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Experimental Investigation for Establishing Empirical Relation of Temperature with Speed and Feed Rate in Machining Operation

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Abstract

In present research work experimental establishment of empirical relation for heat generation in terms of temperature in turning operation with conventional machine is proposed. This research work establishes the empirical relation through experimental results and scientific computing through MATLAB. Five different speeds from low to high with three feed rates are used for experiment. Aluminium and high speed steel is used for work piece and tool respectively. The experimental data that are recorded during the experiment are used in scientific data computing tool (MATLAB) and formulated to an empirical relation using higher order polynomial surface plot technique. The main objective is to minimize the coolant usage and increase the surface finish of work piece.

Keywords: Tool temperature, work piece temperature, Empirical relation, Surface fitting, Curve fitting.

INTRODUCTION

Machining is a process in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process. Much of modern day machining is carried out by computer numerical control (CNC), in which computers are used to control the movement and operation of the mills, lathes, and other cutting machines. An unfinished work piece requiring machining will need to have some material cut away to create a finished product. Heat generation is one of the main problems in machining. It causes tool wear, uneven surface finish, a low quality of products. Today CNC machines provide high surface finish using coolants. But conventional machines need skilled labour and more time to get high end products, which causes loss of time and money.

Besides CNC's waste a lot of coolants to achieve surface finish, which can be avoided by determining the cooing rate. This paper investigates the process involved in determining the cooling rate by establishing a numerical and empirical relation between tool temperature, feed rate and speed and work piece temperature, feed and speed.

PROBLEMS IN MACHINING

Problem associated with machining is heat generation in work piece and tool, which affects surface finish and machining efficiency. Prediction of temperature during cutting process is also a tedious process. FEA analysis is developed to predict surface finish with given speed, feed rate and depth of cut. Temperature prediction models are also under research. In design point of view, FEA simulation is much needed and should be used. In case production, simulation is also required now. Small industries couldn't go for FE modeling software because cost is major problem.

PROPOSED SOLUTION

In present research work experimental establishment of empirical relation for heat generation in terms of temperature in turning operation with conventional machine is proposed. This research work establishes the empirical relation through experimental results and scientific computing through MATLAB. Five different speeds from low to high with three feed rates are used for experiment. Aluminium and high speed steel is used for work piece and tool respectively. This empirical relation can be used for determining cooling rate in future.

EXPERIMENTAL CALCULATIONS

A. LIMITS AND MACHINE SPECIFICATIONS

1. Experiment will be conducted on conventional turning centre with 5 speeds and 5 feed rates.
2. Machine job size is 600mm diameter.
3. Power is 3 phase 3HP.
4. Speeds 1000, 750, 500, 225, 150 are chosen for study.
5. Feed rates 0.1, 0.25, 0.5, 0.75, 1 mm/rev are chosen for study.
6. Swing over machine bed Min. 350mm
7. Swing over cross slide Min. 190mm
8. Distance between centres Din 806-MT3 750-800mm
9. Turning Length 700-750mm
10. Width of bed Mini.260mm
11. Spindle diameter in front bearing 60mm
12. Spindle Bore 35mm

13. Normal Chuck diameter 160mm
14. Max.diameter of face plate and clamping disk 315mm
15. Guide Length of carriage 350-365
16. Cross-slide travel 175-190
17. Width of cross-slide 140mm
18. Compound slide travel Min. 100mm
19. Width of top slide Min 110mm
20. Stroke of quill 100-120
21. Diameter of center sleeve 50mm
22. Taper socket DIN 228 MT3
23. Cross Travel += 10MM

B. TEMPERATURE CALCULATIONS

Temperature measurement over work piece surface and cutting tool tip during operation is difficult to measure. Therefore, temperature at tool tip and work piece surface is measured after operation is stopped. Time is measured from after machining is stopped. Then, temperature during operation is calculated using Newton's law of cooling-Cooling rate of an object is directly proportional to difference between object temperature at that instant and room temperature.

$$\frac{dT}{dt} \propto (T - S) \quad \text{Or} \quad \frac{dT}{dt} = k(T - S)$$

By integrating above OD equation, following algebraic equation is arrived.

$$T = S + Ce^{kt}$$

T – Temperature of object at that instant

S –Room Temperature

k – Proportionality Constant

C – Integral Constant.

