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DEVELOPMENT OF A GRINDING DYNAMOMETER FOR AN INDUSTRIAL MODEL

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Abstract Grinding dynamometers are used to measure radial and feed forces between grinding wheel and the workpiece in a plunge surface grinding operation. The essential requirements of dynamometer are its mechanical rigidity and sensitivity. In this paper, an octagonal extended ring type dynamometer has been designed, fabricated and calibrated, which describes the set up, fabrication, mounting of strain gauges and calibration. Stainless steel is chosen as constructional material, and strain gauges are cemented on the surface of the dynamometer. The two terminals of the strain gauges are fitted on an arm of Whetstone bridge circuit. A linear operational amplifier has been used as a force measurement display unit to measure directly the force components. The experimental results are analyzed and presented. The main results are: feed and radial forces during electrochemical grinding are very less compared to conventional grinding for similar conditions, with the increase of feed rate they increase and the feed force is about half of the radial force, process efficiency increases with the increase in current density and decreases with the increase in feed force.

Keywords: Grinding dynamometer, Electrochemical grinding, Strain gauge, Calibration.

INTRODUCTION

There are many methods for measuring two components of grinding force and elongated octagonal rings are used mainly for two dimensional dynamometer in grinding operations. An industrial model for electrochemical grinding machine with hydraulic feed control has been developed at Indian Institute of Technology (IIT), Kharagpur, India. A grinding dynamometer has been incorporated to measure force components produced during machining operation of tungsten carbide and stainless steel.

In the design and application of metal cutting tools, it is very much essential to know the forces which act upon the tool as well as on the machine tools, and the fixture and power required under a given set of cutting condition for the purpose, it is essential to study the effect of different variables of cutting on cutting forces. [Ponkshe, 1966] .Among the cutting variables, feed rate and current density play an important role that influence the magnitude of cutting forces in ECG process. Many research workers [Ito et al., 1980 & Bhowmick and Mishra, 1998] have carried out some experiment to investigate the effect such variables on cutting forces.

Two components of force namely radial and feed are measured with the help of a grinding dynamometer. Normally, the dynamometer forms a link between the work and machine bed in ECG process. An octagonal extended ring type dynamometer has been designed, constructed and calibrated. Completely circular rings are not considered because they have a tendency of rolling under the action of cutting forces. Octagonal rings are used to avoid the rolling tendencies. In an elongated octagonal ring, the rigidity and the output per unit displacement decreases [Ito ET al., 1980] The essential requirement of the dynamometer used for ECG in its sensitivity to measure the grinding forces with sufficient accuracy. The design is based on conventional size to handle, accuracy of measurement provision for modification, provision for change of parameter, mechanical loading and sensitivity.

Keeping the essential requirements of a good dynamometer in view, stainless steel is chosen as constructional material. Besides the above, the specialty of the stainless steel is its non-corrosiveness which is very much essential for ECG process. On the surface of the dynamometer, strain gauges are cemented. The two

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terminals of the strain gauges are fitted to an arm of a Whetstone bridge circuit.

Many researchers [Ito et al., 1980 and Bhowmick and Mishra, 1998] suggested that the dynamometer should possess the following characteristics:

i) It should be simple in design and easy to handle and vice versa.

ii) It would be rigid enough so as not to give rise to vibrations at least within the operating range.

iii) It should be sufficiently elastic so as to give an appreciable deformation on all bodies. Its measuring element should be sensitive and should be free from cross-effects so far as possible.

iv) It should be stable and unaffected by humidity and temperature variations. It should also give consistent readings with passage of time.

v) The calibration curves should be fairly linear and facilities interpolation of the intermediate ranges.

vi) The frequency response of the dynamometer should be high enough so that the results are accurately noted unaffected by 'dynamic instability' of the measuring system.

The common feature in all types of dynamometers is the measuring springs whose deflections are proportional to cutting forces. The major difference in the design of various dynamometers lies in the technique employed to measure spring deflection [Bhattacharyya, 1984].

