MACHINABILITY AND CORRELATION OF MACHINING VARIABLES OF NON-FERROUS METALS DURING TURNING

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ABSTRACT

Machinability is closely related to manufacturing process, especially metal cutting or machining. Machining is the first step taken to manufacture any product to the required shape. Machining is a term that covers a large collection of manufacturing processes designed to remove unwanted materials in the form of chips, from a work piece. Machinability can be quantitatively assessed. Manufacturers may take tool life or cutting forces or machining costs to evaluate machinability of a material. Thus machinability helps us in knowing the ease of materials being machined which in turn helps in improving the manufacturing process by optimizing cost, productivity and quality.

In today's world due to the development of technology, flexible manufacturing system (FMS) and computer integrated manufacturing (CIM) is used to assess machinability by taking into account total number of chips collected or ease of chip disposal. And improvised regression models fitted to machining variables can be correlated.

With the light of the above, in the present work, comparative machinability and correlation between different machining variables of the three different non ferrous metals namely, wrought aluminum, brass and cast aluminum were selected by considering different parameters of cutting process such as cutting speed, cutting temperature, surface finish, and power consumption while turning operation. The results from the experimentation indicated that wrought aluminum possesses the highest machinability, followed by brass. Cast aluminum has the lowest machinability.

The analysis and results of the process are represented systematically in graphs and comparisons between the non ferrous metals machining properties are presented. Multiple linear regression analysis is performed to derive the equations relating to all the variables of metal cutting operation.
The machining variables such as speed, temperature,, power consumption, are used in multiple linear regression analysis to fit a common equation for machining operation during drilling

INTRODUCTION

The machinability of metal in a metal removal process depends not only on the metallurgical properties (chemical composition, physical properties and microstructure) but also on machining variables like tool, cutting speed, cutting fluid, depth and feed of cut.

The turning operation was carried [1] out on a centre lathe; various arrangements were made to assess the machinability parameters. The operation was carried out both in dry condition and using the coolant. Tool dynamometer was fixed to the lathe to measure the forces. Non contact type thermocouple was used to measure the tool tip temperature. Ammeter and voltmeter were connected in series and parallel to the lathe, to assess the power consumption. The quantity of chips collected was weighed in the digital balance. The initial diameter of the work piece was noted down. Once the initial adjustments were made, the machine was switched on and the initial ammeter and voltmeter readings were recorded. The pre-selected speed and depth of cut were maintained. The length of the tool travel i.e., length for which machining is carried out was fixed.

Time taken for machining was noted using a stop clock. The temperature at the tip of the tool was measured using the non contact type thermocouple. At the time of ending the process, again the ammeter and voltmeter readings were noted down. Power consumed was calculated by subtracting the initial reading from the final reading. The process was carried out for various combinations of depth of cut, speed (keeping 2 of these 3 parameters constant [2] and varying one parameter). The tool was weighed after each set of trials. Surface finish of the work piece was assessed at the end using the tally surf. All the trials were carried out (a) without coolant and (b) with coolant. [3]

Regression analysis methods were used by the previous researchers [4] & [5] in order to predict the surface finish and also to use it in determining the optimum machining conditions.

In this paper, multiple linear regression analysis is carried out on the turning parameters like speed cutting force, cutting temperature and power consumption. Hence, correlations between the different machining parameters are derived by fitting a regression model to interpolate and extrapolate the results at various parameters.

EXPERIMENTAL WORK

Chemical composition is initially carried out with optical emission spectrometer on all ferrous metals and results obtained are:

Al	Mg	Fe	Mn	Si
97.77 %	0.653% ,	0.142 %	0.527 %	0.782 %

Brass:

Cu	Zn	Fe	Ni	Sn	Mn
56.76%	39.572%	0.291%	0.314%	0.463%	0.070%

Cast Aluminum:

Mg	Ti	Fe	Si
4.0%	0.03%	0.008%	0.019%

The experiments were conducted on three different materials, for turning operations:

The machinability of the wrought aluminum, brass and cast aluminum is assessed by the cutting forces, cutting temperature, surface finish, and power consumption measurement in turning operation.

