PERFORMANCE CHARACTERISTICS OF A CAM TURNING ATTACHMENT

by

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ABSTRACT
A modification of a cylindrical turning unit has been done to give a non-cylindrical turning attachment for production of irregular shapes, like cams on the lathe machine. To assess the performance of the attachment, cutting forces have been measured using a 'Sigma' Cutting Tool Dynamometer. Furthermore, the effect of cutting parameters, such as, cutting speed, depth of cut and feed rate on the cutting forces, machining power and specific cutting energy have been investigated.

1. INTRODUCTION

Generally, a lathe machine belongs to the most versatile machine tools group, with which some of the basic cutting operations, such as turning can be performed. With attachments, the lathe machine can be used for such special operations like non-cylindrical turning. The production of irregular objects like cams in workshops can be a time-consuming and expensive operation requiring much careful machining by skilled machinists. Though with some limitations, for example, as to the shape that can be produced, the attachment can be used to' produce cans of various shapes and many other irregular workpieces.

Usually, in ordinary turning operations, [2] cutting speed is kept between 3 m/min and 200 m/min but in exceptional cases, may be as high as 3000 m/min. Feed rates may be as low as 0.0125 mm per revolution and with very heavy cutting up to 2.5 mm per evolution. Depth of cut may vary from nil over part of the cycle to over 25mm.

For the performance characteristics tests, three metal cutting variables have been considered with the tool rake angle and tool over hang maintained constant. The three variables are the cutting speed, feed rate and the depth of cut. Because of the shape of the flat cam template, with a maximum pressure angle of 24^0, which is affected by the size of the base circle [2], the maximum cutting speed used for the experiment was 18.85 m/min. It should be noted however, that speeds up to 30 m/min can be achieved depending on the shape of the master piece and the size of the workpiece needed.

A "Sigma" Cutting Tool Dynamometer has been used to record the cutting forces, from which machining power and specific cutting energy have been computed.

2. THE CAM TURNING ATTACHMENT

Briefly, the attachment is made up, of a drive system and a hydraulic turning unit. The drive system, which is used to drive the master piece, is made up of a suitable flexible shaft, a lathe spindle clutch and a shaft supported in ball bearings to carry and drive the master piece. This is shown in figure 1.

The hydraulic turning unit which is intended for cylindrical turning has been modified and used in conjunction with the drive system, as shown in figure 2, for non cylindrical turning.

The modified follower of the hydraulic turning unit is then used to follow a rotating masterpiece and a properly ground turning tool, mounted on the tool post, is used to produce cams of various sizes, since the master piece is rotated at the same speed as the lathe spindle. Figure 3 shows a cam as it is machined using the attachment. Other irregular shapes can also be produced in this manner.

3. EXPERIMENTAL WORK

An appropriate cutting bit with a rake angle of 10^0 is mounted on the tool holder of 'Sigma' Cutting Tool Dynamometer. The tool holder of the Dynamometer is then rigidly mounted on the tool post of the cam turning attachment. The vertical indicator of the dynamometer is then used to record the cutting forces at various values of speed, feed and depth of cut while machining, using mild steel as the workpiece. The set up for the experiment is as shown in figure 4. No cutting fluid (Coolant) was used for the tests.

4. RESULTS AND ANALYSIS

Measured values of the cutting forces at various cutting speed, feed rate and depth of cut values are shown in Tables 1 to 4. Also the values of energy consumption during machining and the specific cutting energy are shown in the tables as computed using the following equations [3, 4]:

$$p_m = p_c \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where p_m is the machining power and v is the cutting speed

$$p_s = \frac{p_m}{z_w} = \frac{f_c}{A_c} \ldots\ldots\ldots\ldots\ldots\ldots.. (2)$$

Where p_s is the specific cutting energy, z_w is the metal removal rate, and A_c, is the cross-sectional area of the uncut chip, which is the product of feed rate and underformed chip thickness.

Graphs have been plotted of the cutting variables-feed rate, depth of cut and cutting speed, against the cutting force, machining power and the specific cutting energy. These graphs are shown in Figures 5, 6,7,8,9,10,11,12 and 13. Also plotted is the graph of the follower- master piece contact pressure against the cutting force. This is shown in Figure 14, and it can be seen that the contact pressure does not affect the cutting force. From the graphs (figures 5,6 and 7), the cutting force increases with increase in cutting speed, feed rate and depth of cut. Similarly, the machining power (figures 8, 9 and 10) increases with cutting speed, feed rate and depth of cut. The specific cutting energy (figures 11, 12 and 13), which is a function of cutting force and cross sectional area of uncut chip, decreases exponentially (towards attaining a constant energy value) with the cutting speed, feed rate and depth of cut.

