MILITARY TECHNICAL COLLEGE
CAIRO - EGYPT

THE INFLUENCE OF SOME FACTORS ON SURFACE FINISH AND GRINDING WHEEL WEAR IN DRY SURFACE GRINDING.

H.A.NAGI

ABSTRACT

Workpiece of EN-8 plain carbon steel have been dry surface ground using Alumina grit,vitreous bonded wheels(WA 46 HV) under constant metal removal rate.The effect of the crossfeed and the downfeed in addition to the workpiece speed on the surface finish of the ground workpiece,and the wheel wear have been investigated. Empirical formulae have been derived, by which the grinding ratio,and the surface finish of the ground surfaces have been expressed in terms of the grinding parameters.

Basically,three series of tests were performed.Each series was performed with on of the above parameters,and the product of the other two parameters fixed. Firstly, the workpiece speed was fixed at 43.2 mm/sec. and the product of the downfeed and the crossfeed was fixed at .032 mm^2. Secondly, the downfeed was fixed at 0.05 mm. and the product of the workpiece speed and crossfeed was fixed at 27 mm^2/ sec. Thirdly,the crossfeed was fixed at 0.625 mm. and the product of the downfeed and the workpiece speed was fixed at 2.16 mm^2/sec.

It has been found that the grinding ratio and the workpiece surface roughness are both affected by the grinding conditions in the following order of significance: crossfeed,workpiece speed and downfeed. It has also been found that the grinding ratio increase is always accompanied by a decrease in the surface roughness of the ground workpiece.

Assistant Professor,Dept.Of Mech.Engneering
Al Azhar Uni. ,Cairo ,Egypt.

INTRODUCTION

In the grinding process,the possible varieties of grit types sizes,bond types and bond quantities give an extremely large number of possibilities of wheel constitutions.

Nowadays,gringing is widely used in modern industry for producing precise surfaces of low surface roughness.In spite of the big advance in science and technology in many fields, grinding still remains,to a large extent an emoirically formulated process.The grinding process is a mutual machining process.Because material is removed from both the grinding wheel and the workpiece.In most cases the amount of wheal wear is much less than the amount of material removed from the workpiece but this i not always so.When grinding to a high accuracy,measurement accuracies,especially those of geometry,would become obsecured if the surface finish obtained by grinding was not also of high quality.

In fact,it is of considerable importance to investigate the influence of all factors affecting the grinding process on the quality of surface produced and on the grinding wheel wear because what is required from grinding is to obtain good surface finish and low wheel wear in a reasonably economic way.since wheel wear and workpiece surface finish are related,then factors affecting the grinding wheel wear are also affecting surface finish.

The present work only included the influence of workpiece speed,downfeed,and crossfeed on the wheel wear and on the surface finish of the ground workpiece under constant metal removal rate.

Workpiece Speed (v).

In surface grinding,the effect of the workpiece speed on the wheel wear has been briefly mentioned by Weill[18] without referring to experemental results.he stated that an increase in the workpiece speed causes an increase in wheel wear.this agrees with the trends indicated by an examination of equation (1) given by Shaw 16 as follows:

$$t = \left(\frac{4v}{Vnr} \sqrt{\frac{d}{D}} \right)^{\frac{1}{2}} \qquad (1)$$

Downfeed (d).

The downfeed is defined by the height of the workpiece surface above the plane which contains the lowest point on the grinding wheel,and which is parallel to the workpiece surface.

It can be seen from the work by Weill[18],Pollock[14] and Field[6],that the wheel wear increases,and the grinding ratio decreases with increased downfeed. This agrees qualitaively with equation (1) shown before and with the formulation made by Lindsay[10] in equations (2)and (3)shown below.

$$Z'_s = 6.3 \times 10^{-8} \times \frac{d^2}{D} \left(4 I.33\ H + 2.2\ s - 8 \right) V\ F_n'^2 \qquad (2)$$

$$\alpha = \left(\frac{n}{X} - \left(\frac{V}{v}\right)^2 \right) \left(\frac{t_m}{A} \right) \qquad (3)$$

Where α is the leading edge angle illustrated in fig.1.