Power consumption is one of the parameter assessing machinability. It is directly related to the cutting force. The material consume more amount of power if it is very hard to machine. An arrangement is made to measure the power consumption. A Voltmeter (parallel connection) and an ammeter (series connection) are made to the input source of the lathe machine. The initial power consumption readings V_1 and I_1 are taken as the machine start running. Similarly, V_2 and I_2 are noted at finished stage of the experiment. Thus the gross power consumed in, turning operation is calculated by the formula,

POWER CONSUMED= $(V_1 \times I_1)-(V_2 \times I_2)$. [2]

Where, V_1= Initial voltmeter reading,
I_1= Initial ammeter reading,
I_2= Final ammeter reading.
V_2= Final voltmeter reading

Experiment procedure in turning operation.

A work piece of 45mm diameter is prepared; the lathe machine is switched on for few minutes' Initial power consumption readings V_1 and I_1 are noted from voltmeter and ammeter respectively. The lathe tool dynamometer is kept in calculate mode and all the forces reading are set to the value of 500. The dynamometer is shifted to read mode and the forces readings are set to 0. The turning operation is performed by varying depth of cut and keeping the feed and cutting speed constant. In each trial cutting forces (F_x, F_y and F_z) and cutting temperature are noted from lathe tool dynamometer and tool work thermocouple respectively. The final power consumption readings V_2 and I_2 are noted. The surface roughness readings are taken before and after machining. The same procedure is followed and turning is done by varying cutting speed and keeping the depth of cut and feed constant. The experiment is performed on all the three materials exactly the same manner as mentioned above.

In order to obtain multiple regression model in the form, [4]

$$Y_i=b_0+b_1X_{1i}+b_2X_{2i}+\dots+b_kX_{ki} \quad \text{--------- (1)}$$

We obtain the values of b_0, b_1, $b_2 \dots b_k$ by generating the set of k+1 normal equations.

$$kb_o+b_1\sum X_{1i}+b_2\sum X_{2i}+\dots\dots\dots..+b_k\sum X_{ki}=\sum y_i$$

$$b_0\sum X_{1i}+b_1\sum X^2_{1i}+b_2\sum X_{1i}X_{2i}+\dots\dots+b_k\sum X_{1i}X_{ki}=\sum X_{1i}Y_i$$

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$$b_o\sum X_{ki}+b_1\sum X_{ki}X_{1i}+b_2\sum X_{ki}X_{2i}+\dots\dots.+b_k\sum X^2_{ki}=\sum X_{ki}Y_i$$

Where i = number of data present, k=number of variables.

The above equations can be solved for b_o, b_1, $b_2 \ldots b_k$ by any appropriate method for solving systems of linear equations.

By substituting the above values in the equation (1) we obtain the regression equations.

RESULTS AND DISCUSSIONS

The experiments are conducted on three different materials, the machinability of the wrought Aluminum, brass and cast aluminum is assessed by the Cutting forces, cutting temperature, Surface finish & Power consumption during turning operations.

Machinability as indicated by cutting forces in Turning.

The machinability of the material is inversely proportional to the cutting forces. The material with good machining properties will have less value of cutting forces and the material which is hard to machine will have high value of cutting forces.

The following are the result represented in bar graph indicating machinability of different non ferrous metals.

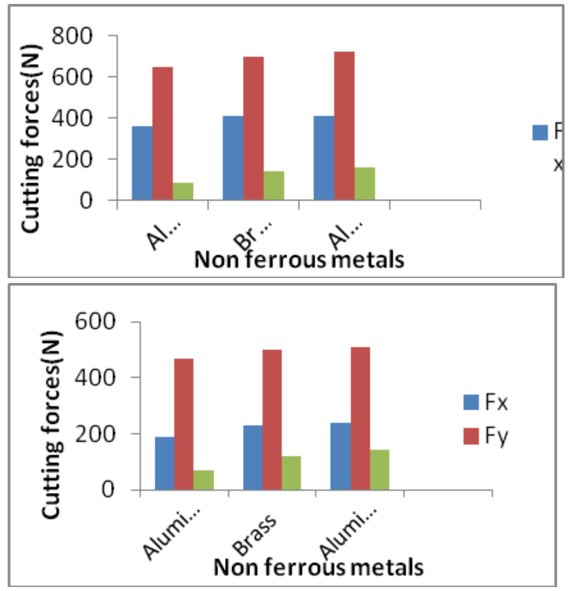


Fig 1 & 2 Cutting forces of different non ferrous metals at constant cutting speed 260rpm, varying depth of cut (without & with coolant).

