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ANALYSIS OF CUTTING FORCES WHILE TURNING DIFFERENT MATERIAL

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ABSTRACT

The measurement of cutting forces in metal cutting is essential to estimate the power requirements, to design the cutting tool and to analyze machining process for different work and tool material combination. Although cutting forces can be measured by different methods, the measurement of cutting forces by a suitable dynamometer is widely used in industrial practice. Mechanical and strain gauge dynamometer are most widely used for measuring forces in metal cutting. The principle of all dynamometers is based on the measurement of deflections or strain produced from the dynamometer structure from the action of cutting force. In this project, a dynamometer is used to measure cutting force, feed force and radial force by using strain gauge accelerometer while turning different material in lathe. The dynamometer is a 500kg force 3-component system. As the tool comes in contact with the work piece the various forces developed are captured and transformed into numerical form system. In this project three forces of different materials such as aluminum, mild steel, brass, copper have been noted down. The forces on these materials with variation in speed and depth of cut are studied. Graphs are drawn on how these forces vary due to variation in speed.

Keywords: *Lathe tool dynamometer, Turning, cutting speed, Depth of cut, cutting force and Cutting tool*

1. Introduction

Force measurement in metal cutting is essential requirement as it is related to machine part design, tool design, power consumptions, vibrations, part accuracy, etc. The purpose of the measurement of cutting force to be able to understand the cutting mechanism such as the effects of cutting variables on the cutting force, the machinability of the work piece, the process of chip formation, chatter and tool wear. It has been observed that the force values obtained by engineering calculations contain some errors when compared with experimental measurements. The cutting force even in steady state conditions is affected by many parameters and the variation of cutting force with time has a peculiar characteristic. The need for measurement of all cutting force component arises from many factors, but probably the most important is the need for correlation with the progress of tool wear. If this can be obtained, it will be possible to achieve tool wear monitoring in turning based on force variation. The reason for the cutting force measurement is that it is a good indicator in detecting tool wear. It is well known that during the cutting process, the cutting parameters such as cutting speed, feed rate and depth of cut often present a deviation from the calculated values. For this purpose, many dynamometers have been developed. In these dynamometers, cutting force measurement is mainly based on elastic deformation of the materials.

Suleyman Yaldiz et al. [1] have used turning dynamometer to measure static and dynamic cutting forces with the help of strain gauge and piezo-electric accelerometer. Cutting force signals were captured and transformed into numerical form and processed using a data acquisition system consisting of necessary hardware and software running on MS-Windows based personal computer. The obtained results of machining tests performed at different cutting parameters shows that the dynamometer can be used reliably to measure static and dynamic cutting forces.

Morten et al. [2] used Finite Element Method based Lagrangian approach for prediction of cutting forces in metal cutting. The cutting force and thrust force were predicted and compared with forces measured during experiments. The analysis which predicted the best agreement between force output from analysis and force output measured from experiments and at the same time, predicted a realistic chip formation was found.

Malagi et al. [3] computed the cutting forces analytically and compared with measured experimentally predicted values. Cutting tests are done

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on the Kirloskar Lathe having maximum power of 3.75 Kw, using Brazed Carbide cutting tools and a Syscon cutting force Dynamometer. Work piece used is of mild steel material of 25mm dia. The results show that the cutting force increases as the feed rate and depth of cut increases. The percentage of error is in the acceptable range hence the developed application can be used for the estimation of cutting forces.

Sanjeev Sharma et al. [4] evaluated the design of lathe tool dynamometer with the capacity of 500 kg. In this, mechanical gauges were replaced by resistance strain gauges which are being utilized to sense the cutting forces during machining and give the necessary information of cutting forces in terms of resistances which is the measure of cutting and feed forces w.r.t. Feed rate, depth of cut and feed/revolution. They concluded that the cutting & feed forces is directly proportional to depth of cut & feed rate of tool and inversely proportional to feed/rev.

Naveen Kumar et al. [5] determined the cutting force, feed force and thrust/Axial force by using strain gauge accelerometer. In this study single point cutting tools with different rake angles, are used to measure forces on stainless steel and aluminum materials with variation in speeds and depth of cut and graphs were drawn on how these forces vary due to variation in speed and rake angles. The results concluded that as the rake angle increases cutting force increased at all speeds in aluminum material whereas cutting force & thrust forces increased stainless steel metals at all speeds.