DYNAMOMETER SET UP

For designing the dynamometer, some assumptions have been considered such as the width of dynamometer is about half of the width of the vice, the minimum load conditions neglecting the cross-sensitivity of strain gauges, and the two octagonal rings are of identical shape and size so that it can carry equal loads. The total minimum load has been found to be 183.7N including the weight of minimum load due to minimum wheel pressure, minimum load due to electrolyte pressure and dead load of vice, perspex box and the plate. Similarly, considering the wheel and electrolyte pressure, for maximum value, the total load would be calculated as 473.5 N. The thickness of the dynamometer and the arm length of octagonal ring edge have been determined as 3mm and 15.7 mm respectively.

Thickness of the dynamometer has been calculated considering the order of strain as 40 x 10^{-6} The radius of the octagonal ring has been assumed to be 16 mm so that the length becomes 64 mm according to the relation L / r [Bhattacrarjyya, 1984]. From the above discussion it is found that the thickness of the dynamometer is 3.0 mm when the strain value becomes 8.7 x 10^{-7}. And the sensitivity of the dynamometer is found to be 81.6x10^{-6} /N/mm which is satisfactory. Though the deflection due to minimum load is very small, 6 mm gap has been considered for the design.

Fabrication

All the fabrication works are performed in house. A rectangular stainless steel block is roughly made for maximum stock removal and then machined to get the desired size as shown in Fig.1. In making the octagonal rings, two holes are drilled by radial drilling machine followed by boring operation. A stainless steel block is cut into an octagonal shape with the help of a vertical milling machine. The slit between the two horizontal members is made using a slitting saw in column and knee type horizontal milling machine. Finally, all the surfaces are ground and polished. Two blind holes are made on the dynamometer to fit with the vice by nut-bolt system. All the dimensions are shown in the figure.

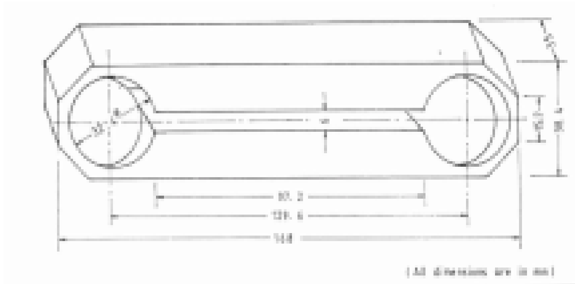

Fig. 1 Designed Dimension of the Dynamometer

Mounting of Strain Gauges

Considering the factors like environment, space availability, extent and type of deformation and the desired life of gauges, strain gauges are cemented. The scales, rust, grease or any type of contamination of the measuring surfaces are removed and cleaned with chemical agent. The bottom surface of the gauge is cleaned by cotton wool socked in acetone and a thin layer of cement is applied on the back of the gauge by means of soft brush. The corners are also covered with cement. The test surface is then coated with a thin adhesive layer (Bakelite adhesive) with a suitable hair brush. It is kept about 10 minutes to dry in open air. the strain gauges of Bakelite type are mounted on each half ring in proper direction as shown in Fig.2 [Shaw, 1984].

A load of about 1/2 kg is applied for few hours for proper cementing. The resistance of the gauge is checked. When strain gauges are cemented, they are connected to lead wires to form the required bridge for measurement as shown in Fig.3 and the connections can be seen from the photograph as shown in Fig.4.

