ISSN: 2454-4248
168 – 172

Tool Forces Dynamometer for Shaper Machine

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***Abstract*—**For cutting force measurement, a beam type load cell dynamometer was designed and fabricated using beam theory of bending for measuring cutting forces during shaping operation. The strain gauges were used for forces at different load. The experimental data were recorded on a computer during all experiments. The designed dynamometer calibrated to measure cutting & thrust forces. The effects of cutting parameter, different tool shape, and material were analyzed for cutting forces by using single variable experiments.

***Keywords*—** *Cutting force, thrust force, shaping operation*

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I. Introduction

The cutting operation by shaper machine is depends on the stroke length and force/torque produced by the machine through ram. As we know, the tool is fitted on the ram so the same force may produce by the cutting tool on the workpiece. So the type of operation are also depends upon the selection of type of tool for a particular operation on workpiece. The cutting should be designed on the basis of this cutting force. The tool failure may be come on a particular portion, where it will have low strength or reduced strength below the cutting force offered by the tool. It may cause by more feed in a stroke, more temperature generation on the tool, and large stroke length etc.

A dynamometer (Shaw, 1989) is used to measure forces that occur in metal cutting or any other operation. Cutting force is the most important parameter which plays an important role in machining and for attaining good surface qualities like surface finish, surface roughness and accuracy of dimensions. Lal [1994] stated that, in metal cutting, the knowledge of the magnitude and the variation of the cutting forces under the various cutting condition is useful for design of rotational machine tools. It helps the designer in deciding how the machine should be constructed and what should be the dimensions of the various machine components should have, and how much power will be necessary to drive the tool and machine table. The same knowledge will also help choosing the suitable tool for a particular job with regards to its capacity and durability. Due to these aforesaid reasons, the measurement of cutting forces is very important in machining because such forces directly affect the tool life & surface quality. The life of the tool depends on the heat generation and stresses produced in the tool during the machining.

Hallam and Allsopp [1962] designed and developed a dynamometer for boring machine. It was tested to measure cutting forces during boring operation by using a cantilever type boring bar and analyse the effect of cutting parameters on forces.Taglia and Tani [4] propped a simulation method for cutting force measurement by measurement of force exerted on the tool.

Based on similar study a dynamometer have also designed and developed for drilling machine by Vankataraman et al. [5]. In continuation of that Raffaello and Levit also measured the forces on twisted drill by the help of drill press dynamometer.

It is required to measure the cutting forces in three perpendicular direction such as x, y and z direction in turning operation on lathe [King and Foschi, 1969]. It was stated that the x, y and z directional components are assumed as feed component, radial component and tangential component respectively. Lee and Tarang [7] predicted the cutting force during the turning operation on lathe machine for which a mathematical model have developed. Saglam et.[8] developed an experimental setup to measure the cutting forces on CNC lathe. It was observed that the cutting forces are more affected by rake angle and tool temperature. Other researcher also carried out the parametric analysis of CNC machine tool [9].

In continuation of the development of dynamometer, some researchers have also developed and experimentally analysed dynamometer for the force measurement of cutting tool on broaching machines. Few researchers have developed a mathematical model to relate the load on chip & force during broaching process. The concept of the mathematical modelling presented the actual force on the chip during broaching process. [Kuljanic] [10], Gopalkrishnan et.al [11]]Sutherland et.al [12]Chang et.al [13] experimentally measured the forces in super finishing process on lapping machining using piezoelectric transducer. The experiments have performed on case hardened steel tool and the force transducers fixed by specially developed holder.

Korkut [14] developed a strain gauge based force measuring dynamometer for milling machine. The data were also recorded on computer using suitable software and hardware, it is also suitable for turning, grinding and drilling operation. Totis [15,] developed a piezoelectric sensor based dynamometer for accurate measurement of forces in milling and turning CNC machine tool. The dynamometer is experimentally verified for statically and dynamically. It was stated that the device is more accurate for force measurement. In continuation of that it have designed and developed a new plate dynamometer for milling and drilling machine, and the parametric study have also been done .[16]. EmrullahKorkmaz et.al [17] designed and developed a multi axis dynamometer is for accurate measurement of three force components. The developed technique of measuring forces using a designed artefact was facilitating the applying impulsive force to the dynamometer at different position in three dimensions. This technique has been able to measuring forces within a broad

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168 – 172

range of frequency. The force measurement on tool in shaping machine is required more experimental work, because different shapes, materials and nose radius should be affect the tool strength and life time. In this communication the tool forces have been measured for different configurations and for which we have designed a dynamometer which fitted on machine vice. It can measure the forced offered by the tool by the assumption of action and reaction law of Newton. Conformity of style throughout conference proceedings.