2. Experimental Analysis

2.1 Experimental procedure

The work piece is held in the chuck and facing operation is performed to make the end face of the work piece flat. The work piece is center drilled to provide tapered hole which can then accommodate and be supported by a running center in the tail stock. Undercutting operation is done to provide a groove on the work piece in order to have a reference point, sensing unit of the dynamometer is placed on lathe tool post and clamped rigidly. With the help of cable provided, cable is connected on sensing unit to socket on back plate of Force Indicator Unit. Force Indicator is connected to 230 V, single phase supply and switch on power supply. Waited for 5 to 10 minutes to balance the channels to get zero readings on display with tare pots on the panel. Mounted solid work – piece in the chuck. Selected the speed by engaging the levers to a suitable combination to get the specified speed and start the Machine. Fed the tool manually to start cutting and then automatically. Waited to stabilize the output of the bridges and measured the maximum output for cutting, feed & radial forces. Noted down the reading and repeated the same procedure for various speeds and depth of cut. The experimental specimens are shown in Fig.1 to Fig. 4.

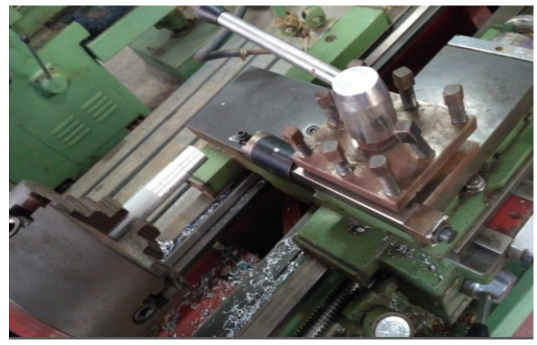


Fig. 1 Turning operation in Aluminum material for the measurement of cutting force

Fig. 2 Turning operation in Mild steel material for the measurement of cutting force

Fig. 3 Turning operation in Brass material for the measurement of cutting force

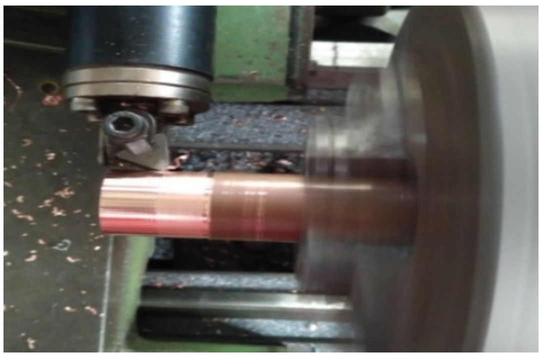


Fig. 4 Turning operation in Copper material for the measurement of cutting force.

3. Results

3.1. Measurement of cutting force - experimental result.

By varying the speed (360,580,800RPM) and depth of cut (0.05mm, 0.10mm, 0.15mm) the cutting force, radial force for different material (aluminum, mild steel, copper, brass) is observed and noted down in below Table 1.

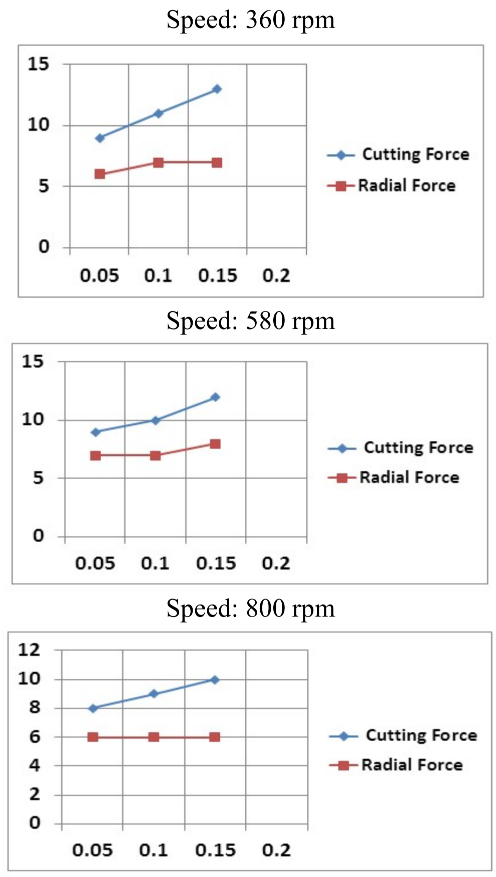
Table 1 Experimental Cutting Force and Radial Force Values at Different Depth of Cuts.