For the purpose of an approximate comparison Boothroyd [3] gave the relationship of the specific

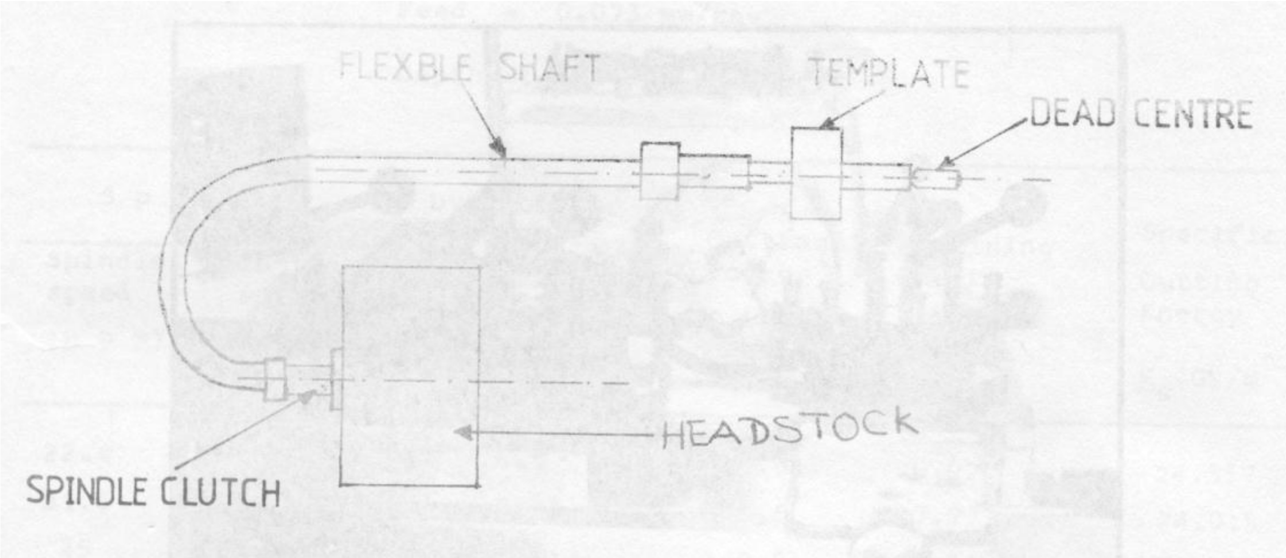

Fig.1 power from the headstock using flexible shaft drive

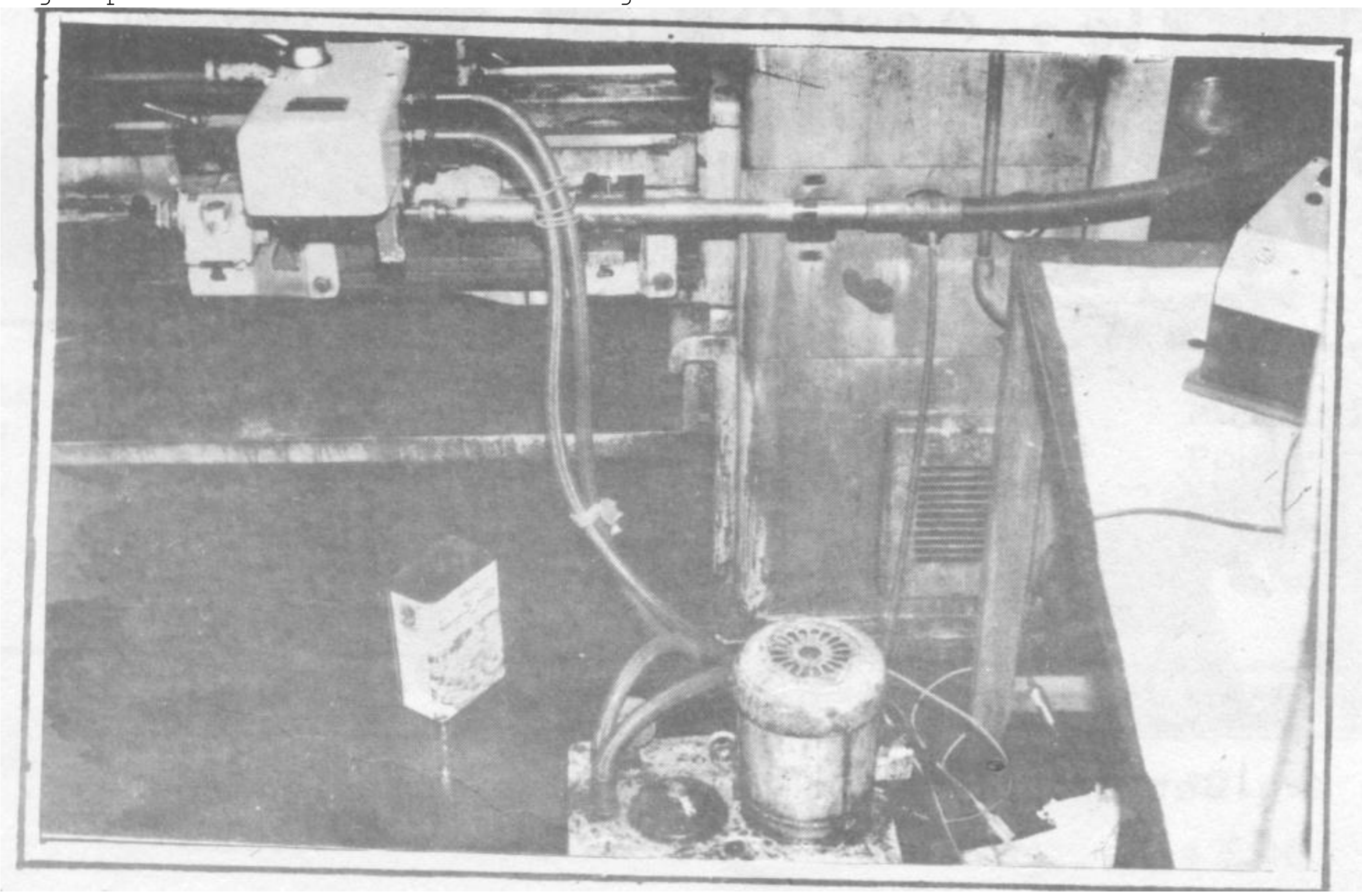

Fig.2: modified hydraulic turning unity and the drive system.