Crossfeed (X).

The crossfeed is defined by the amount of the table feed in directio normal to the direction of reciprocation per stroke.

The wheel wear expressed in terms of the grinding ratio has been investigated by Yang [19] for titanium alloys surface grinding fig.2,and Field [6] for surface grinding of steel fig.3.It can be seen that the grinding ratio decreases with crossfeed increase which agrees with equation (1).

In equation (1), increasing the crossfeed may probably cause a decrease in the value of (h) which causes an increase in the undeformed chip thickness which leads to an increase in the wheel wear.Also an increase in the crossfeed(X),makes the wheel appear softer,therefore,the wheel wear increases. It is well known that increasing the crossfeed(X),is always accompanied by an increase in the force intensity (F'_n) which leads to an increase in the wheel wear,equation (2).

Surface Finish.

sato[15] showed that :

$$h = (I/8) \times (I/R) \left(\frac{v}{V}\right)^2 a^2 + \frac{1}{4} \frac{b^2}{d_o} \left(\frac{X}{E} \right)^2 \qquad (4)$$

It can be seen that surface roughness increases with the increase of the square of the workpiece speed(v),and the square of crossfeed(X). This agrees with an equation presented by Yang[19] in principle as follows:

$$h = \left(v / 2Vrn\ D \right)^{2/3} \qquad (5)$$

It is clear that the equation does not include the crossfeed but this does not necessarily mean that the surface roughness is independant of such parameter.

Workpiece Speed (v).

Koenigsberger [2] agrees with Sato[15] that the surface roughness increases with the increase with the workpiece speed.

Downfeed(d)

It can be seen from the results obtained by Yang[19],Weaver[4], Gresbrook[7],Mc Kee[12],Krabacher[8],Farnworth[3],and Armarego[1],that the surface finish worsens with the increase of the downfeed as shown in fig.15.

The Workpieces.

The workpieces were manufactured from EN-8 plain carbon steel. They were finished ground to a nominal size of 100mm., by 50mm., by 12.5mm.

The Dressing mechanism.

The dressing mechanism is shown in fig.1 A diamond is brazed to a rod which is fixed to a slide and inclined at 10° to the vertical. A rack was fixed to the slide to move with constant speed over a pinion. A reversing gear mechanism was used to reverse the diamond traverse motion.

EXPERIMENTAL PROCEDURE AND TECHNIQUES

Preparation For Grinding Tests

Before any grinding test was commenced, the grinding machine spindle and table drive mortors were switched on and allowed to run for at least twenty mintues. This gave the hydraulic and lubricating oils sufficient time to flow throughout the machine system and allowed the spindle bearings to warm up and attain normal conditions.

Grinding Test Procedure

When this settling period is elapsed, the workpiece was located and clamped on the table by means of magnetic chuck in such a way that the 100 mm. dimension lying in the direction of the table movement. A thin initial layer of the workpiece was then removed under the same test conditons. The initial wheel surface profile and the wheel profile after each test was obtained by passing the wheel over an edge of a razor of 1.5 mm thickness, 50 mm. length and 12.5mm. width fixed at the edge of the table, fig.8. The roughness of the surface produced was measured at 5 different points by means of a portable Talysurf, fig.9 and the wheel surface profile was obtained after each cut.
The grinding wheel was dressed before each test. Since the dressing techique affects the condition of the wheel working surface the dressing procedure was never varied for all grinding tests.

The Grinding Ratio.

The wheel wear equales the area under the trace, fig.10, times the wheel circumference assuming no wear happens to the back edge of the wheel in the radial direction. The amount of the initial wheel wear was substracted from the measured wear to obtain the net wear during the grinding operation.