MATERIALS		ALUMINIUM		MILD STEEL		BRASS		COPPER	
Speed (rpm)	Depth of cut (mm)	C.F	R.F	C.F	R.F	C.F	R.F	C.F	R.F
360	0.05	9	6	9	8	4	17	10	12
	0.1	11	7	12	9	5	18	11	13
	0.15	13	7	15	9	7	18	13	10
580	0.05	9	7	10	6	3	10	9	10
	0.1	10	7	10	8	4	12	10	10
	0.15	12	8	13	8	6	14	12	12
800	0.05	8	6	7	8	2	9	7	8
	0.1	9	6	9	7	3	12	8	9
	0.15	10	6	12	8	5	15	11	8

C.F : Cutting Force (kgf) R.F : Radial Force(kgf).

3.2. Graphical report

3.2.1 Effect of depth of cut on cutting force and radial force while machining Aluminum



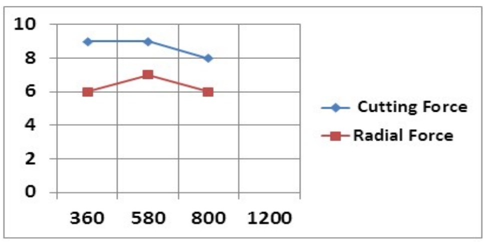
(X-axis: Depth of cut) (Y-axis: Tool Force)

Fig. 6 Effect of Depth of cut on Cutting force and Radial force (Aluminum).

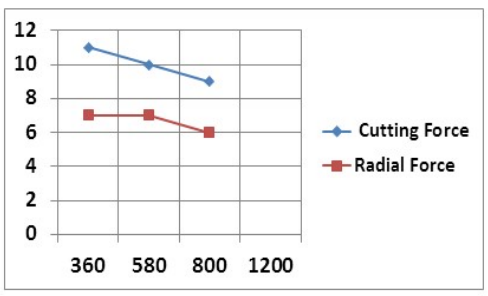
From the Fig. 6 it has been observed that as the Depth of cut increases, the Cutting forces also increase. With the increase in the depth of cut the chip thickness becomes significant whip causes the growth of volume deformed and that requires enormous cutting forces to cut the chip. Cutting forces developed at 360 rpm are higher compared to 580rpm and 800 rpm. At 800 rpm the radial force remains constant with respect to depth of cut. At 360 rpm and 580 rpm the radial force remains constant and then increase with respect to depth of cut.

3.2.2 Effect of Cutting Speed on Cutting force and Radial force while machining Aluminum

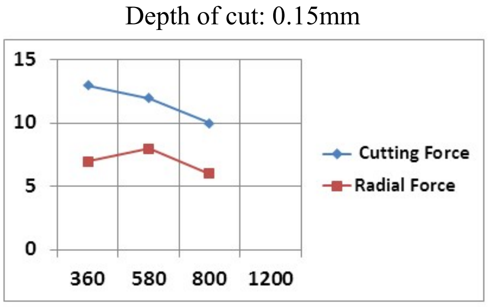
Depth of cut: 0.05mm



Depth of cut: 0.1mm



Depth of cut: 0.15mm



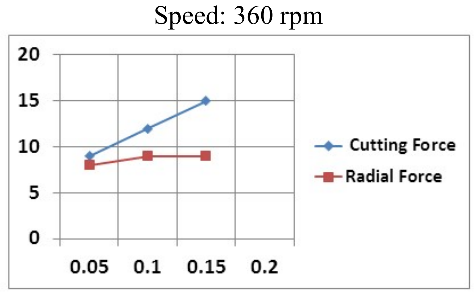
(X-axis: Cutting Speed) (Y-axis: Tool Force)

Fig. 7 Effect of Cutting Speed on Cutting force and Radial force (Aluminum).