In this equation, any parameters can be found by knowing c and k of phenomenon. C and k can be found by using experimental measurement of T and S at two instants (t, time).

Table 1. Experimental Data

Sl.No	Speed (RPM)	Feed (mm / rev)	Tool Temp (°C)	W.P. Temp (°C)
1	150	0.1	42.190	46.439
2	225	0.1	42.885	54.470
3	500	0.1	43.069	55.440
4	750	0.1	44.105	50.984
5	1000	0.1	42.344	48.717
6	150	0.25	38.426	41.411
7	225	0.25	38.534	42.699
8	500	0.25	38.553	43.909
9	750	0.25	39.203	44.690
10	1000	0.25	38.615	45.422
11	150	0.5	42.190	46.580
12	225	0.5	42.885	49.047
13	500	0.5	42.471	49.614
14	750	0.5	43.435	55.059
15	1000	0.5	42.192	55.301
16	150	0.75	43.105	54.675
17	225	0.75	44.017	56.810
18	500	0.75	46.187	57.637
19	750	0.75	46.519	57.887
20	1000	0.75	46.644	58.995
21	150	1	49.596	58.673
22	225	1	50.234	59.399
23	500	1	50.758	59.735
24	750	1	57.494	60.643
25	1000	1	58.176	61.551

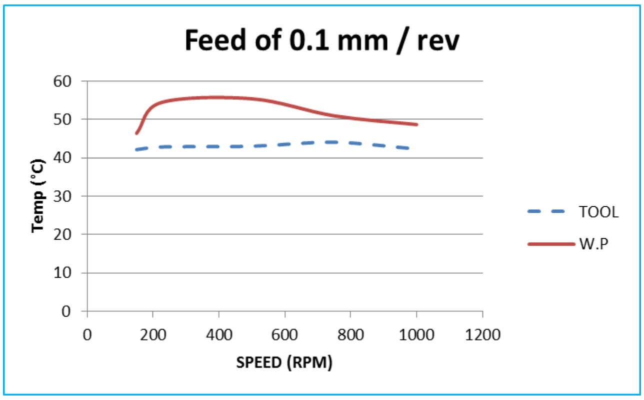

Figure 1. Speed Vs Temp at 0.1 mm / rev

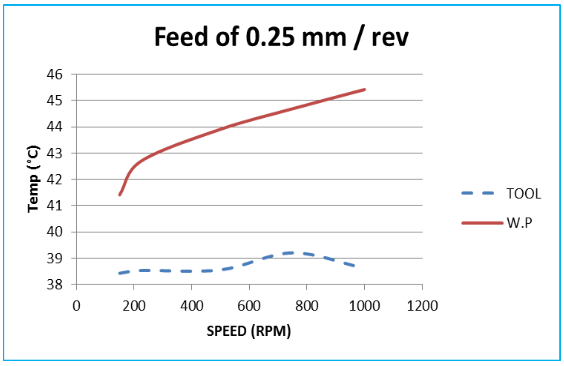

Figure 2. Speed Vs Temp at 0.25 mm / rev

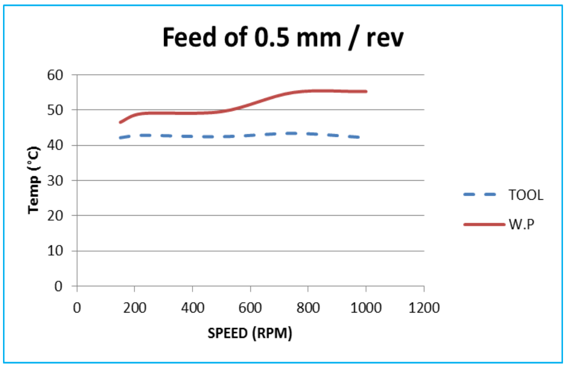

Figure 3. Speed Vs Temp at 0.5 mm / rev

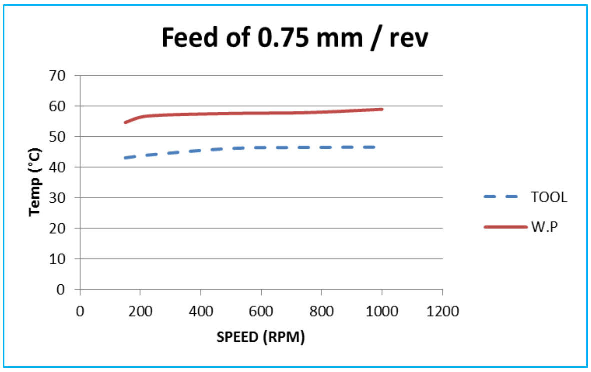

Figure 4. Speed Vs Temp at 0.75 mm / rev

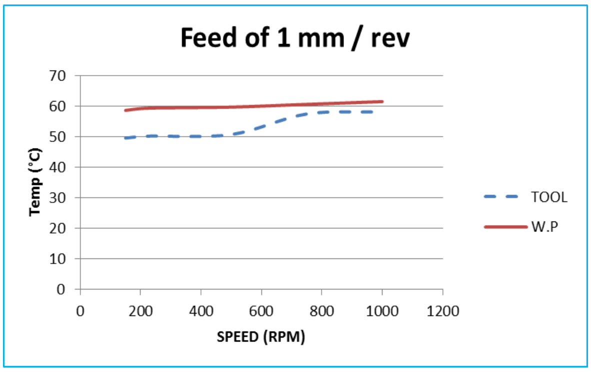

Figure 5. Speed Vs Temp at 1 mm / rev

EMPIRICAL RELATIONS

