A Study on Effect of Basic Cutting Variables on Machining Characterestics of Low Carbon Steel Work-Material in Turning

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***Abstract*—Machining is the most versatile manufacturing process and is influenced by a number of cutting parameters. The selection of parameters values for optimum result and maximizing material removal rate is crucial in realizing economy in manufacturing. The present work is aimed to establish the influence of feed, depth of cut and cutting speed on cutting characteristics of a standard work-material like Low Carbon steel under dry and wet conditions of machining. Using the cutting force data, an empirical model for power component of cutting force was developed. The goodness of fit of the model with the data was also tested. The surface roughness measurement indicates better surface finish with smaller feed magnitude and increased magnitudes of cutting speed. The application of cutting fluid improves surface finish. The specific power consumption decreases with increase in feed values, but shows a rising trend with high values of cutting speed indicative of ineffectiveness of cutting fluid at high speeds.**

Keywords—Low Carbon Steel,Machine Characteristics,Basic Cutting Variables

I. INTRODUCTION

In machining of materials, the material removal rate and machining time are influenced by basic cutting variables like depth of cut, feed and cutting speed. In turning, the cylindrical work blank is held on the work holding devices of the lathe and driven at a speed depending on the tool-work pair. The magnitudes of feed, depth of cut and cutting speed determine the material removal rate and influence the quality of the surface. The cutting force developed during machining causes distortion on the tool, work piece and machine tool components. There is a need to control the magnitude of the cutting force so as to control the deformations and relative positional variations of the cutting elements. The cutting force is a function of cross sectional area of the uncut layer, cutting speed and mechanical properties of work material. The magnitudes of cutting variables influence the magnitude of the cutting forces. An empirical model for the power component of cutting force, P_z of the form,

$$P_z = K_z t s^{0.78}$$

where t is the depth of cut, s is the feed and K_z is the constant, is a typical relation of its kind found in literature(1). The power consumed in machining depends on cutting force and the cutting speed selected for machining. As the power consumption directly varies with the size of cut, the power consumed at different magnitudes of feed and depths of cut cannot be directly compared. The specific power consumption can be used to compare the energy absorbed at different machine settings.

The surface finish obtained in machining is affected by the tool tip shape, feed rates and cutting speed in addition to the cutting fluid. A good surface finish is the chief objective in all finishing machining operations. Therefore, the dependence of surface finish on different machine settings for cutting is important. Surface finish may be measured in terms of one or more of surface roughness parameters. A knowledge on variation of surface roughness in relation to cutting variables is essential to save machining time and achieve desired surface finish on the machined components. Increased feed magnitudes reduce machining time, but increases surface finish (9). High cutting speeds yields smoother surface finish (16). Early investigators have described the influence of tool tip geometry on surface texture of the machined texture; the larger the nose radius of the tool, the better is the surface finish.

II. MACHINING SET UP

The experimental equipment is a standard all geared centre lathe. The work material selected for the investigation is low carbon steel (bar stock of size 64mm diameter and 350mm long). The cutting tool is HSS tool bit fastened to a mechanical type dynamometer (designed and fabricated for the work). The dial indicator of the dynamometer is positioned close to the tool tip; to monitor the tool deflection during cutting and hence the determination of cutting force from the calibration chart of the dynamometer. The machining set up is illustrated in Fig.1.

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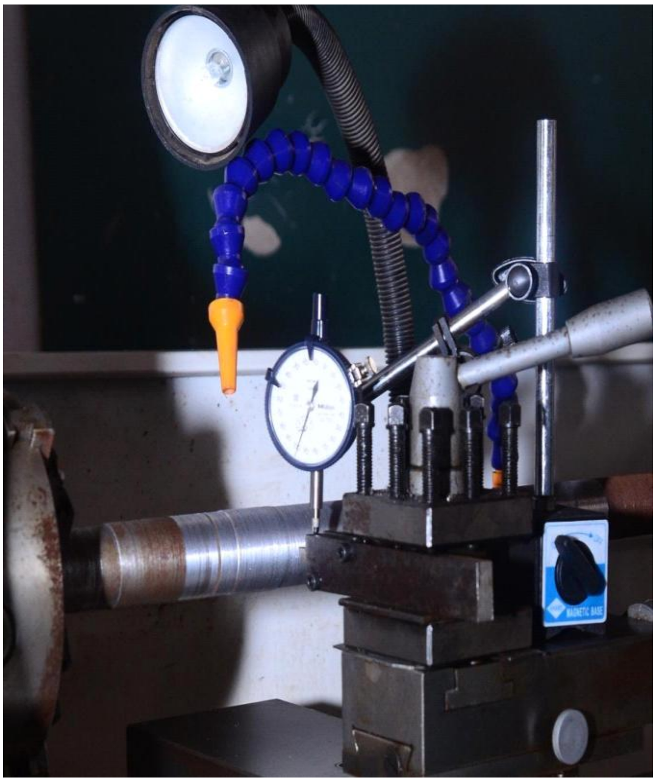