Results shown in fig.4 agree with equation (1) in principle. Equation (4) presented by Sato[15] indicates that the downfeed does not affect the surface quality of the workpiece specimen. Although equation (5) does not include the downfeed term but also the experimental results obtained by Yang[19], fig.5, shows that at relatively high downfeeds, the surface roughness increases with increased downfeeds, but at low downfeeds the downfeed effect on the surface roughness was marginal.

Linsay[9] expresses the proportionality of the surface roughness to the grinding conditons as follows;

$$h \propto (I/D)^{0.17} d_o^{0.33} L^{0.5} (C/L)^{0.3} (F/W)^{0.33} / \sigma_y^{0.5} \qquad (6)$$

It is known that increasing the downfeed causes an increase in the normal interface pressure between the workpiece and the wheel, therefore the results shown in fig.4, agree indirectely in principle with equation(6).

Relation Between The Wheal Wear And The Surface Finish

It has been shown by Bernard[5], Makino[11], Mc Kee[12], Armarego[1], Krabacher[8], Sherwood[17], Opitz [13], and Weaver [4], that the grinding wheel wear and the quality of the surface finish produced are related in such a way that an improvement in the surface finish was always accompanied by a low wheel wear rate.

Examining the factors affecting the grinding process, it can be understood that obtaining a low surface roughness by chaning these factors is always accompanied by a low wheel wear which agrees with equations (1) and (2).

EXPERMINTAL EQUIPMENT

The Grinding Machine.

The grinding tests were performed on a standard Churchill 457mm. by 150 mm., grinding machine to which certain additons had been made in order that selected machine movements could be accurately and easily controlled. Ratchet mechanisms, fig.7, were fitted so that the desired wheel head downfeed and table crossfeed could be achieved quickly. In additions a microswitch fixed to the machine and connected to a universal counter was used for table speed calculations.

The Grinding Wheel.

A vitreous bonded, 46 grit, alumina wheel(WA 46 HV) was used through the tests. The wheel was 12.5 mm., wide and initially of 175 mm. diameter.

DISCUSSION

Wheel Wear.

It can be seen from fig.11, that the grinding ratio decreases with the increase of the crossfeed and the decrease of the downfeed under constant table speed. One would expect generally that an increase in the downfeed causes an increase in the undeformed chip thickness and therefore the wheel wear increases and the grinding ratio decreases. This is true if the crossfeed is constant, but because the product of the crossfeed and the downfeed is constant, an increase in the grinding ratio is expected.
The obtained results may be formulated empirically within the employed range of grinding conditions, as follows:

$$G = 62 \times d^{0.09} / X^{0.13} \qquad (7)$$

The equation reveals that the crossfeed has a greater influence on the grinding ratio than has the downfeed. The results agree with the finding of Mc Kee[12], Yang[19] and Field[6].

Fig.12, shows that the grinding ratio decreases with the increase of the crossfeed and the decrease of the workpiece speed under constant downfeed. It is known that decreasing the workpiece speed decreases the undeformed chip thickness and therefore increases the grinding ratio, but the shown decrease is attributed to increase in the crossfeed while the workpiece speed decreases. The results obtained may be emperically formulated as :

$$G = 66 \times (X^{-0.13} \; v^{0.09}) \qquad (8)$$

The grinding ratio decreases about 7% while the crossfeed increases and the workpiece speed decreases 16 times within the employed range which means that the crossfeed has a slightly greater influence on the grinding ratio than the workpiece speed.

The results shown in fig.13, is expected because increasing the workpiece speed increases the undeformed chip thickness and decreases the grinding ratio. The obtained results may be empircally formulated as follows:

$$G = 88 \times (d^{0.09} / v^{0.08}) \qquad (9)$$

The grinding ratio decreases about 80% while the downfeed decreases and the workpiece speed increases 16 times. This means that the workpiece speed has greater influence on the grinding ratio than the downfeed.

