"Design and Development of a Tool Dynamometer Based on Load Cell for Analysis of Various Forces on RDM"

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Abstract : In this research work the two main objectives first is to developed such a experimental setup by which we measure torque and radial thrust directly and second objective is to investigate tool quality on various materials. The recent study consists of experimentations, parametric analysis using Visual basic software and finally mathematical modeling using software. Experimentation generally specifies the machining of Copper, Brass and Aluminum specimen on Radial drilling machine. The Objective of this research work is to establish thrust and torque model of drilling processes for enlarging holes, based on varying geometry and cuttings such models are potentially useful in a global drilling process simulation of tool motion and the generation of surface topography for a concurrent engineering design system. Such work is surely needed for meeting tolerance requirement, process planning and system monitoring

***Index Terms* – RDM, copper, brass, aluminum.**

I. INTRODUCTION

A machine manages power to accomplish a task. Some of the good examples of it are a mechanical system, a computing system an electronic system, and a molecular machine. In common usage, the meaning is that of a device having parts that perform or assist in performing any type of work. A simple machine is a device that transforms the direction or magnitude of a force. Historically, a device required moving parts to classify as a machine; however, the advent of electronics technology has led to the development of devices without moving parts that many refer to as machines, such as a computer, radio, and television.

Machine design is an important part of engineering applications, but what is a machine? Machine is the devise that comprises of the stationary parts and moving parts combined together to generate, transform or utilize the mechanical energy. All the machines are made up of elements or parts and units. Each element is a separate part of the machine and it may have to be designed separately and in assembly. Each element in turn can be a complete part or made up of several small pieces, which are joined together by riveting, welding etc. Several machine parts are assembled together to form what we call as complete machine.

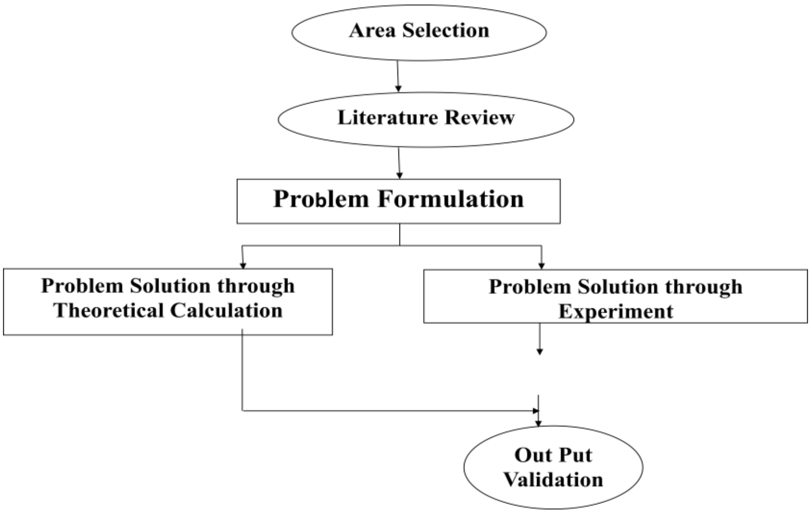
II. PROBLEM FORMULATION

In this thesis the two main objectives first is to developed such a experimental setup by which we measure torque and radial thrust directly and second objective is to investigate tool quality on various materials. The recent study consists of experimentations, parametric analysis using Visual basic software and finally mathematical modeling using software. Experimentation generally specifies the machining of Copper, Brass and Aluminum specimen on Radial drilling machine.

2.1 objectives

The Objective of this research work is to establish thrust and torque model of drilling processes for enlarging holes, based on varying geometry and cuttings such models are potentially useful in a global drilling process simulation of tool motion and the generation of surface topography for a concurrent engineering design system. Such work is surely needed for meeting tolerance requirement, process planning and system monitoring. From the dynamic point of view, the proposed thrust and torque models should be able to reflect variations of the thrust and torque due to change of the drill geometry. (see figure 3.1)
The following two aspects must be included in this research work:
(1) The drill force varies with the change of cutting parameters such as feed rates, spindle speeds and work piece materials.
(2) The drilling force changes with the deflection of the drill structure.