Fig.1. Machining set up

III. CUTTING TESTS

Machining tests were carried out to establish cutting characteristics of low carbon steel work material under different machining conditions. The basic cutting variables chosen for this investigation are depth of cut, feed and cutting speed. Machining was done with and without application of cutting fluid. The output parameters chosen for the study include cutting force, cutting power and surface roughness. To conserve experimental effort, four levels of primary parameters were chosen as described in table1. Instrumentation was provided to the available lathe, for the measurement of cutting force and electrical energy consumption. Replications of cutting trials were done to confirm repeatability of the observations.

Table.1. Variables and their levels for cutting tests

Variables	Level1	Level2	Level 3	Level 4
feed rates (mm/rev)	0.06	0.122	0.177	0.214
Depth of cut(mm)	0.25	0.50	0.75	1

Sample observations on cutting force measurements with different levels of cutting variables under dry and wet cutting conditions are given in Tables.2 & 3

Table.2 Cutting force data(Dry cutting)

Cutting Velocity (m/min)	Depth Of Cut (mm)	Feed (mm/Rev)	Cutting Force (N)
36.7	1	0.06	20-24
36.7	1	0.122	22-26
36.7	1	0.177	24-32
36.7	1	0.214	33.5-41
36.7	0.75	0.06	17-20.5
36.7	0.75	0.122	20.5-24.5
36.7	0.75	0.177	28-32
36.7	0.75	0.214	32-36
36.7	0.5	0.06	13_16.5
36.7	0.5	0.122	20.5_24
36.7	0.5	0.177	20.5-28
36.7	0.5	0.214	24-28
36.7	0.25	0.06	9_10
36.7	0.25	0.122	12-15.5
36.7	0.25	0.177	13-16.5
36.7	0.25	0.214	20-27

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Table 3 Cutting force data (Wet cutting)

Cutting Velocity (m/min)	Depth Of Cut (mm)	Feed (mm/Rev)	Cutting Force (N)
47.291	1	0.06	10_12
47.291	1	0.122	13-17.5
47.291	1	0.177	14-16.5
47.291	1	0.214	14.5-17.5
47.291	0.75	0.06	7.5-11.5
47.291	0.75	0.122	10.5-11.5
47.291	0.75	0.177	10.5-13
47.291	0.75	0.214	12-15.25
47.291	0.5	0.06	7_9
47.291	0.5	0.122	7_10
47.291	0.5	0.177	7-10.5
47.291	0.5	0.214	6-11.5
47.291	0.25	0.06	4-5.5
47.291	0.25	0.122	4_6
47.291	0.25	0.177	4.5-7
47.291	0.25	0.214	6-7.5

A. Dependence of cutting force on cutting variables:-

It is well known that the cutting force is strongly dependent on the area of cross section of the uncut layer being transformed into chips during cutting. The basic variables, that determines the area of cross section of the uncut layer in turning is depth of cut and feed. Several attempts to correlate these parameters with cutting orce is reported in literature. From the cutting force measurement, it has been observed that the force magnitude is strongly dependent on the magnitudes of feed and depths of cut. Also, it is seen from technical literature that a number of varying models are suggested linking feed depth of cut cross sectional area of uncut layer, etc by different investigators.

In the present work, an attempt is made to fit an empirical model of the form, $P = k\, s^{x}\, t^{y}$ (N), where s, t are the feed rate and depth of cut, and k, x and y are the constants with cutting test data, using the statistical method of curve fitting.