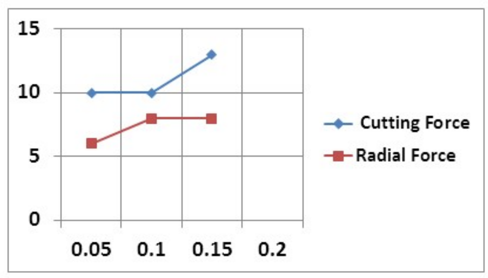
From the Fig. 7 it has been observed that as the Cutting speed increases, the Cutting force decreases. This is due to the rise in the temperature in the cutting zone which makes the metal machined more plastic and consequently the efforts necessary for machining decreases. At the 0.05 mm and 0.15 mm Depth of cut, the radial forces increase to certain limits and then decreases with respect to the Cutting speed.

3.2.3 Effect of depth of cut on cutting force and radial force while machining mild steel

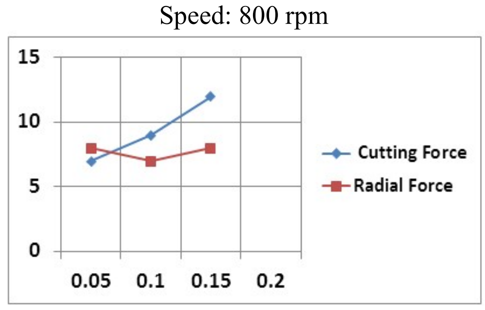
Speed: 360 rpm



Speed: 580 rpm



Speed: 800 rpm



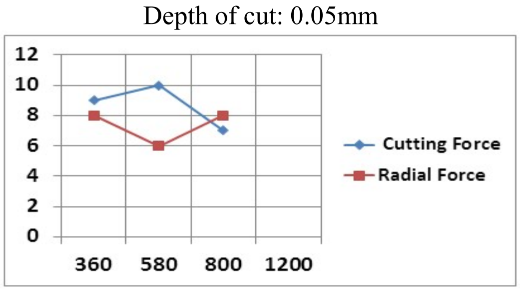
(X-axis: Depth of cut) (Y-axis: Tool Force)

Fig. 8 Effect of Depth of cut on Cutting force and Radial force (Mild Steel).

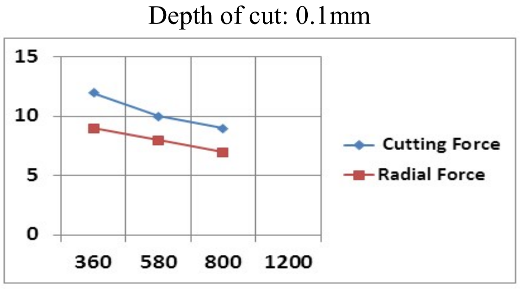
From the Fig. 8, it has been observed that as the Depth of cut increases, the Cutting forces also increase. Cutting forces developed at 360 rpm are higher compared to 580rpm and 800 rpm. At 800 rpm the radial force decreases to certain limit and then increase with respect to depth of cut. At 360 rpm and 580 rpm the radial force increases to certain limit and after that remains constant with respect to depth of cut.

3.2.4 Effect of Cutting Speed on Cutting force and Radial force while machining mild steel

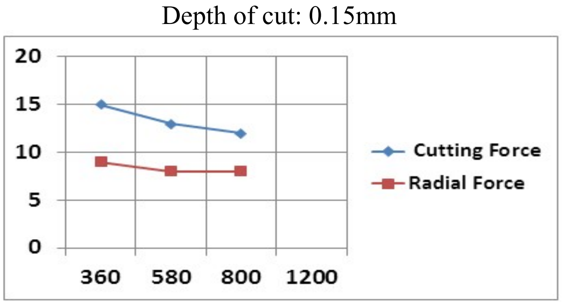
Depth of cut: 0.05mm



Depth of cut: 0.1mm



Depth of cut: 0.15mm



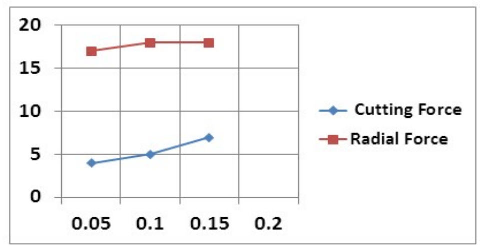
(X-axis: Cutting Speed) (Y-axis: Tool Force)

Fig. 9 Effect of Cutting Speed on Cutting force and Radial force (Mild Steel).