Table 2. – Technical specification of Load Cell

Technical Data	Unit	Model:
Sensitivity	mV/V	2 ± 10%
Zero Balance	%FS	± 1% of rated output
Non Linearity	%	±0.02
Hysteresis Error	%	±0.02
Input Resistance	ohms	420 ± 20
Output Resistance Voltage	ohms	350 ±3
Reference Excitation	V	5~12
Maximum Excitation Voltage	V	15
Safe Load Limit	%	150
Ultimate Load Limit	%	300

II. MATERIAL & METHODS

A. Experimental Set Up

The experimental set-up is consists with the shaper tool of different configurations, shaper machine and Dynamometer. The dynamometer is fitted on the machine table as per the assumption of the same force is measured by the dynamometer equivalent to the force acting the work piece in cutting. It means it follows the action reaction law of Newton's law of motion. The complete picture including all arrangements is shown in figure 1.

The Dynamometer or Load cell is used for force measurement made of load master manufacturer. The technical specifications of load cell are shown in table 1, and arrangement for both sides machining table is represented in Figure 2. The sensitivity, non-linearity, and hysteresis errors are 2 ± 10%, ±0.02 and ±0.02 accordingly. The safe limits of the load cell for forward and backward directional movements of the tool are 300kg and 150 kg.

Figure 1: Shaper Machine

In this analysis a shaper machine have used which makes by Master India pvt.ltd Ludhiana. The belt driven arrangements electrical motor which operates the machine for 3 speeds and other specifications are given in table.

Table1. Specification of Shaper machine

No. of Speed	RPM	Motor Power (Kirlosker)	Stroke	Table size	Max. feed	Table Travel
03	1440	1hp	8"	8.5" x 10.5"	0.35	15"

B. *Maintaining the Modified Machining table with fixing of Load Cell*

The template is used to format your paper and style the text. All Aluminium material is used to fabricate beam type load cell structure as per the drawing shown in Fig.3. It shows that total eight strain gauges are fixed on the machining table, Where 1& 2 are fixed in the one side and 3 & 4 fixed in another side. Similar practice is used for fixing the 5, 6, 7, 8 strain gauges. From the Figure 4, it can be seen that strain gauges1, 2, 3, 4 and strain gauges 5,6,7,8 are mounted to complete the Wheatstone bridge, which will be used to measure the cutting force (F_P) & thrust force (F_Q) respectively.

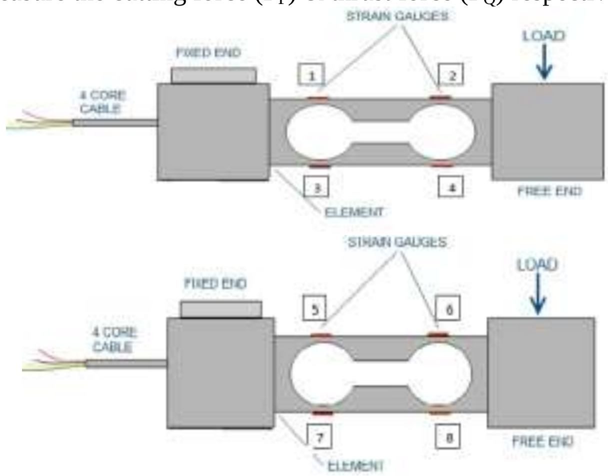

Figure3. Schematic diagram of beam type load cell dynamometer for cutting force measurement

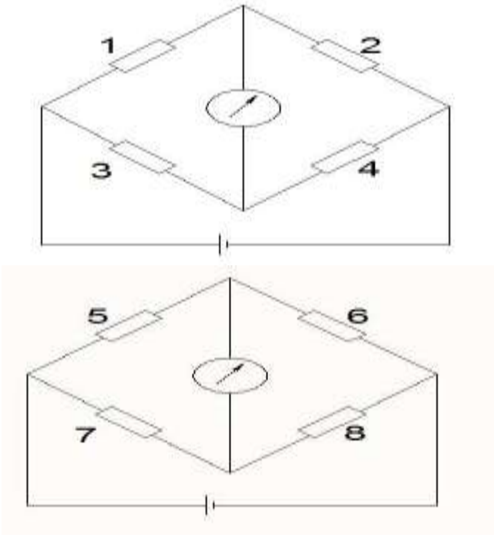

Fig. 4 – Strain gauge whetstone bridge circuit for measuring cutting forces

III. RESULTS & DISCUSSION

Using the above mentioned experimental set up the cutting and thrust forces for during shaping operation are measured. The resistance type strain gauges are used for measurement, with the Wheatstone bridge principal, when there is no load on the load cell the wheat stone bridge is balance and when the load is applied the bending of beam concept is applied. In Beam type load cell dynamometer, when the load applied by applying the load the two strain gauge were in compression and other two were in tension. As the load is applied, resistance of all four strain changed gauge and sum of total resistance change of strain gauge is proportional to the applied load on the cell. The display unit of experimental set up shows the excitation voltage in mili volt/V as an output. As load is applied, the signal strength is change due to change in resistance of strain gauge that is directly related with the change in applied load.