Generally, the variation of the grinding ratio with the workpiece speed, the downfeed and the crossfeed may be expressed as follows:

$$G = K \times d^{0.09} / (X^{0.13} v^{0.08}) \qquad (10)$$

Where K is a constant depends upon the grinding conditions and the fixed parameter during the tests.

Examining this equation,figs.11,12,and 13,it can be seen that the crossfeed has the greatest influence on the grinding ratio and its influence is slightly greater than the influence of the workpiece speed but the downfeed has the least importance.

SURFACE FINISH

It can be seen from fig. 14, that the surface roughness increases with the increase of the crossfeed and the decrease of the downfeed. One would expect that the decrease in the downfeed decreases the surface roughness but because of the increase in the crossfeed, the surface roughness increases.The obtained results may be empirically formulated asfollows:

$$R_a = 0.143 X^{0.21} / d^{0.14} \qquad (11)$$

and $$R_a = 0.09 X + (0.002 / d) + 0.122$$

It can be understood from equation (11) and fig. 14, that the crossfeed has a greater influence on the surface roughness than has the downfeed. The results agree with the findings of Farnworth[7], Yang[19], and in principle with equation (4).

Fig. 15, shows that the surface roughness slightly increases with the increase of the crossfeed and the decrease of the workpiece speed under constant downfeed. Decreasing the workpiece speed improves the surface roughness but the results may be attributed to the greater influence of the crossfeed on the surface roughness than that of workpiece speed.The results may be formulated as follows:

$$R_a = 0.155 X^{0.021} v^{0.019} \qquad (12)$$

$$R_a = 0.009 X - (0.127 / v) + 0.276 \qquad (13)$$

The results agree with the findings of Sato[15] and Koenigsberger [2]and in principle with equations (6)and(7).

The surface roughness increases with the increase of the workpiece speed and with the decrease of the downfeed under constant crossfeed,fig.16.The increase in the surface roughness while the downfeed decreases only occurs because the workpiece speed has a greater effect on the surface roughness than has the downfeed. The results may be presented as follows:

$$R_a = 0.09 v^{0.19} / d^{0.14} \qquad (14)$$

$$R_a = (0.002 / d) - (0.127 / v) + 0.25 \qquad (15)$$

The variation of the surface roughness with the workpiece speed, the crossfeed and the downfeed therefore may me expressed generally as follows:

$$R_a = \bar{K}\, X^{0.21}\, v^{0.19} / d^{0.14} \qquad (16)$$

$$R_a = 0.009\, X - (0.002 / d) - (0.127 / v) + \bar{D} \qquad (17)$$

where $\bar{K}$ and $\bar{D}$ are constants depending upon the grinding conditions and the fixed parameters during the tests.

It can be seen from the prvious discussions that the crossfeed has the greatest influence of the surface roughness and its influence is slightly greater than the influene of the workpiece speed but the downfeed has the least importance with the respect to the surface roughness.

THE RELATION BETWEEN THE GRINDING RATIO AND THE SURFACE ROUGHNESS

An attempt has been made to draw the relation between the surface roughness R_a against the grinding ratio,it has been found that no simple curve can express such relation.The general trend of this relation can be understood by examining figures 11,12,13,14, 15and 16.It can be seen that for all tests the surface roughness increase is always accompanied with grinding ratio decrease. This feature agrees with the findings of Bernard[5],Mc Kee[12], Makino[11],Armarego[1],Krabacher[8],Sherwood[17],Opitz[13], Weaver[4]and in the basic principle of the prvious equations.

CONCLUSIONS

Under constant metal removal rate conditions in reciprocating action surface grinding,the grinding ratio and workpiece surface finish are both affected by the studied parameters in the following order of significance.Crossfeed,workpiece speed and downfeed.

The relation between the grinding ratio and the roughness of the ground surface and the grinding parameters studied may be empirically as prviously stated.