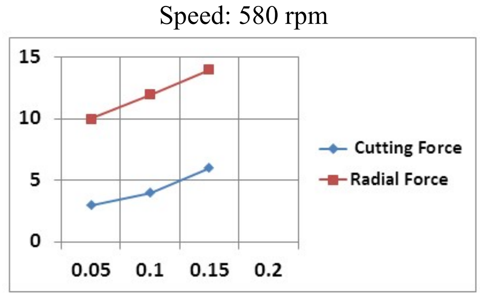
From the Fig. 9, it is observed that as the Cutting speed increases, the Cutting force decreases. This is due to the rise in the temperature in the cutting zone which makes the metal machined more plastic and consequently the efforts necessary for machining decreases. At the 0.05 mm Depth of cut, the radial forces decrease to certain limits and then increases with respect to the Cutting speed. At the 0.1 mm depth of cut, the radial force decreases with respect to cutting speed.

3.2.5 Effect of Depth of cut on Cutting force and Radial force While machining Brass.

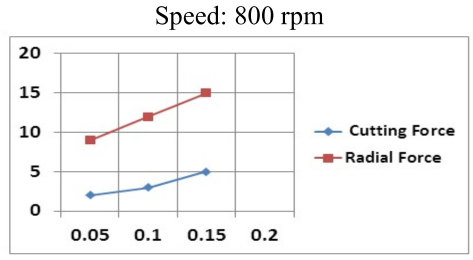
Speed : 360 rpm



Speed: 580 rpm



Speed: 800 rpm



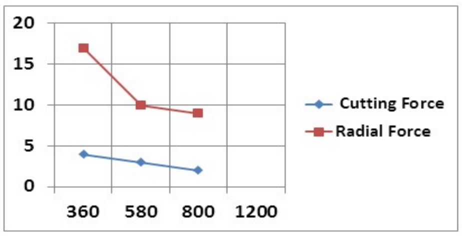
(X-axis: Depth of cut) (Y-axis: Tool Force)

Fig. 10 Effect of Depth of cut on Cutting force and Radial force (Brass).

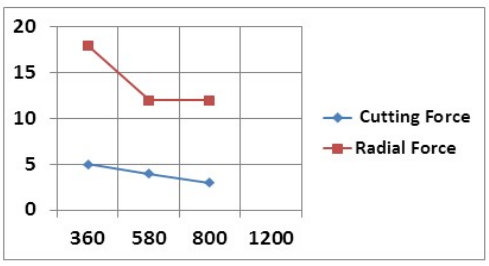
From the Fig. 10, it has been observed that as the Depth of cut increases, the Cutting forces also increase. Here the cutting force is lower compared to the aluminum and mild steel. Cutting forces developed at 360 rpm are higher compared to 580rpm and 800 rpm. At 580 and 800 rpm the radial force increases linearly with respect to depth of cut. At 360 rpm the radial force increases to certain limit and after that remains constant with respect to depth of cut.

3.2.6 Effect of Cutting Speed on Cutting force and Radial force While machining Brass

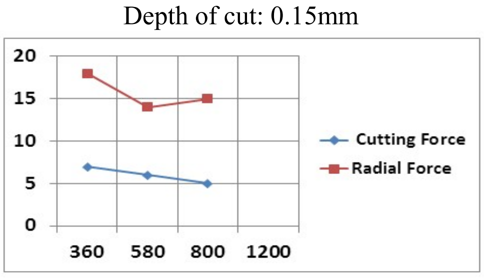
Depth of cut: 0.05mm



Depth of cut: 0.1mm



Depth of cut: 0.15mm



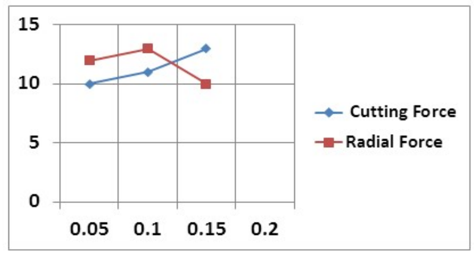
(X-axis: Cutting Speed) (Y-axis: Tool Force)

Fig. 11 Effect of Cutting Speed on Cutting force and Radial force (Brass).