Uncertainty Analysis:

A load cell is used to measure the weight and force for different conditions. Strain gauges are used in the load cell, in wheat stone bridge circuit. It is a transducer that converts force into electrical signal. These signal are usually comes out in millivolts.The uncertainty is characterized the dispersion of the values attributed to a measured quantity in load cell. As per the standard the load cells must be annually calibrated. It is calibrated and calculated the uncertainty of the load cell system is $\pm$0.0195. The designed and fabricated dynamometer was calibrated for hysteresis & cross sensitivity. To check the precision level of the dynamometer, it was calibrated using the loads on February 8, 2017. For linear uncertainty, the calibrated data are shown in Figure 5. The experimental work has been carried out in the machine shop of Institute of Engineering and Technology Alwar [27° 34' N, 76° 38' E], India. Mild steel [AISI-1018] workpiece is used for the cutting operation on shaper machine.

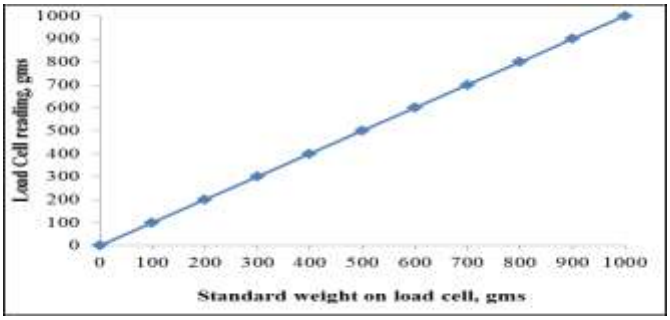

Fig 5.Calibration of Load Cell (Linear Uncertainty)

In this experiment, different tools according to tool materials such as HSS, P30, TTM, YG6 and K20 (cemented carbide) are used. In another experiment different shapes of tools also varying for the same tool material. Figure 6, shows that the thrust forces always lower than the cutting force. And the maximum cutting force (126.812 N) is offered by radius shape tool and lowest (86.338 N) for V-shape tool for same cutting speed (5.34 m/min), depth of cut (0.5 mm) and feed (0.3 mm/stroke).The motive is that more contact area between tool & work piece leads to a higher friction, hence increases cutting as well as thrust the forces. It is also observed that the thrust force is also highest for Radius shape tool and Lowest for V-shape tool such as 67.13 and 19.698 N respectively.

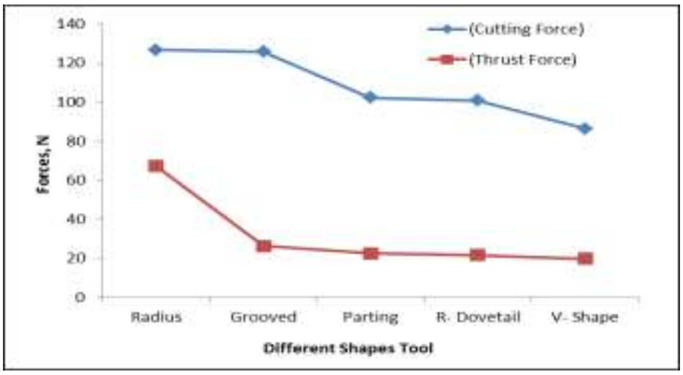

Fig. 6. - Forces offered by various tools

In continuation of above experimental work, the work is being repeated for same different rake angles such as: 0°,3°,5°,7°, and 9° for same material as HSS. The figure 7 shows the force offered by different rake angle tools for same cutting speed (5.34 m/min), depth of cut (0.5 mm) and feed (0.3 mm/stroke). It is found that, the maximum cutting force (90.65 N) is offered by tool which having zero rake, which also offered maximum thrust force. And minimum cutting force (73.304 N) and thrust force (13.818 N) are offered by 9° rake angle tool. So zero rake angle tools have more wear and tear than positive rake angle tool. The reason is that as rake angle increases the tool become more sharpen and pointed, it reduces the strength of the tool. But the more rake angle provided for easy removal of chips/machine cutting. In view of that it reduces the power requirements for cutting. Higher rake angle reduces the strength of the tool so it is not feasible solution to increase the rake angle more than optimum limit. Therefore it is necessary to optimize the rake angle of the cutting tool.