III. RESEARCH METHODOLOGY



3.1 Area selection

Drilling is the one of the most basic machining operations performed by machinists. The process is used to make hole by first fixing a drill to the end of a rotating spindle, and then boring a hole through a stationary work piece. Drills are easily worm by friction, heat, etc and sometimes break when subjected to sever cutting forces at the lips, which are the main cutting regions and the weakest parts of the drill. By specifying the work piece materials, operating conditions, and drill geometries, the thrust and torque model are used to predict the corresponding cutting forces and machining performance.

3.2 Literature Review

A review of the literature pertaining to the development of thrust and torque models of drilling processes for hole enlargement is divided into four sections: machining system modeling, models of drilling structures, models of thrust and torque, and purpose of the study. The first section presents a well-developed model to dynamically characterize a machining system, some applications and continued development. The second section includes a survey of the developed theoretical models of drilling structures and an experimental method for structural identification. In the third section, the foregoing research work is discussed and the cutting force in two-dimensional cutting is studied

3.3 Problem formulation

Thrust force during drilling can be defined as the force acting along the axis of the drill during the cutting process. Cutting forces help monitor tool wear, since forces increase with tool wear. Thrust force is also used to monitor tool wear and, in turn, monitor tool life. Tool failure can occur if tool wear is not monitored. Other than being an important factor in the monitoring of tool wear, thrust force is considered to be the major contributor of delaminating during drilling. Considerable research has been done to prove that there is a critical thrust force that causes delaminating, and thrust force below that will constrain or eliminate delaminating during drilling.

3.4 Problem Solution through Theoretical Calculations

The geometrical analysis of a drill is very complex, because, the inclination angle, the normal rake angle and the effective rake, vary radically as we go from the inner most part of the cutting edge to the outer part. The point of the drill may be considered as consisting of two parts: the cutting edges and the chisel edge. The chisel edge does not cut in the usual sense, but rather displaces the metal sideways as if we were performing the hardness test. The total torque and thrust can thus be divided into two components:

(i) Due to cutting edge

(ii) Due to chisel edge.

The contribution of chisel edge to total torque is only small but to total thrust is considerable. The depth of cut '*d*' in drilling from the solid metal is one-half the drill diameter. The feed '*f*' is the movement of the drill along its axis in mm per revolution. The type of drill selection for a particular task depends upon several factors. As shown in following figure 3.2.

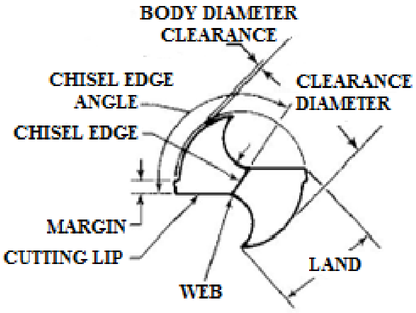


Figure 3.1 Tool Geometry

The chip thickness

$$t=\left(\frac{f}{2}\right)\times\sin\alpha_p \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

and, the width of cut, *b* is

$$b=\frac{D}{2\sin\alpha_p} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

Where, *D* is drill diameter

$2\alpha_p$ is the point angle of the drill.

Figure shows the torque force acting on the cutting edges

$$F_P=\sigma_C\times\text{Chip Cross-section}=\sigma_C\times\frac{f}{2}\times\frac{D}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

$$=\sigma_C\times b\times t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (4)$$

where σ_C is the contact stress, equal to Brinell hardness H_B. The moment due to two forces, F_P separated by half the drill diameter is

$$M=\frac{\sigma_c\times D^2\times f}{8}=\frac{H_B\times D^2\times f}{8} \quad \ldots\ldots\ldots\ [1]\ldots\ldots\ldots\ldots\ (5)$$

The thrust force T_1 due to cutting edges can be estimated if the mean make angle is known. However, the effective rake angle goes from a positive value near the outer radius to a negative value near the chisel edge.

Taking

$$\frac{F_t}{F_p}=0.05\text{ to}1.0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (6)$$

$$T_1=(0.5\text{ to}1.0)\times2\times\sin\alpha_p\times\left(\frac{D}{2}\right)\times\left(\frac{f}{2}\right)\times\sigma_c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

For $2\alpha_p=118^0$

$$T_1=(0.21\text{ to }0.42)\times\sigma_c\times D\times f \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (8)$$

From equation (7) and (8)

$$T_1=(1.7\text{ to}3.5)\times\frac{M}{D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (9)$$

It is difficult to estimate T_2 (thrust due to chisel edge) as it is very difficult ascertain area of contact between the chisel edge and metal. To a very crude approximation, the shaded contact area is taken as 10 to 20% of the area of a circle inscribed with in the web. The web thickness w is,

$$w=0.2D\text{ for }D<3.2\text{mm}$$

$$w=0.1D\text{ for }D>25.4\text{mm}$$

As mentions above, the cutting action of chisel point is very similar to a hardness test.