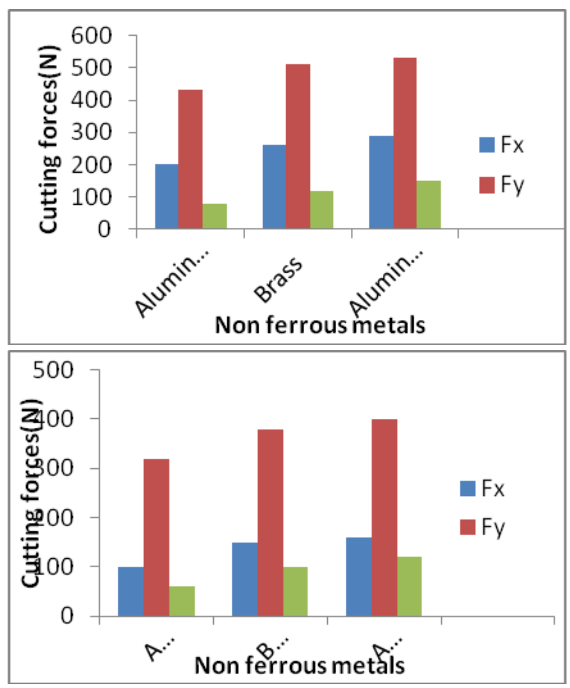


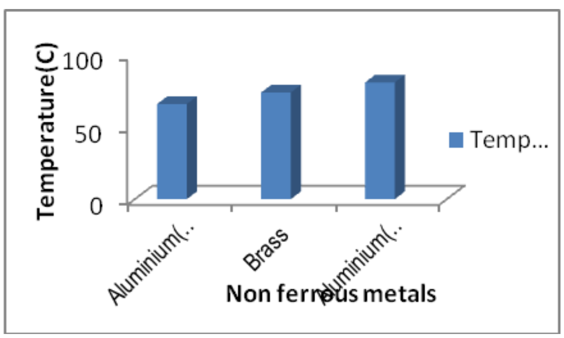
Fig 3 & 4 Cutting forces of different non ferrous metals at constant (0.2mm) depth of cut, varying cutting speed (without & with coolant).

The results from the graph and the experimentation are:

The cutting force is inversely proportional to machinability of the non ferrous metals. The forces F_x, F_y and F_z values varies appreciably for different metals. The Wrought Aluminium metal has the lowest value of cutting force, so the machinability of the Wrought Aluminium is very high. The Brass has the intermediate value of cutting forces. Thus it will be placed in second position in machinability ranking. The Cast Aluminium has the highest value of the cutting forces. The cast aluminium will be the hardest material to machine.

Machinability as indicated by cutting temperature.

The following are the result represented in bar graph indicating machinability of different non ferrous materials.



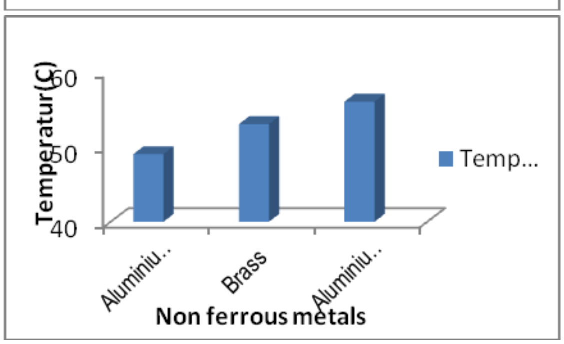


Fig 5 & 6 Temperature of different non ferrous metals at constant cutting speed 260rpm &, constant depth of cut of 0.2mm, varying cutting speed (without& with coolant).

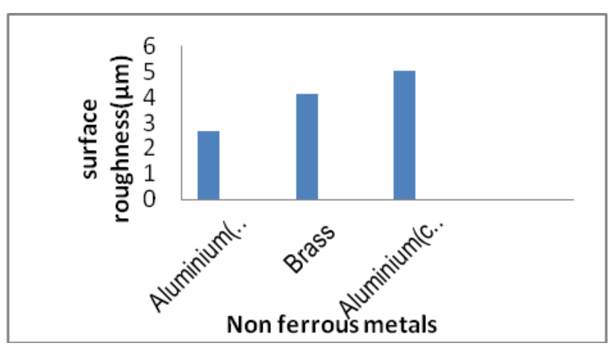
The results from experimentation and graph are:

The temperature of the tool chip interface increases as the cutting speed and depth of cut increases. Wrought aluminum resulted in lowest cutting temperature. Thus the wrought aluminium possesses the best machining properties. Brass has the value higher than the wrought aluminum and lesser than cast aluminum. Hence, Brass is the second metal with good machinability. Cast aluminium has the highest value of cutting temperature in turning. Thus cast aluminium is the hardest metal to machine with lowest machinability.