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B. *Power consumption in cutting*

The energy consumed during machining was measured through an energy meter hooked into the power supply side of the equipment. Energy utilized for machining operation was measured and convert the energy value (KWH) into power (watts). That is, input power = energy consumed during known time × 3600×1000 / time for machining. Specific Power Consumption (SPC) is a better measure for comparison of cutting power at different parametric values. Specific Power Consumption is determined from its definition as,

Specific Power Consumption =

Cutting Power / Material Removal Rate.

C. *Surface finish measurement*

Work blanks, annular cylindrical discs, of low carbon steel materials mounted on a mandrel are machined under different cutting conditions. The surface finish was monitored by using a stylus type Profilometer offline. Typical surface profile traces obtained under varying conditions of machining are presented in Figs. 2 to 5

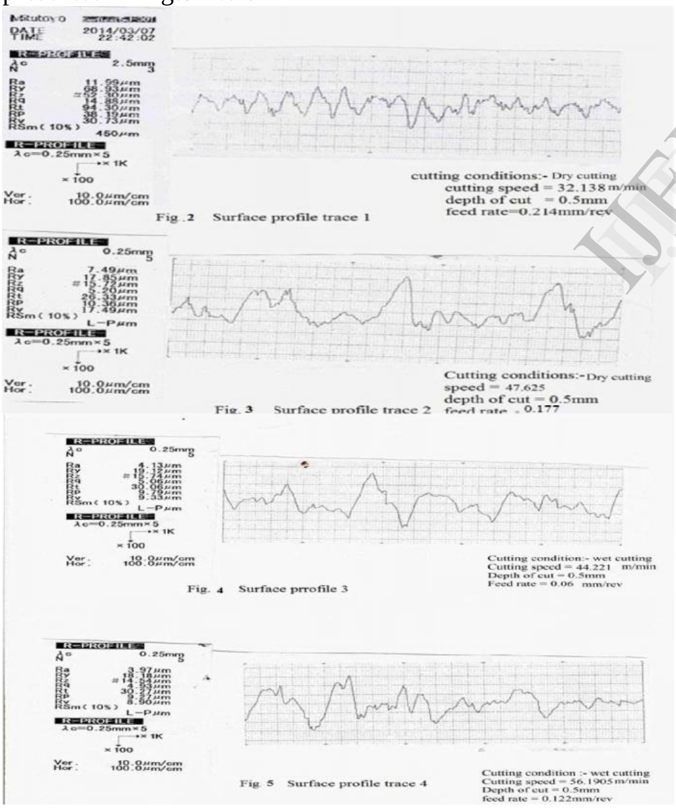

Fig. 2 Surface profile trace 1

Fig. 3 Surface profile trace 2

Fig. 4 Surface prrofile 3

Fig. 5 Surface profile trace 4

IV. RESULTS AND DISCUSSION

A. *Cutting force analysis:-*

1) Influence of depths of cut in cutting force: Cutting tests were carried out at different depths of cut, viz. 0.25, 0.5, 0.75 and 1 mm with feed and cutting velocity being maintained constant under dry and wet cutting conditions. The variations of cutting force with depths of cut are presented in fig.6 during dry cutting and fig.7 during wet cutting operation. The cutting force depicts an increasing trend with increasing value of depths of cut within experimental limitations. As is being expected, wet cutting condition yields higher cutting force magnitudes compared to dry cutting conditions.change the default, adjust the template as follows.

2) Influence of feed rates on cutting force:
In machining, the area of the uncut layer is dependent on feed and hence feed rate, becomes a strong parameter influencing cutting force. From among the mechanized feed rates, available on the lathe, for levels of feed rates viz. 0.06, 0.122, 0.177 and 0.214mm/rev were chosen for the investigation ensuring their feasibility.

Cutting tests were performed under dry cutting and wet cutting conditions with constant values of depths of cut and cutting speeds. The repeatability of result was ensured repeating the cutting trials at-least once, scrapping erratic values of results wherever occurred. The dependence of cutting force in feed is presented in fig.8 for dry cutting conditions and fig.9 for wet cutting conditions. Cutting force, in general, increases with increasing values of feed with higher for dry cutting condition.