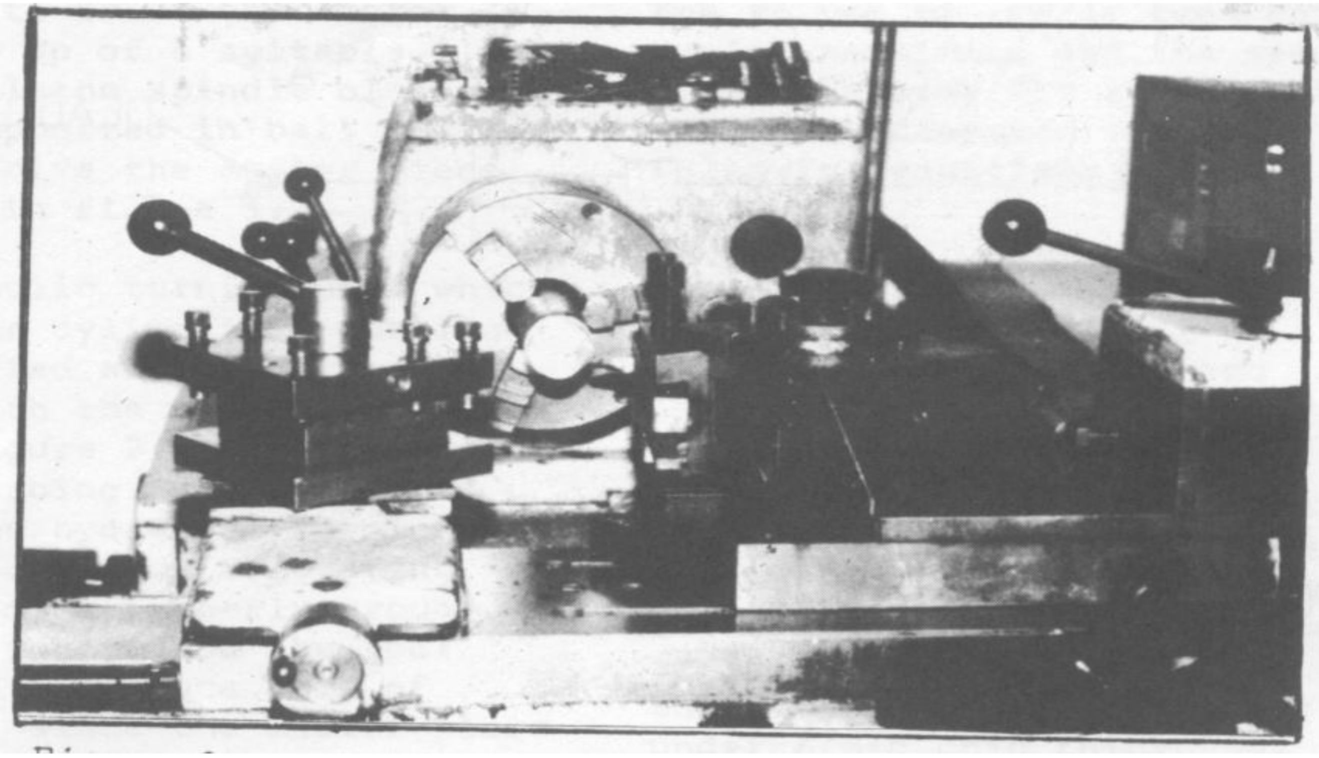

Figure 3: A cam as it is machined using the attachment

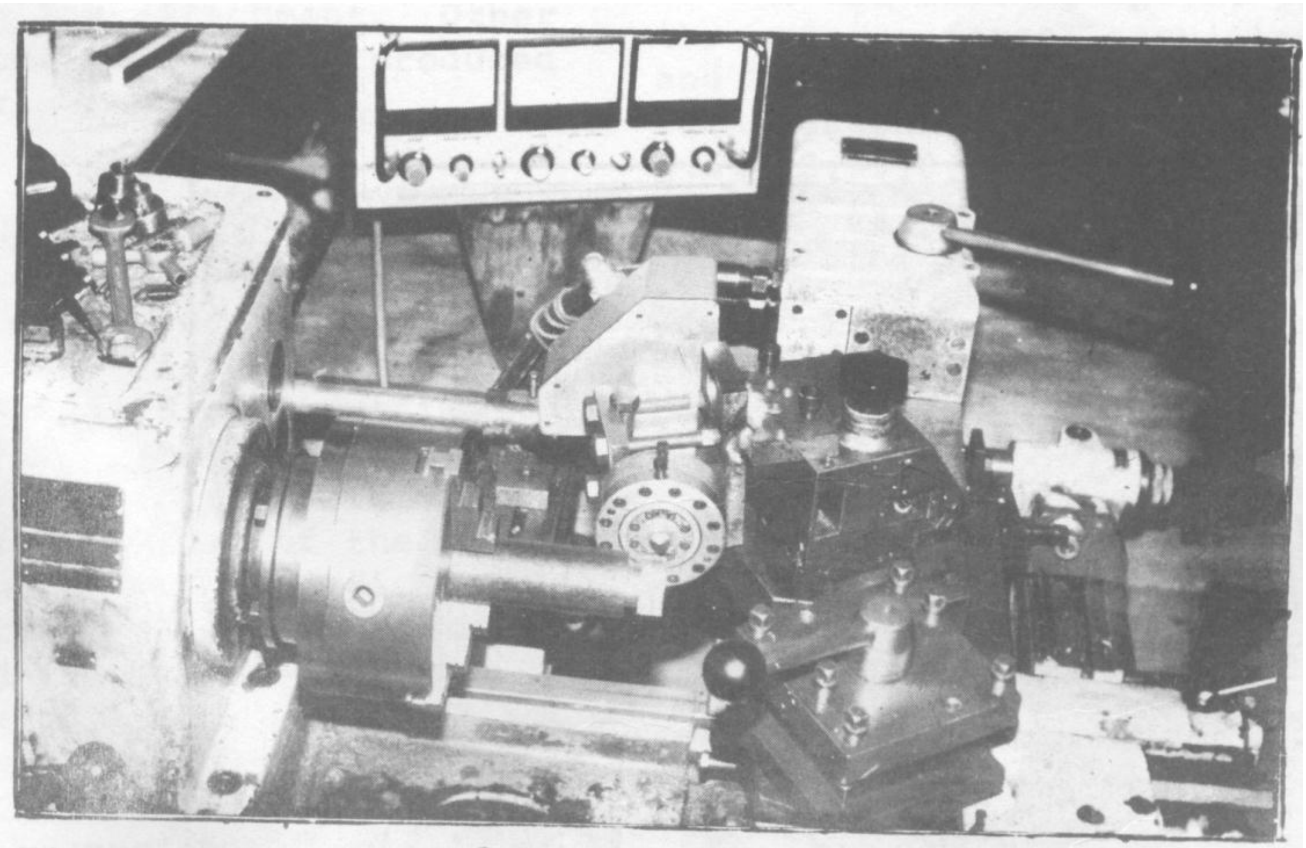

Fig. 4: Set-up for the measurement of cutting force

Table 1: measured cutting force and calculated power and energy with speed variations feed = 0.073mm/rev
Depth of cut = 0.2mm

Speed		Dynamometer inductor reading. (Vertical component.)	Cutting force F_C (N)	Machining power P_m(w)	Specific, cutting energy P_S GN/m^2
Spindle, speed (R P M)	Cutting speed v(m/min)				
22.4	3.38	1.63	355.61	20.02	24.357
31.5	4.75	1.57	350.6	27.77	24.015
45	6.79	1.55	349.5	39.54	23.95
63	9.5	1.54	347.4	55.00	23.80
90	13.57	1.52	345.6	78.18	23.671
125	18.85	1.42	335.5	105.4	22.98

Table 2: Measured Cutting Force and Calculated Power and Energy with Variations in Depth of Cut
Spindle Speed = 63 rpm
Feed = 0.040 mm/rev;

Depth of cut (mm)	Cutting, speed v (m/min.)	Dynamometer, Indicator Reading (vertical Component)	Cutting, force F_C (N)	Machining, power p_m(w)	Specific, cutting energy P_S GN/m^2
0.2	7.84	1.00	294.30	38.46	36.788
0.4	7.92	1.12	306.56	40.47	19.16
0.6	8.00	1.63	355.61	47.40	14.817
0.8	8.08	2.25	416.93	56.12	13.029
1.0	8.16	2.5	441.45	60.04	11.036
1.2	8.24	2.75	465.98	63.98	9.708