Machinability as indicated by surface roughness in turning operation

The surface roughness is considered to the most important factor in deciding the machinability of the metals. The arithmetic mean deviation, R_a, is taken to measure the surface roughness of the metals. The metal with lowest value of R_a, will have highest machining properties.

The following are the result represented in bar graph indicating surface roughness of different non ferrous materials.



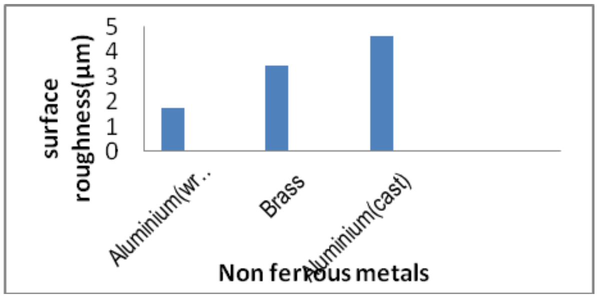
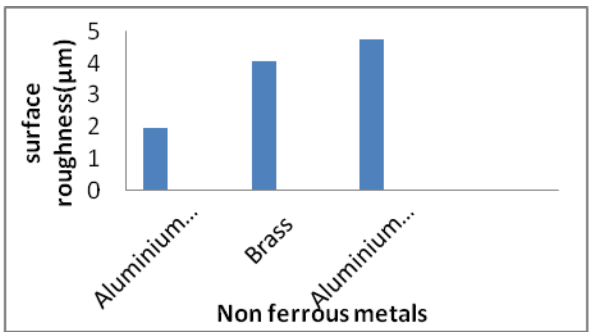


Fig 7 &.8 Surface roughness of different non ferrous metals at constant cutting speed 260 rpm, varying depth of cut (without & with coolant).



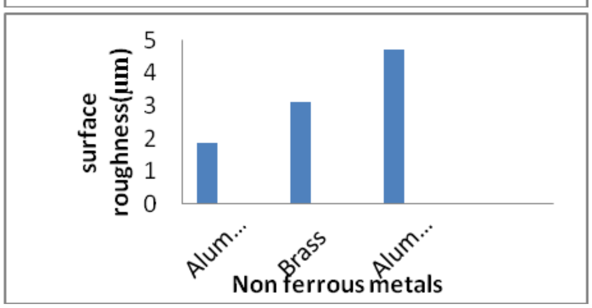


Fig 9 &.10 Surface roughness of different non ferrous metals at constant depth of cut 0.2mm, varying cutting speed (without & with coolant).

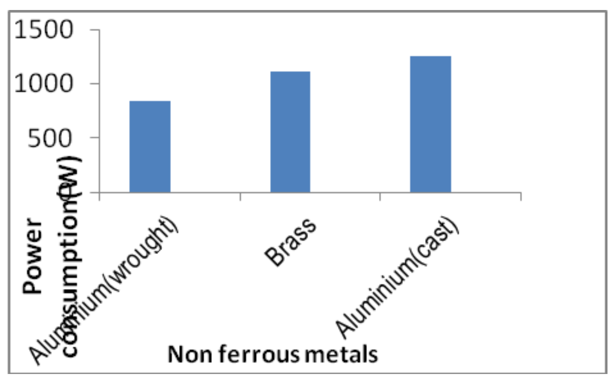
Results from experimentation and graph are:

The depth of cut and cutting speed influenced the surface finish for all materials dominantly. The surface roughness of the all metal decreased considerably by the use of the coolant. Cast aluminium has a high value of R_a, thus cast aluminium is the hardest material to machine, wrought aluminium has lowest value of R_a, and so wrought aluminium metal will be the metal with highest machinability. Brass value of R_a, is in between the wrought aluminium and cast aluminium. Thus the machinability of Brass is placed in between the other two metals. [3]

5.6 Machinability as indicated by power consumption in turning

The power consumption of the metals in the machining process varies inversely with machinability of the metal. The metal with high value of power consumption will have least machining properties. The power consumption and cutting forces are closely related.

