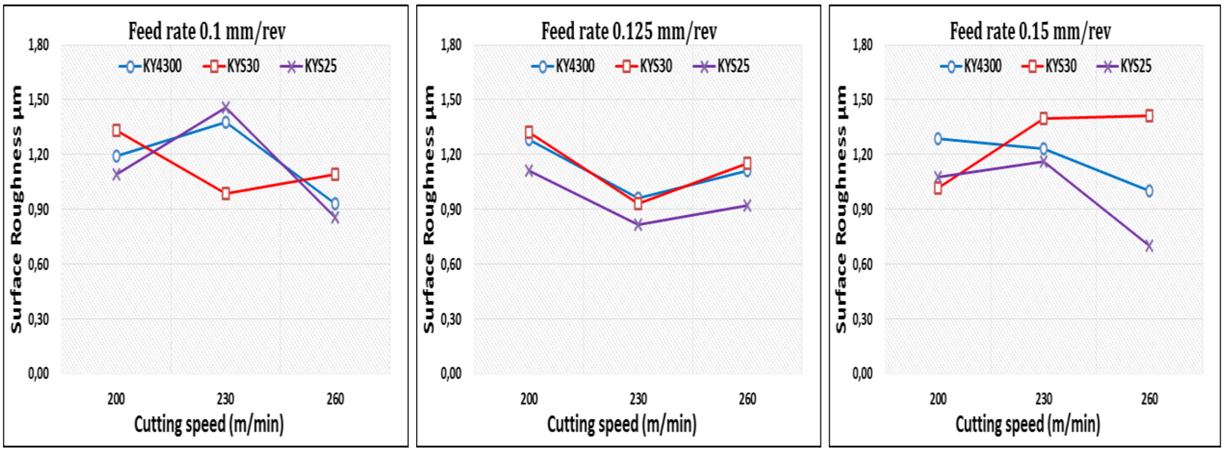

Fig. 3. Change of surface roughness depending on cutting speed in the machining of Rene 41

- CONCLUSIONS

The cutting forces and surface roughness results obtained depending on the cutting speed as a result of machining the Nickel-based Rene 41 superalloy. It was determined that the cutting forces decreased between 18% and 28% with the increase in cutting speed, While the main cutting force of the cutting forces was the highest, the feed force was determined to be the second, 34% lower than the main cutting force, and the radial force was determined to be the lowest force with 80%. 260 m/min cutting speed was determined as a critical speed limit in terms of surface quality. ·

• The lowest main cutting force of Fz 549,49 N was obtained at 260 m/min, 0,1 mm/rev and the highest cutting force of Fz 738,19 N at 200 m/min cutting speed, 0,15 mm/rev both with KYS30 cutting tool. The lowest surface roughness value was obtained 0,698 µm at 260 m/min cutting speed, 0,150 mm/rev feed rate with KYS25 cutting tool.

• Turning test results show that the effect of cutting tool on the surface roughness was seen more than that of cutting tool on the cutting forces when machining the Rene’41 with ceramic tools. The influence of cutting tool and feed rate on the surface roughness was observed more effective.

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