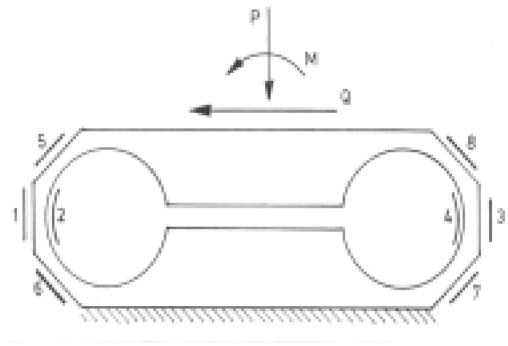

Fig. 2 Grinding Dynamometer showing the position of strain gauges

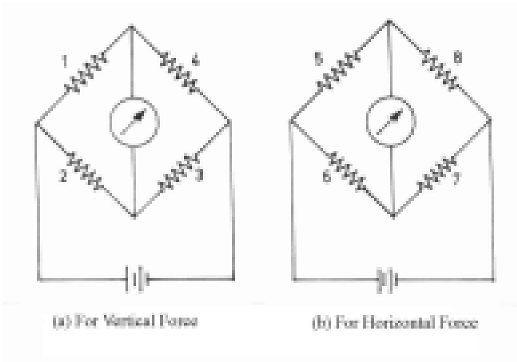

Fig. 3 Bridge Connections

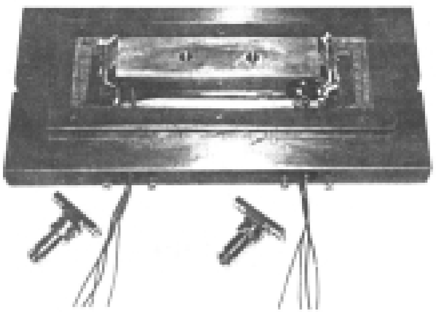

Fig. 4 Strain Gauge Connections

Calibration

Various equipment are used for the calibration of the dynamometers. The aim of the calibration is to obtain the calibration curves. Force transducer is to be calibrated at regular interval. The dynamometer has been calibrated by applying dead loads in vertical and horizontal directions and observing the corresponding meter readings. For the calibration of dynamometer due to vertical load, dead loads are applied from 1 to 15 kg in step of 1 kg (9.81N). The cycle of loading is done by increasing the load and then decreasing in same steps. Corresponding meter readings in milivolt are recorded. This process has been repeated for ten times. For each step loading, average of ten readings is taken to plot the calibration curves. The same method has been followed for the calibration of dynamometer for horizontal load. The curves are shown in Figs.5 and 6

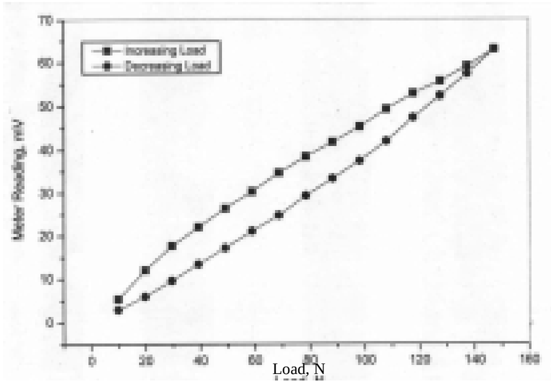

Fig. 5 Calibration Curves for Horizontal Load

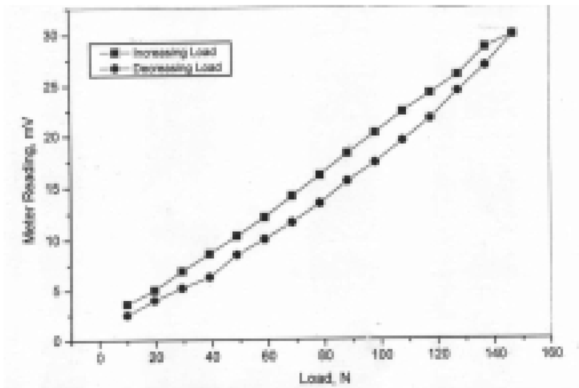

Fig. 6 Calibration Curves for Vertical Load

EXPERIMENTAL

The materials used for experimental studies are tungsten carbide and stainless steel. The wheel used is a diamond - impregnated metal-bonded grinding wheel 150 mm in diameter, 9 mm in width. The width of the layer containing diamonds is 3 mm and abrasive grit size is 80/100. A DC motor (3 Phase, 1.5/2 kW/hp, 1400 rpm) was employed to rotate the grinding wheel. The spindle rotates at 3000 rpm corresponding to a peripheral speed of 1413 m/min. The electrolytes used are KNO_3 and NaCl at different concentrations.