REFERENCES

1. Armarego,and Brown."The Machining Of Metals"
2. Koenigsberger,F.,"Design Principles Of Metal Cutting Machine Tools".
3. Farmwprtj,G.H.,"The Influence Of Vibrations On Quality In Grinding", M.Sc. UMIST, U.K.
4. Weavers,B.K., "The Influence Of Speed On Grinding Of Bearing Steel." M.Sc. UMIST, U.K. 1970.
5. Bernard, C., "Grinding To Microinch Accuracies And High Degree Of Surface Finish".Machinery, London, V.113,n. 2922, Nov. 13, 1968, pp 995.
6. Field, M., "G.Ratio In Grinding,Its Use And Misuse".ASAM, March 6,7,1967, p 92.
7. Grisbrook, H.G., Hollier, R.H., And Varley, P.G.,"Related Patterns Of Grinding Forces,Wheel Wear And Surface Finish". The International Journal Of Production Research,Vol. 1, N. 3, Aug. 1962.
8. Krabacher, E.J., "Factors INfluencing The Performance Of Grinding Weels ". ASME, Paper 58, 1958.
9. Lindsay,R.P., "The Effect Of Parameter Values In Precision Grinding".Trans. ASME, J. A. For Industry,Vol.92, Aug.1970, Series B,N. 3.
10. Lindsay, R.P., Hahn, R.S., "On The Basic Relationship Between The Grinding Parameters". Annals OF THe CIRP,Vol.XVIII.
11. Makino, H., "On The Tool Life Of Grinding Wheel In Precision Grinding Of Hardened Steel,. "Bull.Japan Society Of Precision Eng., Vol.2, N. 1, 1966, pp 47-53.
12. Mc Kee, R.E., "Experimental Study Of Cylinderical Grinding". Trans. ASME, Vol. 69,1947, P. 891.
13. Opitz, H. Ernst, W.E., And Meyer, K.F., "Grinding At High Speeds ",Advances In Machine Tool Design And Research, Sept. 1965, P. 581.
14. Pollock,C.,"Rules For Surace Grinding".Metal Working Production Vol.III, March 15, 1967,P. 71,Pt. 1.
15. Sato,K.,"On The Surface Roughness In Grinding".
16. Show, M.C.,"The Grinding Of Metals".Conference.1958,Inst.Of Mech.Engrs.
17. Sherwood, P., " Which Grinding Wheel For Which Job?". Canadian Machinery And Metal Working, May 1968,Vol.79, Part 5, pp84-5.
18. Weill, R., "Experimental Assessment Of The Grinding Weel Wear Mechamism".Microtechnic,N.6,V.XV, 1961.
19. Yany, C.T., And Show, M.C.,"The Grinding Of Titanium Alloys". Trans.ASME,V. 77, 1955,p.645.

FIRST A.M.E.CONFERENCE

29-31- May 1984 ,Cairo

NOMENCLATURE

A	Wheel constant.	
a	distance between two successive cutting points	mm.
b	Scratch width.	mm.
c	Two times the depth of dress.	mm.
D	Grinding wheel diameter.	mm.
$\bar{D}$	Constant.	mm.
d	Downfeed.	mm.
d_o	Grain diameter.	mm.
A	Grinding wheel width.	mm.
F	Normal interface Force between wheel and workpiece	Kp.
F'_n	Force intensity.	Kp.
G	Grinding ratio.	
H	Wheel hardness.	
h	Mean scratch depth.	mm.
$\bar{K}$	Constant	
L	Dress lead	mm./rev.
n	Number of cutting points per unit wheel surface area.	
R_a	Arithmetic mean deviation.	micron
r	Width /depth ratio of an average cut.	
s	Wheel structure number	
σ_y	Yield strength of workpiece material	$Kp.mm^2$
t	Undeformed chip thickness.	mm.
t_m	Maximum chip thickness.	mm.
V	Wheel circumferential speed	mm./sec.
v	Workpiece speed.	mm./sec.
W	Width of wheel work interface.	mm.
X	Crossfeed.	mm.
Z'_s	Wheel removal rate per unit width of wheel	$mm^3/sec./mm.$