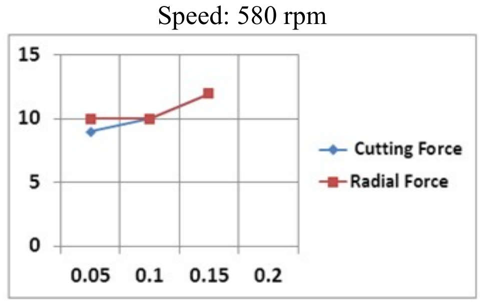
From the Fig. 11, it is observed that as the Cutting speed increases, the Cutting force decreases. This is due to the rise in the temperature in the cutting zone which makes the metal machined more plastic and consequently the efforts necessary for machining decreases. At the 0.15 mm Depth of cut, the radial forces decrease to certain limits and then increases with respect to the Cutting speed.

3.2.7 Effect of Depth of cut on Cutting force and Radial force While machining copper

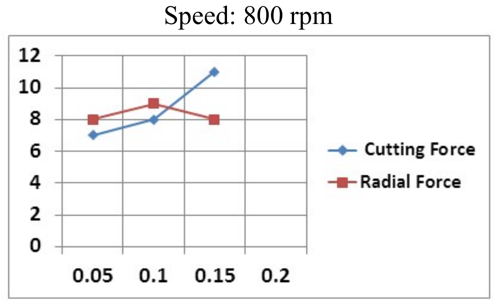
Speed : 360 rpm



Speed: 580 rpm



Speed: 800 rpm



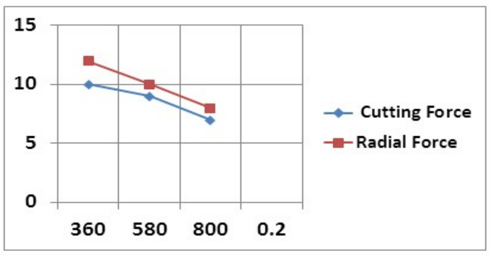
(X-axis: Depth of cut) (Y-axis: Tool Force)

Fig. 12 Effect of Depth of cut on Cutting force and Radial force (Copper).

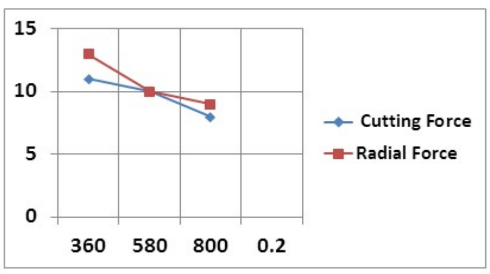
From the Fig.12, it has been observed that as the Depth of cut increases, the Cutting forces also increase. Cutting forces developed at 360 rpm are higher compared to 580rpm and 800 rpm. At 360 rpm and 800 rpm the radial force increases to certain limit and then decreases with respect to depth of cut. At 580 rpm the radial force remains constant and then increases to certain limit with respect to depth of cut.