The strain gauge grinding dynamometer developed is provided for indication of the force components produced during machining operation. Since this force is found to be very small, an operational amplifier of high gains is used to record the feed and radial forces.

The experimental investigations are performed under the following conditions.

a) Applied Voltage : 4 - 15 V
b) Feed Rate : 2.67 - 6.67 mm/sec.
c) Set Depth of Cut : 5 - 30 micron

RESULTS AND DISCUSSION

The most important parameter that effects the electrochemical aspects of the ECG process is current flow between the wheel and work piece. There are some other parameters that govern the mechanical aspects. The electrolyte exposure time depends upon feed rate of the worktable. The grinding force components are due to that feed rate. The main objective is to ascertain the feed force required for the operation of ECG process, which must be very, less than that of conventional grinding.

Effect of Current Density on Feed Force

The variation of the feed force for stainless steel at different current densities is shown in Fig.7. It is seen that up to about 3.1 amp / mm ^{2} the grinding force components decrease rapidly followed by a slow decrease in feed force with further increase in current density. The radial force is found much higher than the feed force produced during electrochemical grinding process. Literature review indicates that radial force component may be greater in ECG than in conventional grinding with larger current densities and higher feed rates [Levinger and Malkin, 1979]. The feed and radial forces are recorded by dynamometer associated with an electronic amplifier.

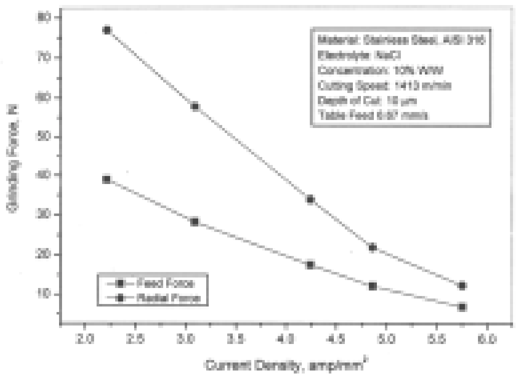

Fig. 7 Effect of Current Density on Radial and Feed Forces

Effect of Feed Rate on Grinding Force

When feed rate is high, mechanical action is more and electrochemical action is less. With increase in feed rate, the feed force increases slowly and more or less linearly. The radial force also increases slowly up to about feed rate of 5.8 mm/sec and then increases at a faster rate as shown in Fig.8. The feed force is found about half of the radial force.

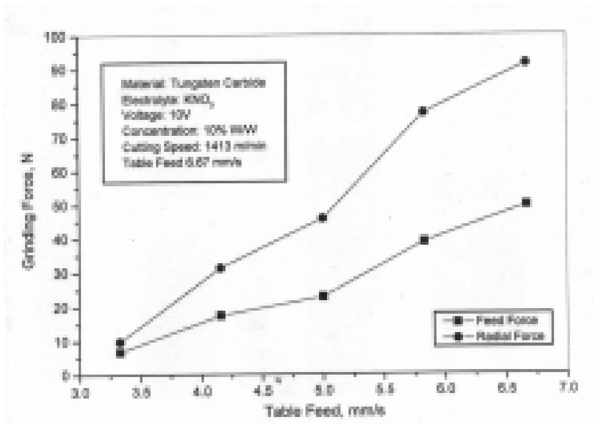

Fig. 8 Effect of Feed rate on Radial and Feed Forces

Effect of Current Density and Feed Force on Process Efficiency

Process efficiency with regards to the ECG process is defined as the ratio of electrolytic metal removal to the total removal. With increase in current density the electrochemical action becomes predominant and hence process efficiency also increases as shown in Fig.9. But with the increase in feed force since mechanical action predominates, process efficiency is found to decrease as shown in Fig..10.