Table 3: measured cutting force and calculated power and energy with feed variations.
Spindle speed = 63 rpm
Cutting speed = 8.316 m/min.
Depth of cut = 0.2mm

Feed (mm/rev)	Dynamometer, Indicator Reading (vertical)	Cutting Force F_C (N)	Machining, Power P_m (w)	Specific, Cutting Energy p_s (GN/m^2)
0.040	1.62	355.6	49.29	44.452
0.073	2.12	404.7	56.09	27.716
0.093	2.25	416.9	57.79	22.415
0.127	2.63	453.7	62.89	17.863
0.254	3.25	515.0	71.38	10.138
0.508	4.75	662.2	91.78	6.517

Table4: measured force and calculated power and energy with variation in template contact pressure
Spindle speed = 63 rpm
Depth of cut = 0.2mm
Feed rate = 0.040 mm/rev.
Cutting speed = 0.1286 m/s

Contract Pressure (N/M^2)	Dynamometer Indicator Reading (vertical	Cutting Force F_C (N)	Machining, Power P_m (w)	Specific, Cutting Energy P_s (GN/m^2)
0.0108	0.8	294.30	37.847	36.787
0.01177	0.9	296.30	38.104	37.037
0.01275	1.0	306.56	39.424	38.32
0.01373	0.9	296.30	38.104	37.037
0.01472	1.0	306.56	39.424	38.32