The following are the result represented in bar graph indicating power consumption of different non ferrous metals in turning operation.



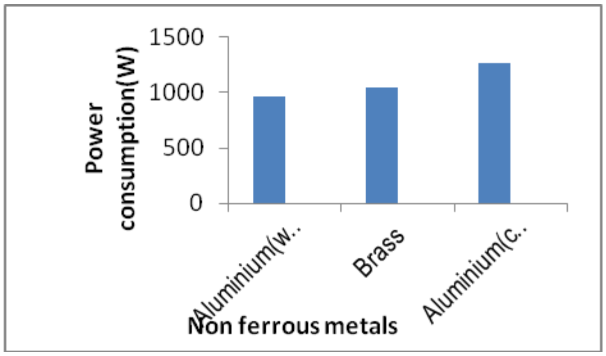
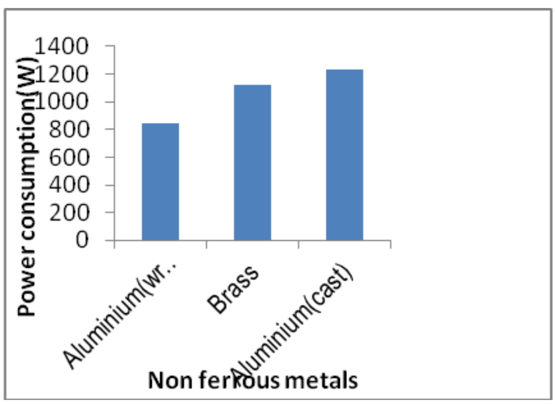


Fig 11&12 Power consumed by different non ferrous metals at constant cutting speed 260 rpm, varying depth of cut (without & with coolant).



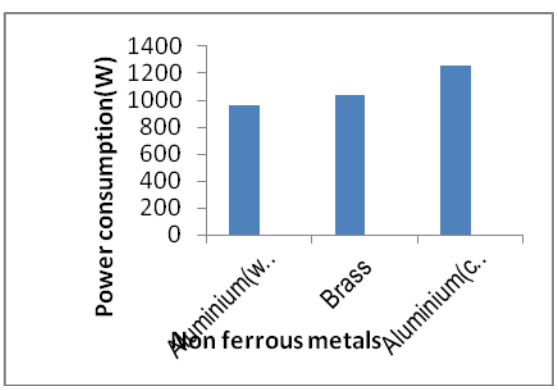
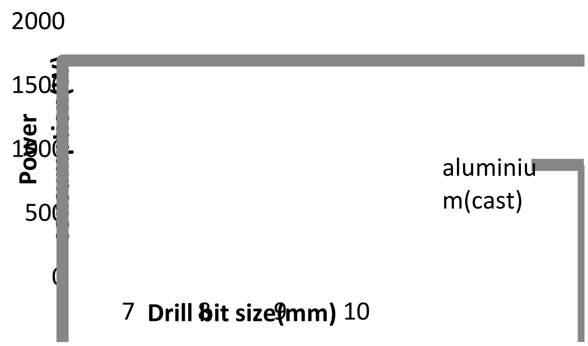


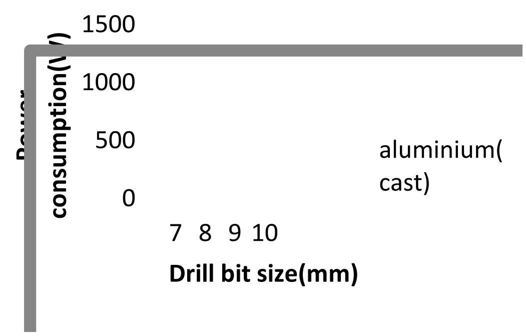
Fig 13 &.14 Power consumed by different non ferrous metals at constant depth of cut 0.2mm, varying cutting speed (without & with coolant).

The results obtained from experiment are:

The power consumption for all metals varied in considerable amount in all trials of turning. The power consumption of the wrought aluminium is lowest indicating that wrought aluminium has the best machining properties. The Brass is the next metal in machinability ranking. Cast aluminium has the highest power consumption and it is the hardest metal to machine.