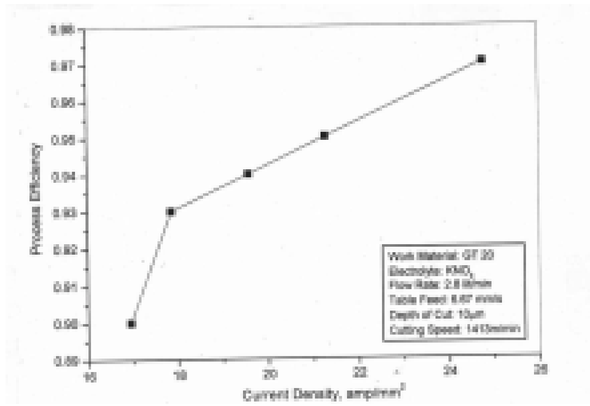

Fig. 9 Effect of Current Density on Process Efficiency

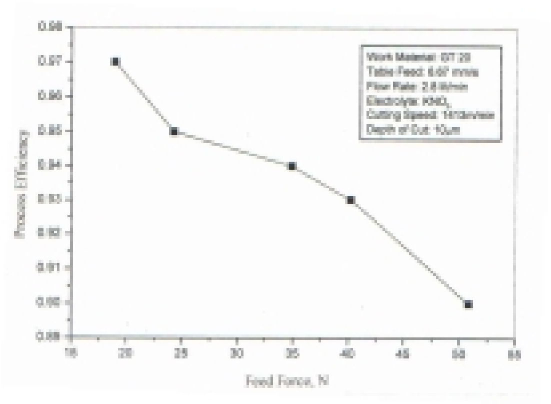

Fig. 10 Effect of Feed Force on Process Efficiency

CONCLUSIONS

From the calibration and performance test of the dynamometer it can be concluded that the dynamometer, designed and fabricated, works successfully in the machine set-up. The calibration curve shows that strain varies more or less linearly with both vertical and horizontal components of forces, and facilitates interpolation of intermediate ranges. No noticeable cross effect is observed between the two components of the dynamometer.

Based on experimental results the following conclusions are drawn.

i) Feed and radial forces are very less in ECG as compared to conventional method of grinding for similar conditions,
ii) They increase with the increase of feed rate, and the feed force is half of the radial force, and
iii) Process efficiency increases with the increase in current density and decreases with the increase in feed force.

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REFERENCES

Bhattacharyya, A., Metal Cutting Theory and Practice, Books and Allied Private Ltd. India, 301-320 (1984).

Bhowmick, T. P. and Mishra, P.K., " Modelling of Feed Force for Electrochemical Grinding Process", Proc. of 18th *AIMTDR Conf.* IIT, Kharagpur, 379-383(1998}.

Ghosh A., Mukharjee, S. S., and Bhattacharyya, A., " A New Electronic Drill Dynamometer", *Journal of Institution of Engineers (India),* XLIII, No. 1, Part ME 1, 1-11(1962).

Ito, S., Sakai, S. and Ishikawa, M., "A Study on a Two Dimensional Dynamometer for Surface Grinding", *Bull. Japan Soc. of Prec. Engg.*, 14, 25-30 (1980).

Levinger, R. And Malkin, S., "Electrochemical Grinding of WC-Co Cemented Carbides", *Journal of Engineering for Industry*, 101, 285-294 (1979).

Ponkshe, G. R. " Design, Construction and Calibration of a Two-component Heavy Duty Lathe Dynamometer", *U.D.C.* 531.78: 621.941, 142-150 (1966).

Shaw, M. C., Metal Cutting Principles, Clarendon Press, Oxford, 130-160 (1984).