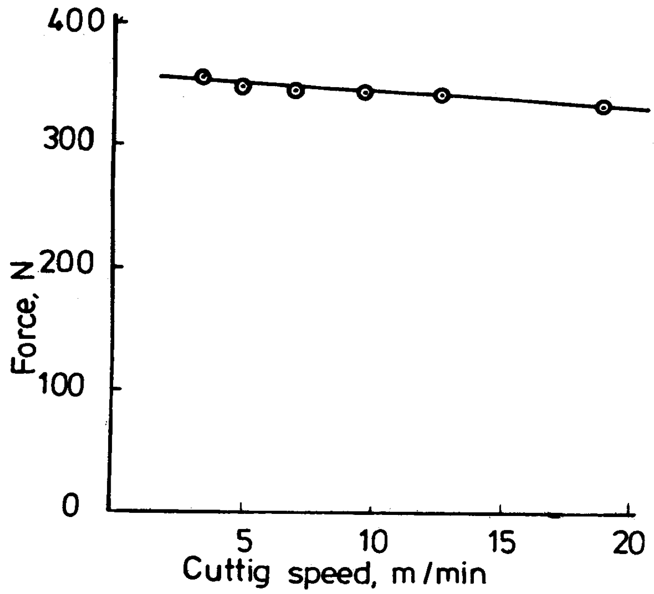

Fig. 5: Cutting force Vs Cutting speed

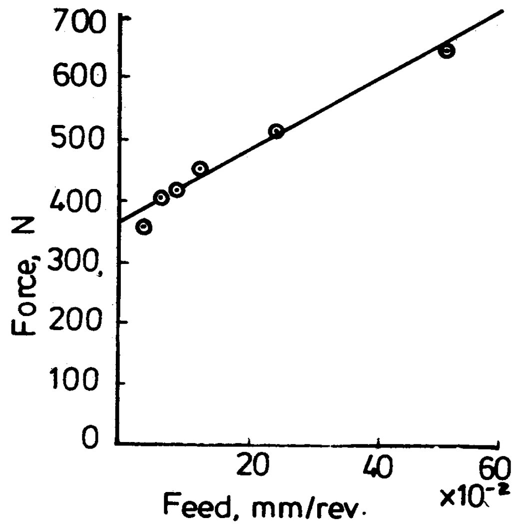

Fig.6: Cutting force Vs feed

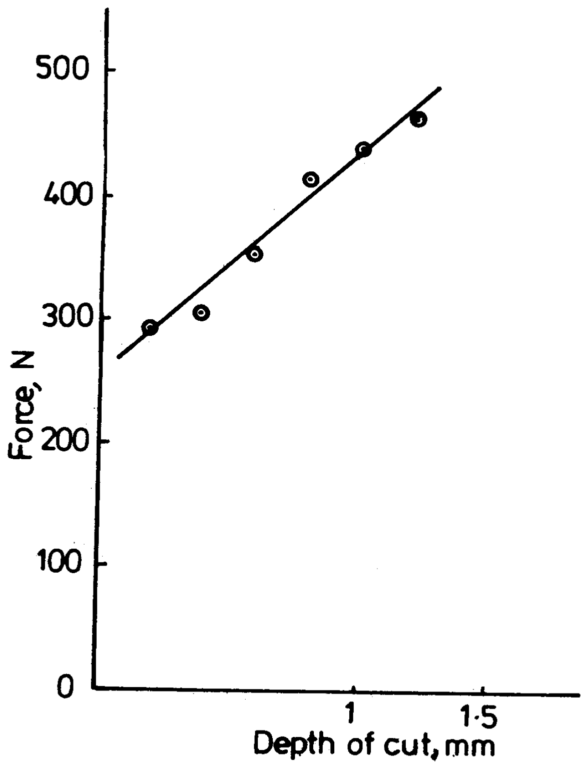

Fig. 7: Cutting force Vs Depth of cut

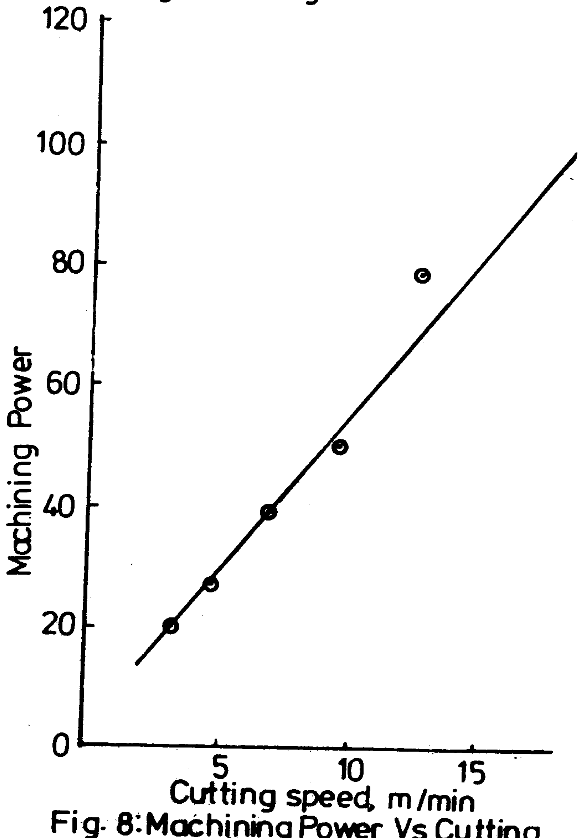

Fig. 8: Machining Power Vs Cutting speed

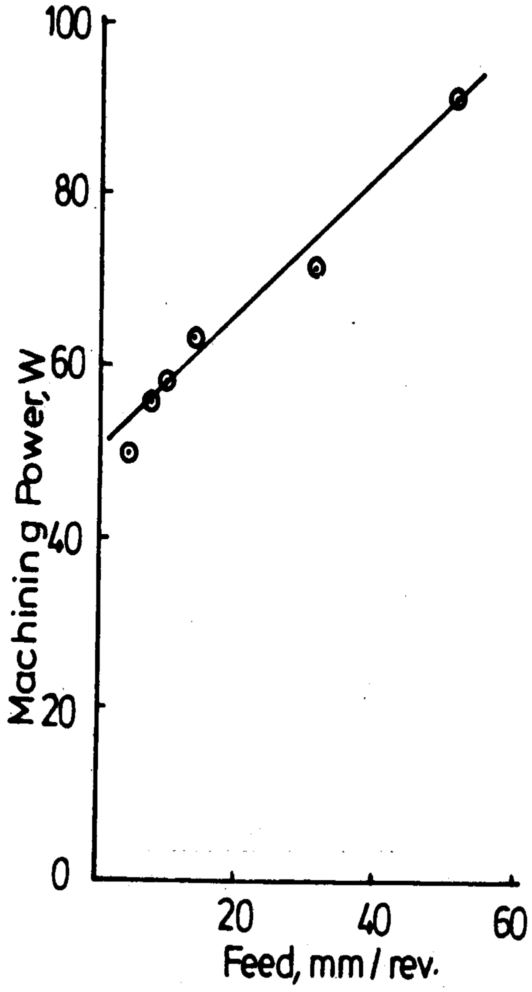

Fig. 9: Machining Power Vs Feed

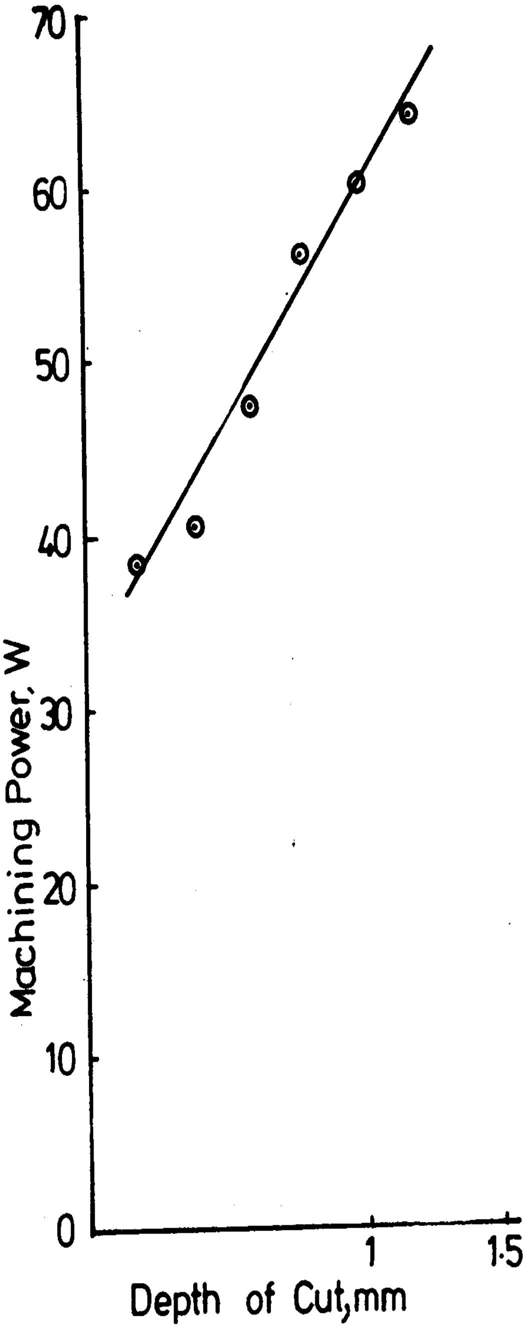

Fig. 10: Machining Power Vs Depth of cut

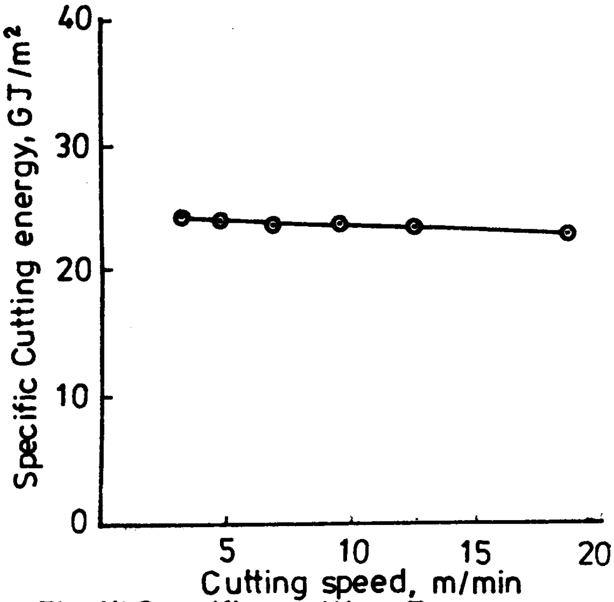

Fig. 11: Specific Cutting Energy Vs Cutting speed

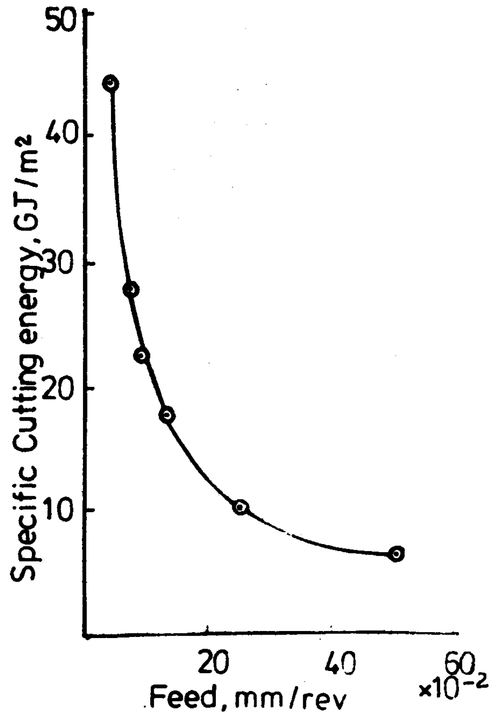

Fig-12: Specific Cutting energy Vs feed

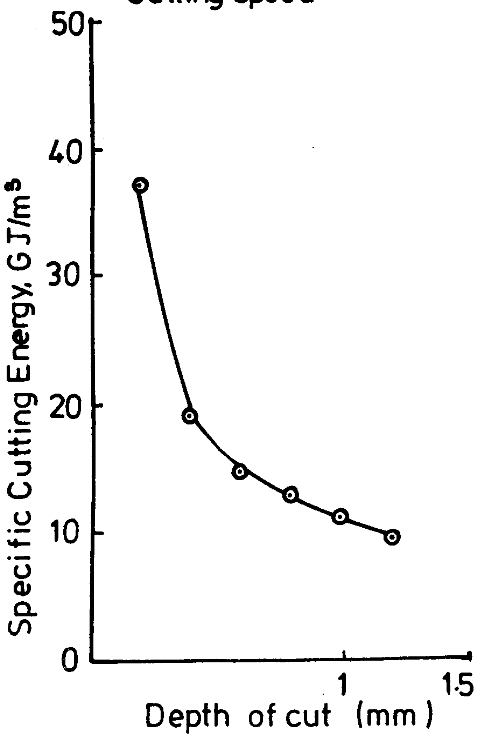

Fig 13: Specific cutting Energy Vs Depth of cut

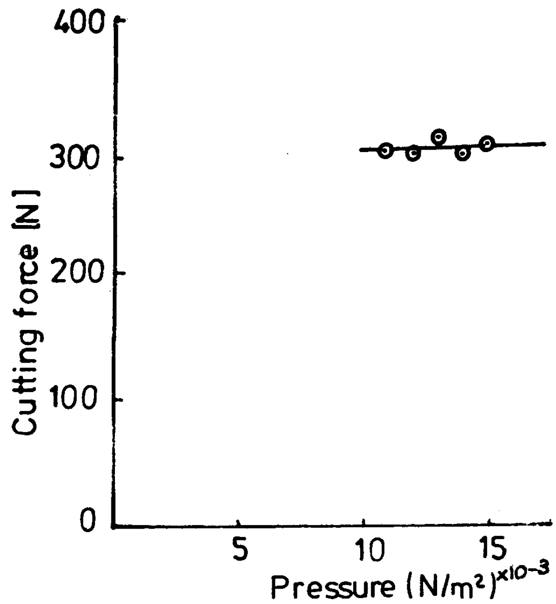

Fig. 14: Cuttingforce Vs follower - Template contact pressure

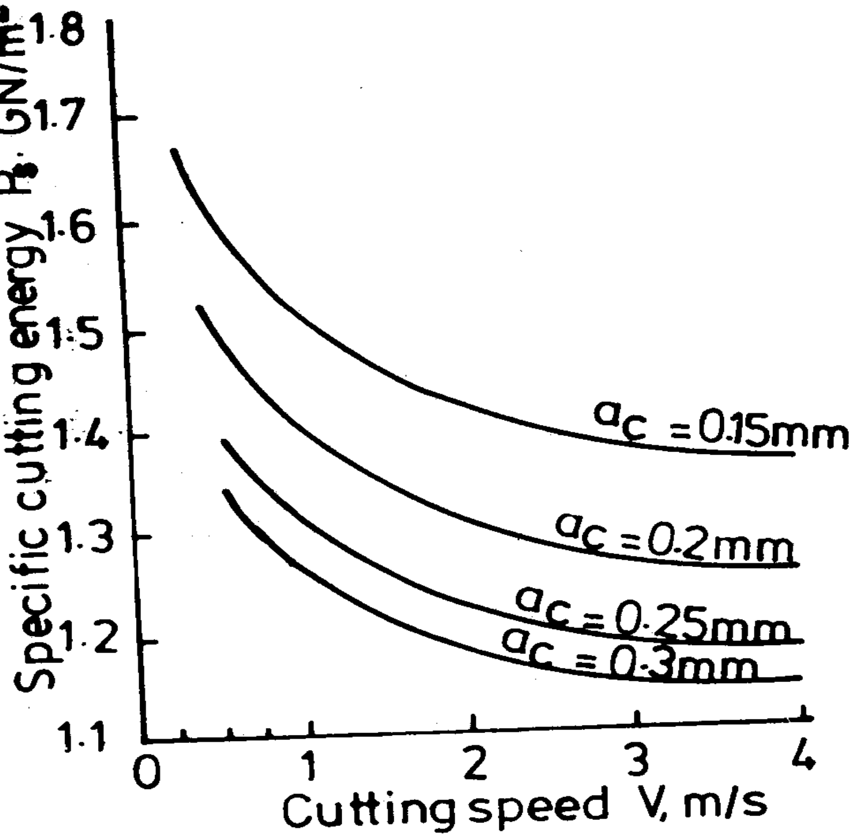

Fig. 15. Effect of cutting speed and undeformed chip thickness on specific cutting energy