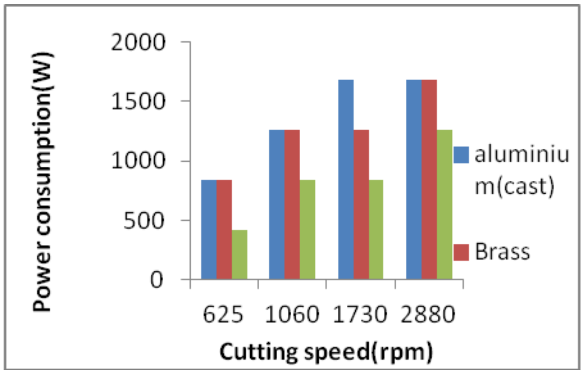
The following are the result represented in bar graph indicating power consumption of different non ferrous metals in turning





operation.

Fig 15 & .16 Power consumption of different non ferrous materials with various drill bit size, constant cutting speed1060 rpm (without & with coolant).



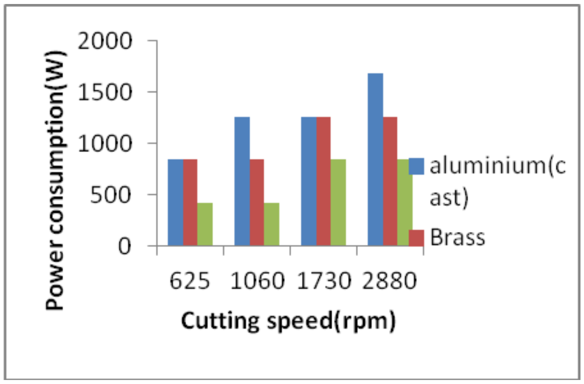


Fig 17 & 18 Power consumption of different non ferrous materials with various cutting speed and at constant drill bit size of 8 mm (without & with coolant).

The results obtained from experiment:

The power consumption mainly depends on the cutting forces and the cutting speed. The wrought aluminium has the least value of power consumption and has maximum machinability. The brass has slightly more value than wrought aluminium, so it is slightly difficult to machine than the wrought aluminium. The cast aluminium has the highest value of the power consumption indicating least machinability

The correlations between the different machining variables are derived by the application of the observed values to the multiple linear regression analysis. Results of regression by keeping cutting speed constant and varying depth of cut.

Equation obtained from regression analysis

Results of the regression in turning without using coolant [5]

Results of regression by keeping depth of cut constant and varying cutting speed here Y= cutting speed.

X1= Fx, X2=Fy, X3= Fz, X4= temperature, X5= power, X6= amount of chips.

Brass

Y=75.8566+1.2115X1+17.4423X2-48.3077X3-0.6871X4-42.5000X5+5.09e^-7X6

Wrought aluminium

Y=-329.6084-1.1253X1-0.2075X2+15.2746X3-0.0053X4-0.4551X5+64.7459X6

Cast aluminium

Y=-1.4681-3.19e^-7X1-0.0002X2+0.0006X3+5.09e^7X4+0.0398e^7X5+0.0094X6

Results of regression by keeping cutting speed constant and varying depth of cut

Here Y= depth of cut. X1= Fx. X2=Fy. X3= Fz. X4= temperature. X5= power. X6= amount of chips.

Brass

Y=0.0023+5.09e^-7X1-0.0014X2+0.0051X3-3.19e^-7X4-0.0048X5+0.565X6

Wrought aluminium

Y=2.4014+0.0023X1+0.0003X2-0.0223X3+0.0055X4-0.0838X5+0.0372X6

Cast aluminium

Y=-0.3512-0.0003X1+0.0017X2-0.0035X3-0.0002X4+0.0157X5+5.09e^-7X6

CONCLUSIONS:

Machinability is a fairly complex phenomenon, not easily studied by the machining process. From the results of this research, it has observed that, out of the considered non ferrous metals, wrought aluminum has the highest machinability followed by brass and cast aluminium respectively. However, when comparing the machinability of the materials whose machinability varies very little from each other, sophisticated methods of measurements are suggested. Through multiple linear regression analysis, equations are found correlating the machining variables. These equations derived from practically observed values, can be satisfactorily used for interpolations.

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