The table 1 shows the experimental data that are recorded during the experiment, the tool and work piece temperatures against different RPM and feed. Using this data scientific computing tool (MATLAB) is used to formulate the empirical relation using higher order polynomial surface plot technique. From the experimental data two empirical relations will be formed and their pseudo forms are given below.

TT = Tool Temperature (°C)

WPT = Work Piece Temperature (°C)

RPM = Cutting Speed (RPM)

Feed = Cutting Feed (mm/min)

Empirical Relation between RPM, Feed and TT is

TT = f (RPM, Feed)

WPT = f (RPM, Feed)

The above pseudo equations show that TT and WPT are functions of RPM and FEED. The following section provides the polynomial curve fitting to formulate the empirical relation using MATLAB.

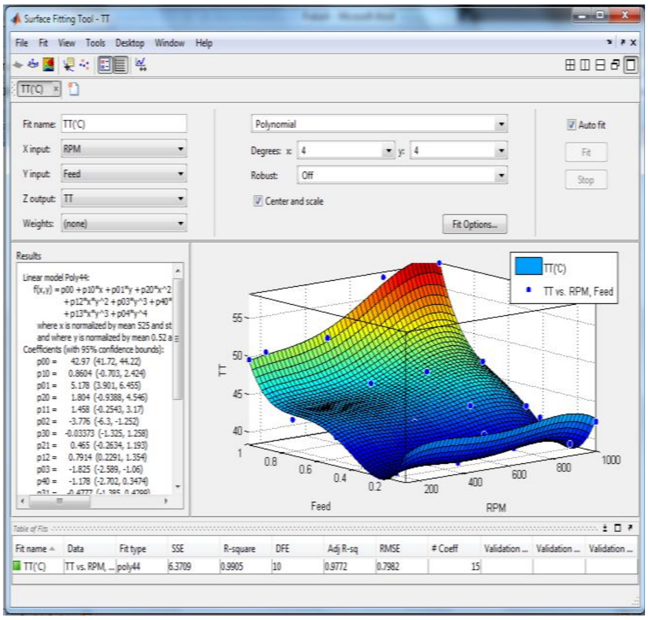

Figure 6. Surface Fitting

The empirical relation is arrived through the surface curve fitting tool of MATLAB, it provides surface plotting through interpolation, polynomial and custom equation method, to achieve empirical relation polynomial and custom method is best preferred, based on the relevance of the curve fitting the equation can be taken for application, the polynomial curve fitting provides one degree to five degree fitting, based on the reliability index(0 to 1) where 0 is nearing a no-fit and 1 is a best possible perfect fit.