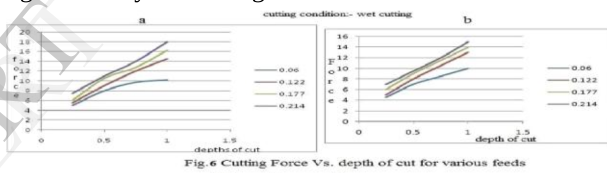

Fig.6 Cutting Force Vs. depth of cut for various feeds

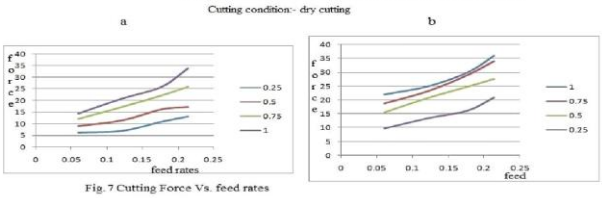

Fig. 7 Cutting Force Vs. feed rates

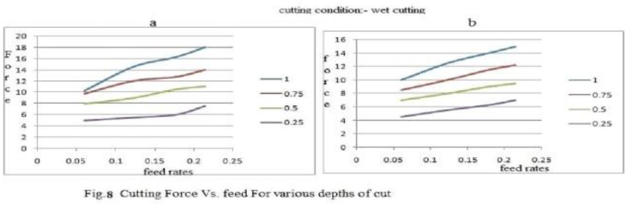

Fig. 8 Cutting Force Vs. feed For various depths of cut

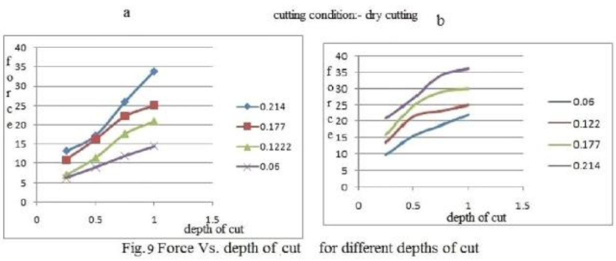

Fig.9 Force Vs. depth of cut for different depths of cut

3) Empirical force model derived from cutting data Tables:

The empirical relationship obtained for cutting force prediction is,

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$$P = 33.533\ s^{0.1099} t^{0.43979}$$ for dry cutting, and

$$P = 19.9601 \times s^{0.205629} \times t^{0.39733}$$ for wet cutting conditions.

By using the above equations for prediction of cutting force for dry cutting and wet cutting conditions, Standard Errors over force measurements were estimated as ξ_{dry}= 5.0239 and, ξ_{wet}=1.4890N respectively.The high value of standard error on force measurements under dry cutting conditions may be assigned to high averaging error of dynamic cutting force observed in force measurements during cutting tests. A more sensitive force transducer and a lathe of better rigidity are likely to bring down the magnitudes of uncertainty observed in force measurements.

4) Effect of cutting variables on surface roughness:

Cutting tests were carried out at varying feed rate levels with constant depth of cut of 0.5mm and cutting velocities, in both dry cutting and wet cutting conditions of machining. The variation of surface roughness parameter Ra value against the feed values as shown in figs.10 and 11 in dry cutting and wet cutting conditions. The graph indicates increasing trend of roughness value with feed. And also figs.6 and 7 indicates decreasing trend of surface roughness with increase in cutting speeds.

5) Energy consumption in machining:

Power measurements were done on the machine to study the power consumption variations with feed, depth of cut and cutting speed. The results of the tests are presented in figs.12 and 13 in terms of specific power consumption. The specific power consumption decreases with increase in feed and depths of cut. However, the specific power has a decreasing trend with increase in cutting speed. At terminal values of cutting speed applied, the specific power consumed shows a rising trend and this can be explained in terms ineffectiveness of cutting fluid application at higher values of cutting speed and a corresponding increase in cutting force. An interesting observation from the specific power consumption data is the existence of optimum cutting speed range of 35 to 50m/min during which the specific power consumption is seen practically constant with variation in feed and depth of cut.