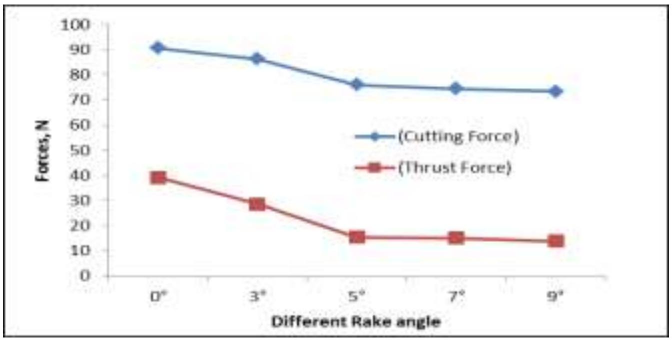

Fig. 7. –Variation of Forces for different tool rake angle

The figure 7 shows the tool offered forces according to the tool nose radius. From fig. 5, It is also clear that the nose radius shape tool is offering highest cutting force so minimum radius similar to the V-shape is a feasible option. So we have find out the effect of radius on cutting and thrust forces offered by the tool of same material (HSS) which shown in figure 8. It is expressed that both the forces observed minimum at minimum tool tip radius as 0.5 mm. Minimum radius is projected after a tool running for a smaller time. It is a desirable to decrease the chattering and minimize the cutting forces requirement in cutting operation by regrinding the tool.

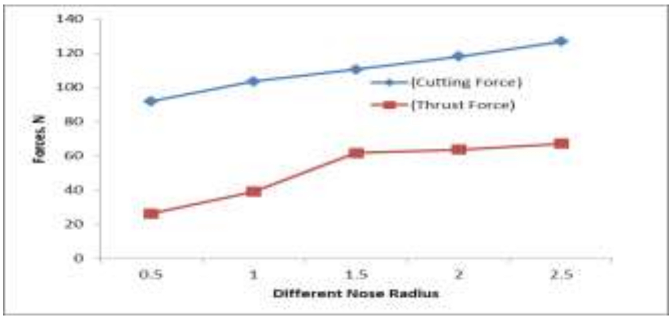

Fig. 8. Variation of forces for different tool nose radius

The tools can be made of many materials and a particular tool is required for the particular workpiece (according to the material contents). In this experiment we have used HSS, P30,TTM, YG6, and K 20 tools for Cutting speed 5.34 meter per minute, feed 0.3 mm/stroke and depth of cut is 0.5 mm. The variation of forces offered by the tool made of different materials is shown in figure 9. It is stated that, HSS toll offered highest forces and K20 offered lowest forces. The K20 tool is more feasible or acceptable for the cutting on mild steel workpiece but as considering the cost of the tool K20 is costly than others. So for all cutting operation where tolerance doesn't matter we prefer low cost tools. In another words, it shows to increases wear resistance, shock resistance & maintain sharpened edge throughout the cutting operation and easy removal of chip and reduce the forces.

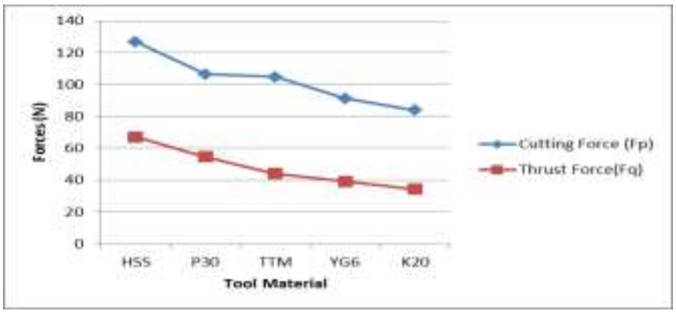

Fig. 9.Variation of forces for different tool material

The experimental work has been carried out in the laboratory for five shapes, five nose radiuses, five angles and five materials. It is observed that lowest cutting force is observed by V shapes (86.338N) compared to other same material different shape tool. As concerned to the nose radius of the tool, it is found that the minimum nose radius (0.5 mm) offered a minimum cutting force (91.924 N) and it is desirable. Among the five different materials K20 tool offered lowest force such as 64.19N, it is harder and having high strength tool. And it is observed smother and easy cutting. The V shape tool is most suitable tool as per the results observed and found minimum cutting force by 83.79 N. The other force like thrust for is always lower for all above concluded configurations. This study can be utilised by the scientific community for reference to the design of tool for shaping operations.

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