EMPIRICAL RELATION OF TOOL TEMPERATURE

$$f(x,y) = p00 + p10*x + p01*y + p20*x2 + p11*x*y + p02*y2 + p30*x3 + p21*x2*y + p12*x*y2 + p03*y3 + p40*x4 + p31*x3*y + p22*x2*y2 + p13*x*y3 + p04*y4$$

Table 2 Tool Temperature Relation

Coefficient	Value
p00	42.97
p10	0.8604
p01	5.178
p20	1.804
p11	1.458
p02	-3.776
p30	-0.03373
p21	0.465
p12	0.7914
p03	-1.825
p40	-1.178
p31	-0.4777
p22	0.2396
p13	0.1435
p04	3.516

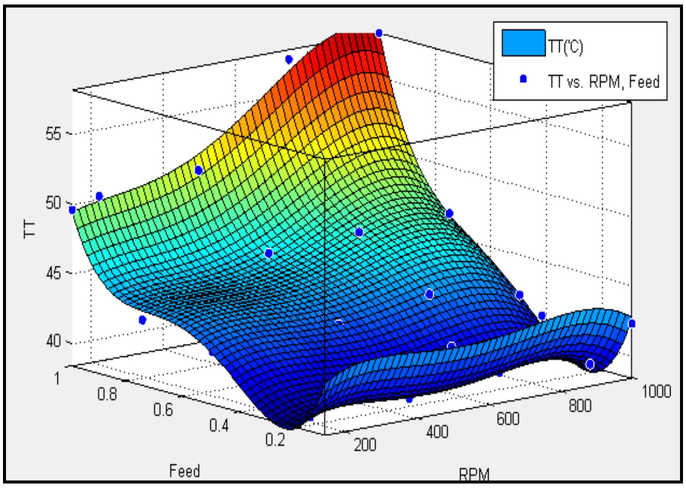

Figure 7. Tool Relation Fit

EMPIRICAL RELATION OF WORK PIECE TEMPERATURE

$$f(x,y) = p00 + p10*x + p01*y + p20*x2 + p11*x*y + p02*y2 + p30*x3 + p21*x2*y + p12*x*y2 + p03*y3 + p40*x4 + p31*x3*y + p22*x2*y2 + p13*x*y3 + p04*y4$$

Table 3. Work Piece Temperature Relation

Coefficient	Average
p00	51.67
p10	0.132
p01	11.1
p20	3.108
p11	0.4766
p02	-4.011
p30	2.528
p21	1.746
p12	-1.403
p03	-6.042
p40	-2.291
p31	-1.169
p22	-0.8258
p13	0.9271
p04	4.209

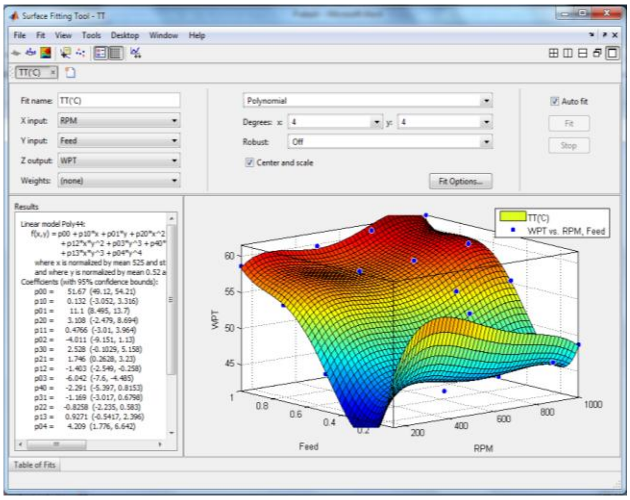

Figure 8. Work Piece Relation Fit

CONCLUSION

From experiment, it is known that temperature of work piece is more than temperature of tool. Temperature of work piece and tool tip isn't increased too much due to removal chip. Therefore, no time for heat transfer between contact point to other area of tool and work piece. Temperature measured above is enough to effect tolerances and finishing of component to be machined. In conventional machining, coolant isn't applied continuously. This reduces accuracy but in case of CNC coolant is applied continuously throughout machining operation. Therefore, accuracy is maintained.

From experimental graphs, it is known that temperature produced increases with feed rate at all speeds. For constant feed, temperature is varied slightly with speeds. Besides, this data is used to produce relationship between speed, feed and temperature produced within one equation by using scientific computing tool MATLAB. This empirical relation will be used find to cooling rate required for machining operation in future based on accuracy required in CNC and reduce wastage of coolant.

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