So, T_2= (0.1 to 0.2) $\times \frac{\pi}{4} w^2 \times H_B$ ……………………………………. (10)

Total Thrust (T)=(1.7to3.5) $\times \frac{M}{D}$ +(0.1to0.2) $\times \frac{\pi}{4} w^2 \times H_B$ [1]……………….(11)

Hardness of material is play an important role for determine the twisting moment in our experiment. For determine twisting moment and drilling thrust, we take a different material like Aluminum, Copper and Brass. Hardness of materials is determined by conducting Brinell hardness test on hardness testing machine.

Brinell Hardness (H_B) of Material is determining by following formula;

$$H_B = \frac{2 \times P}{\pi \times \mathrm{D}\left[\mathrm{D} - \sqrt{\mathrm{D}^2 + d^2}\right]}$$ ….. [2]…………………………. (12)

Where, P = Load Selected (kgf) = 187.5 kg for 20 Sec. for each material = Diameter of Ball (mm) = 2.5mm, d = Diameter of Indentation (mm) (depend upon material)

Theoretical calculation
Drill diameter D= 5mm

For copper material			**For brass material**			**For aluminum material**		
Feed	Thrust	Moment	Feed	Thrust	Moment	Feed	Thrust	Moment
1.96	175.77	439.16	3.40	438.40	1095.83	1.44	112.430	280.83
4.16	372.95	932.10	4.92	634.40	1585.73	3.96	309.01	772.29
6.20	548.61	1371.26	6.80	876.80	2191.66	4.48	348.28	870.47
7.96	699.18	1747.68	7.60	979.90	2449.50	5.72	446.31	1115.54
10.08	889.10	2222.70	9.76	1258.00	3145.67	6.76	525.49	1313.48
11.72	1036.10	2590.16	12.04	1552.00	3880.52	7.88	612.53	1531.08
13.60	1211.08	3029.32	13.64	1758.00	4396.21	9.24	718.24	1795.36
15.00	1330.10	3325.08	15.92	2052.00	5131.06	9.72	755.54	1888.62
17.20	1563.10	3907.65	18.16	2341.00	5853.02	10.00	777.54	1943.63
19.44	1742.40	4355.77	20.80	2681.00	6703.90	11.2	876.79	2191.73
20.12	1803.30	4508.13	23.28	3001.00	7503.21	12.36	963.83	2409.35
21.54	1949.40	4873.33	25.92	3341.00	8354.09	13.56	1057.10	2642.52
23.10	2070.70	5176.56	29.00	3738.00	9346.79	14.48	1128.60	2821.28
23.56	2111.60	5278.91	30.92	3986.00	9965.61	15.64	1218.76	3046.67
24.15	2164.50	5411.10	31.12	4012.00	10030.0	16.84	1315.13	3287.60