3.2.8 Effect of Cutting Speed on Cutting force and Radial force While machining copper

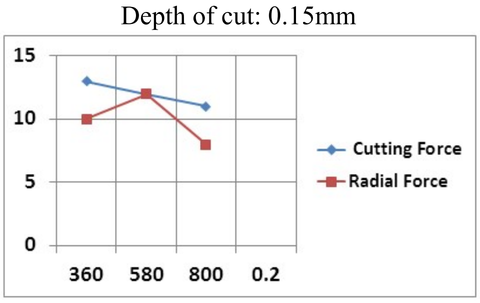
Depth of cut: 0.05mm



Depth of cut: 0.1mm



Depth of cut: 0.15mm



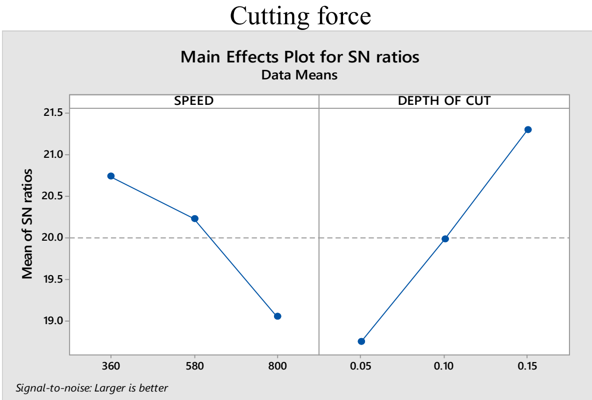
(X-axis: Cutting Speed) (Y-axis: Tool Force)

Fig. 13 Effect of Cutting Speed on Cutting force and Radial force (Copper).

3.3. Analysis of cutting force - SN ratio graph

3.3.1 Aluminum

Cutting force



Radial force

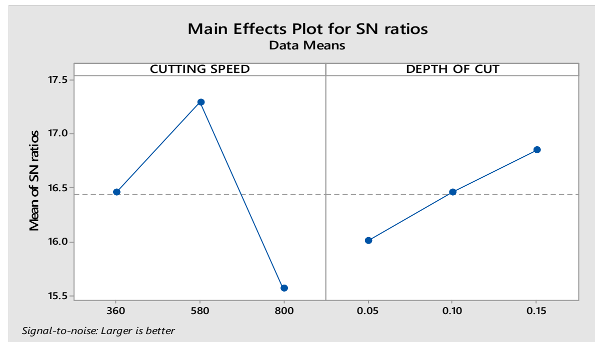
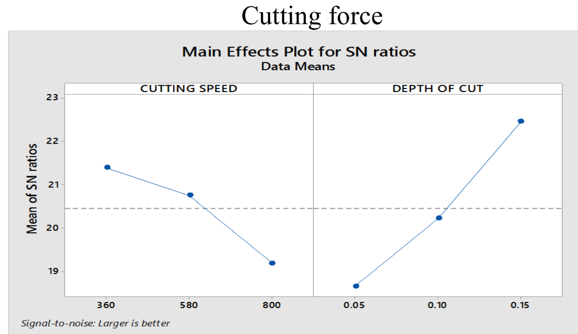


Fig. 14 SN Ratio graphs for Aluminum metal.

From the Fig. 14, it is observed that as the cutting speed increases the cutting force decrease gradually but the radial forces increases to certain limit and the decreases. As the depth of cut increases, the cutting and radial forces also increases.

3.4.2 Mild steel

Cutting force



Radial force

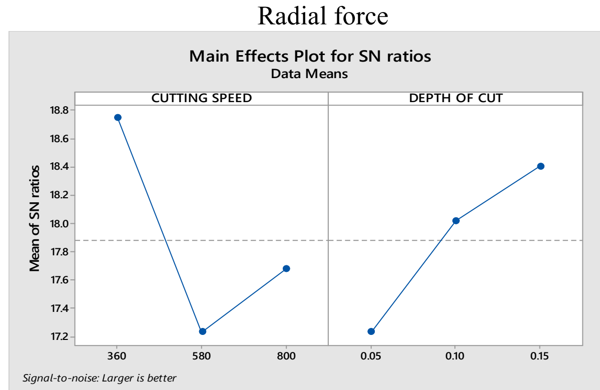
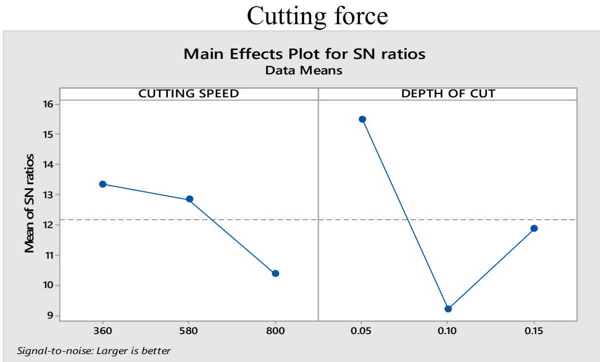


Fig. 15 SN Ratio graphs for Mild steel metal.