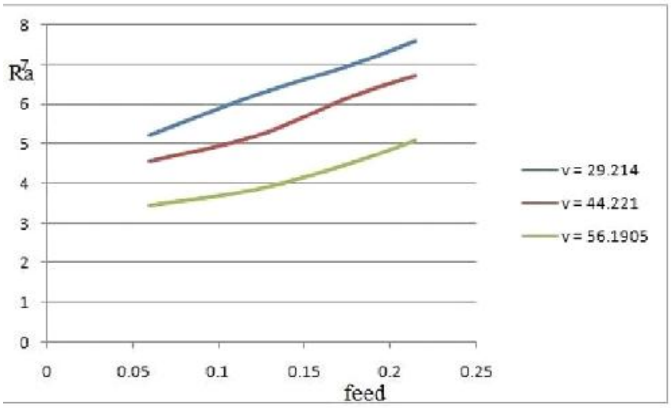

Fig.10Ra value Vs. feed in wet cutting condition

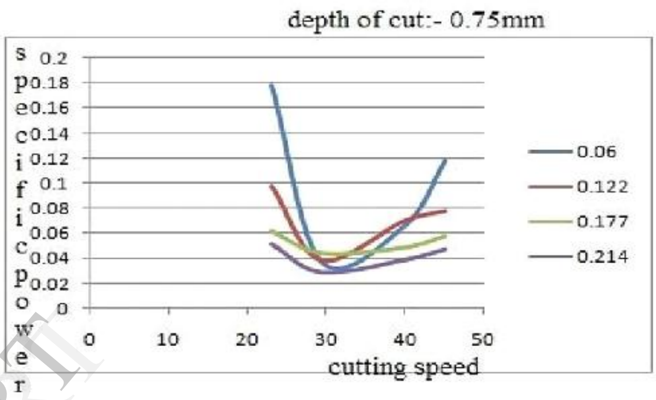

Fig.12 Specific power Vs. cutting speed for various feed rates

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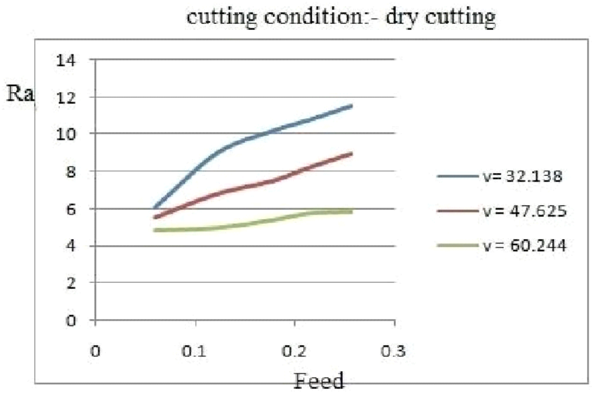

Fig11 surface roughness value Ra Vs. feed

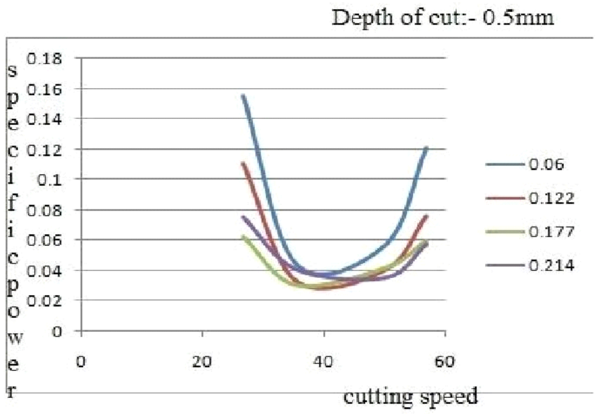

Fig.13 Specific power Vs. cutting speed for various s

V. CONCLUSION.

- The power component of the cutting force is found strongly dependent on basic cutting variables, the depth of cut being a stronger variable.

- There is significant reduction in the magnitude of cutting force with the application of cutting fluid.

- An empirical relationship correlating cutting force with feed and depth of cut in the form $P= k s^x t^y$ has been derived using curve fitting by the method of least squares.

- Cutting speed has relatively smaller influence on cutting force compared to feed and depth of cut.
- The specific cutting power decreases with increase in feed and depth of cut. Even though increase in cutting speed also displaced a similar trend, increase of power consumption is seen at high cutting speeds in wet cutting conditions indicating ineffectiveness of cutting fluid and/or increase of cutting force magnitudes at higher strain rates.

- Low magnitudes of feed rates and high values of cutting speed results in better surface finish and lower values of surface roughness.

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