Cutting energy and speed at various underformed chip thickness values as shown in figure 15. He observed that at low cutting speed and feeds, the specific cutting energy decreases exponentially with increase in cutting speed and underformed chip thickness, towards attaining a constant energy value at large cutting speeds and feeds.

5. CONCLUSIONS AND RECOMMENDATIONS

Generally, many-special operations can be performed on a centre lathe with the aid of specially designed attachments. Tests performed using the cam turning attachment show that cutting force and machining power (which is a function of the cutting force and speed) both increase with the cutting speed, feed rate and depth of cut. Tests performed also show that variation in the follower template pressure, does not affect the cutting force. This implies that the machining power and the specific cutting energy are not affected by the variation in the contact pressure. A parameter giving aft indication of the efficiency of the process, independent of the cutting speed, is the energy consumed per unit volume of metal removed, referred to as the specific cutting energy.

From the graphs of specific cutting energy plotted and compared with Figure 15 [3] it is seen that this parameter decreases with the cutting speed, depth of cut and feed rate. - This agrees with the fact (already pointed out by Boothroyd) that the specific cutting energy can vary considerably for a given material and is affected by changes in cutting speed, feed, depth of ,cut and tool rake. Though with a speed limitation of approximately 30 m/min depending on the pressure angle of the master piece and the size of the work piece required, large feeds and depth of cut can be achieved. The attachment can therefore, be used effectively for production of irregular shapes like cams.

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