From the Fig. 15, it is observed as the cutting speed increases, the mean of SN ratios of the cutting force decreases gradually but the mean of SN ratios of radial forces decreases to certain limit and the increases. As the depth of cut increases, the mean of SN ratios of cutting and radial forces also increases.

3.4.3 Brass

Cutting force



Radial force

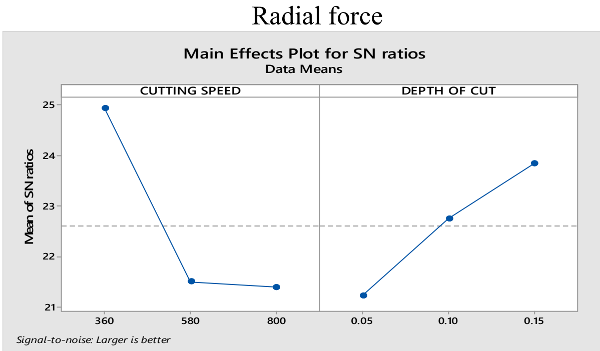
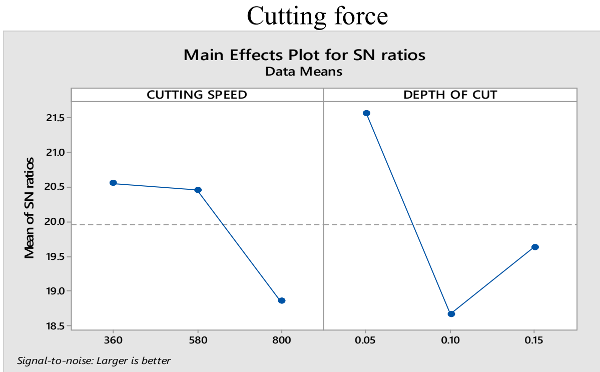


Fig. 16 SN Ratio graphs for Brass metal.

3.4.4 Copper

Cutting force



Radial force

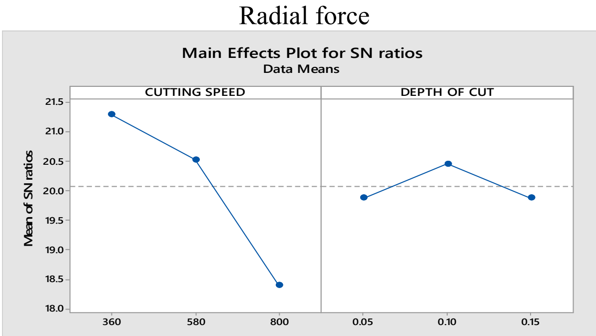


Fig. 17 SN Ratio graphs for Copper metal

From the Fig. 17, it is observed as the cutting speed increases, the mean of SN ratios of the cutting force and radial force decrease gradually. As the depth of cut increases, the mean of SN ratios of cutting forces decreases to certain limit and then increases for both copper and brass metal.

4. Conclusion

In this project the various forces such as cutting force, radial force has been found out with the variation in depth of cut and cutting speed for different materials like aluminum, brass, mild steel & copper. Graphs are drawn on how these forces vary with the variation in the depth of cut. From the above result it is concluded that as the Depth of cut increases, the Cutting forces also increase and as the Cutting speed increases, the Cutting force decreases gradually. Cutting forces developed at 360 rpm are higher compared to 580rpm and 800 rpm in all four metals. The better surface finish can be obtained at higher cutting speed at this condition it have a lower cutting force. For rough surface finish we can recommend lower cutting speed at this condition it have a high cutting force. If the depth of cut increases during machining, the quality of the surface finish will reduce so we can recommend low depth of cut. Finally, for better surface finish we can go for higher cutting speed and lower depth of cut. And in this project, we have studied, how a dynamometer works. And also learnt about various elements involved in metal cutting process. For the further enhancement of this project a thermocouple if connected can be used to find the temperature developed during the machining process.

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