3.5 Problem Solution through Theoretical Calculations

Figure 5.2 Experimental Setup

3.5.1 Experimental readings

Drill diameter D= 5mm

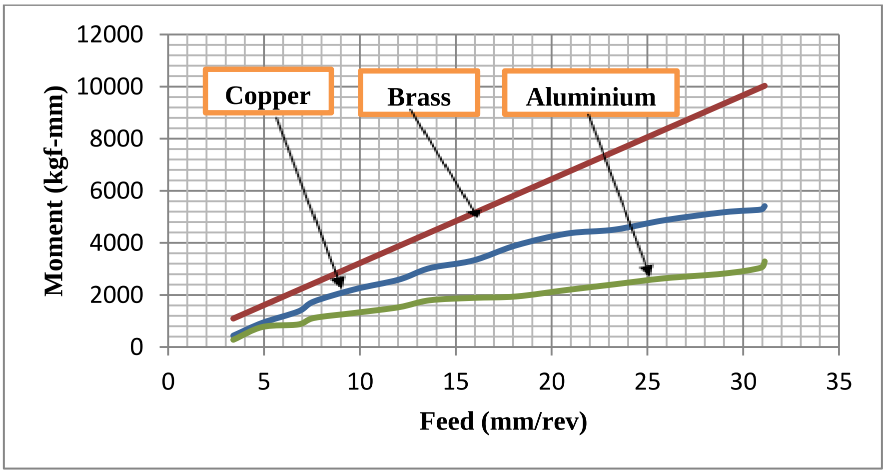
For copper material				For brass material				For aluminum material		
Feed	Thrust	Moment		Feed	Thrust	Moment		Feed	Thrust	Moment
1.96	17.16	439.16		3.40	15.64	1095.83		1.44	10.56	280.83
4.16	13.92	932.10		4.92	15.08	1585.73		3.96	22.68	772.29
6.20	10.60	1371.26		6.80	16.2	2191.61		4.48	18.96	870.47
7.96	12.12	1747.68		7.60	15.52	2449.50		5.72	16.16	1115.54
10.08	10.20	2222.70		9.76	16.96	3145.67		6.76	23.24	1313.48
11.72	12.44	2590.16		12.04	18.12	3880.52		7.88	19.36	1531.08
13.60	17.76	3029.32		13.64	17.68	4396.21		9.24	15.92	1795.36
15.00	22.96	3325.08		15.92	18.28	5131.06		9.72	16.84	1888.62
17.2	8.44	3907.6		18.16	17.80	5853.02		10.00	18.32	1943.63
19.44	10.60	4355.77		20.80	20.32	6703.90		11.20	13.20	2191.73
20.12	12.24	4508.13		23.28	20.24	7503.21		12.36	17.08	2409.35
21.54	14.28	4873.33		25.92	22.12	8354.09		13.56	12.44	2642.52
23.10	12.11	5176.56		29.00	22.28	9346.79		14.48	14.76	2821.28
23.56	10.28	5278.91		30.92	14.48	9965.61		15.64	12.20	3046.67
24.15	16.10	5411.10		31.12	16.47	10030.0		16.84	11.00	3287.60

IV. Result and discussion

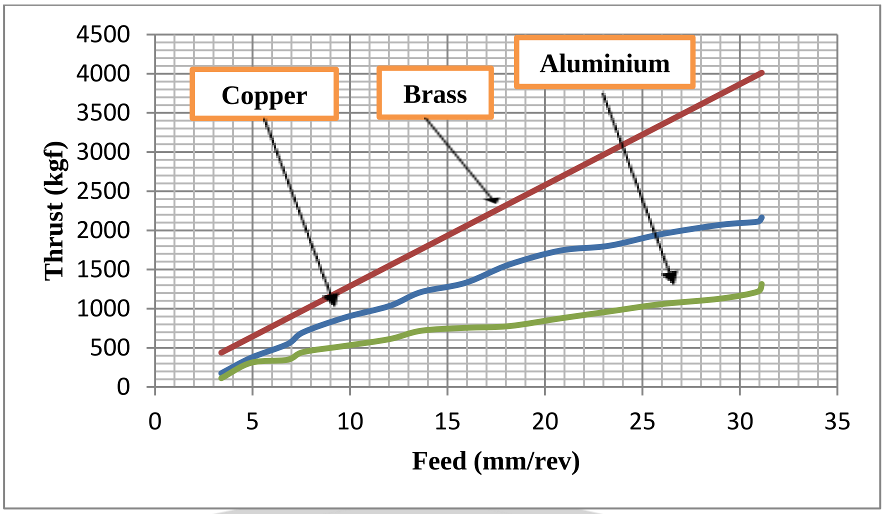
Here combine graphs are plot between Fees Vs Moment and Feed Vs Thrust for Copper, Brass and Aluminum for 5mm drill diameter.

4.1 Based on theoretical reading

4.1.1 Feed Vs Moment for 5mm drill diameter:-

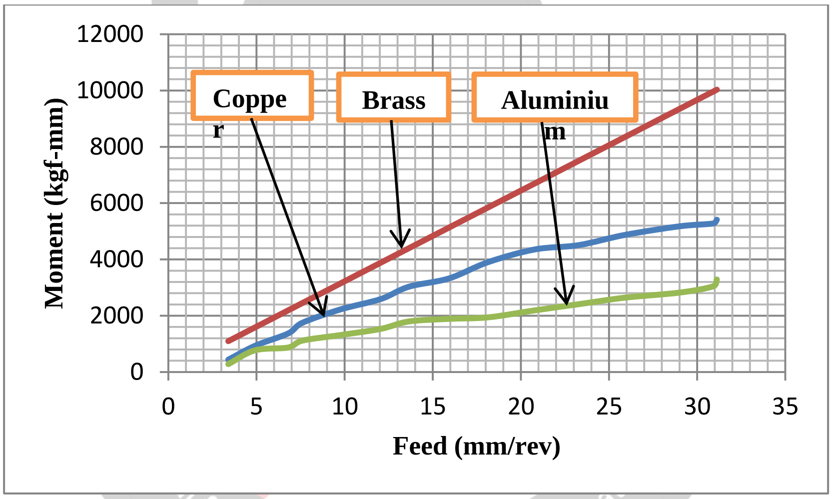


4.1.2 Feed Vs Thrust for 5mm drill diameter:-

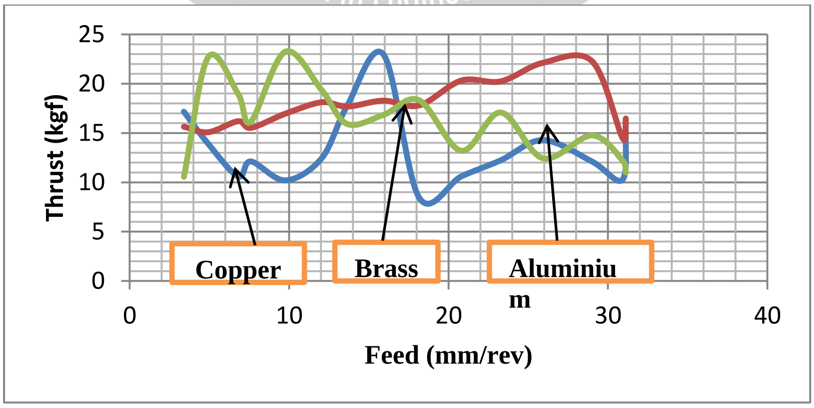


4.2 **Based on Experimental Readings**

4.2.1 Feed Vs Moment for 5mm drill diameter:-



4.2.2 Feed Vs Thrust for 5mm drill diameter:-



4.3. Result and discussion

4.3.1 **Thrust:** - Thrust is more achieve by the experimental setup.

4.3.2 **Moment: -**

- Moment of copper material is 1.56 times more than the aluminium material for 5mm drill diameter.

- Moment of copper material is 1.33 times more than the aluminium material for 7mm drill diameter.

4.3.3 **Feed: -** Feed is directly measure by 10k revolution pot, which is connected to PCB. So feed can read directly on Computer due to the Visual basic software.

4.3.4 Hardness:-Brinell hardness is measure by Brinell hardness Testing Machine.

4.3.5 Economy**: -** Lot product- Low price
Individual product- High

4.3.6 Risk: - Component of PCB and USB is very delicate, so prevent from coolant and take care to handle the box.

Conclusion

In the present study, the investigation of thrust and torque generated during drilling processes is summarized into four aspects; analytical mathematical models, drill structure identification, drilling dynamometer development, and cutting parameters effects estimation.

(1) The mathematical models have been developed for thrust and torque predation based on the drill geometry and the cutting parameters. An orthogonal cutting plane has been found in oblique cutting processes, which is applied to the cutting force analysis along the cutting edge of a drill.

(2) The drill structure is identified through model testing the predicted response based on the identified model parameters is at a reasonable accurate level compared to the measured response during vibration test.

(3) The prototype drilling dynamometer is designed and constructed the measured dynamic signals revel that the fundamental natural frequency of the dynamometer is higher than the lowest natural frequency of the drill structure. The stiffness of whole drilling system does not decrease due to the built dynamometer which guarantees the reliability of the built dynamometer.

(4) By using the dynamometer, the cutting parameters effects on the thrust and torque are estimated. The combination of a low feed rate and high spindle speed is found to be the most efficient method for reducing or controlling the thrust force while maintaining an equivalent machining productivity.

VI. FUTURE ENHANCEMENT

Based on the present study, the following future work in this area are made

(1) The cutting mechanism of the web and the cutting edge near the drill centre is suggested to be investigated for obtaining more complete mathematic models.

(2) Finite element method can be used to simulate the drill structure and Rayleigh-Ritz method can be used to model the structure theoretically.

(3) Semiconductor strain gauges could be useful in fulfilling the high sensitivity requirement.

(4) Development of a model to predict the optimal thrust force necessary for drilling of composites without delimitation since a very low thrust force is known to cause the fibers pull out and other defects during drilling.

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