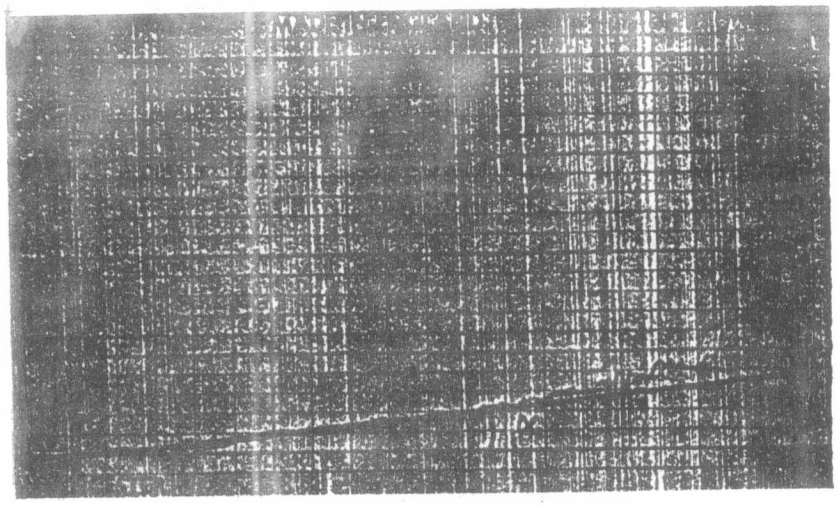


Fig. 1: Leading Edge Angle

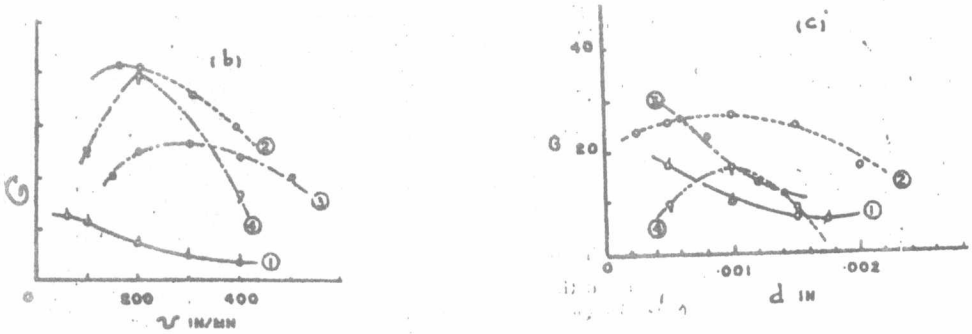


Fig. 2: Variation of Grinding Ratio with Downfeed and Workpiece Speed.

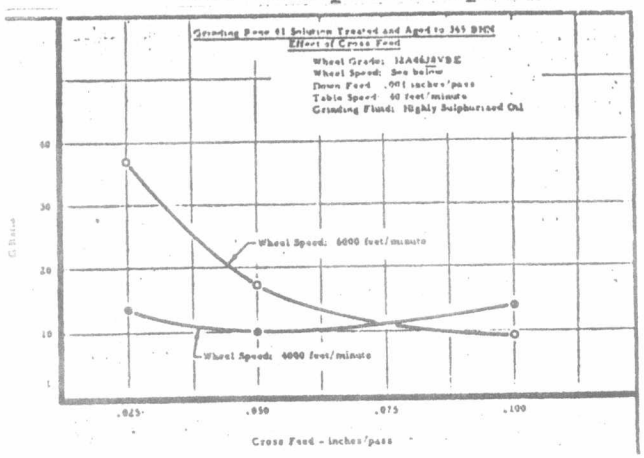


Fig. 3: Variation of Grinding Ratio with Crossfeed.

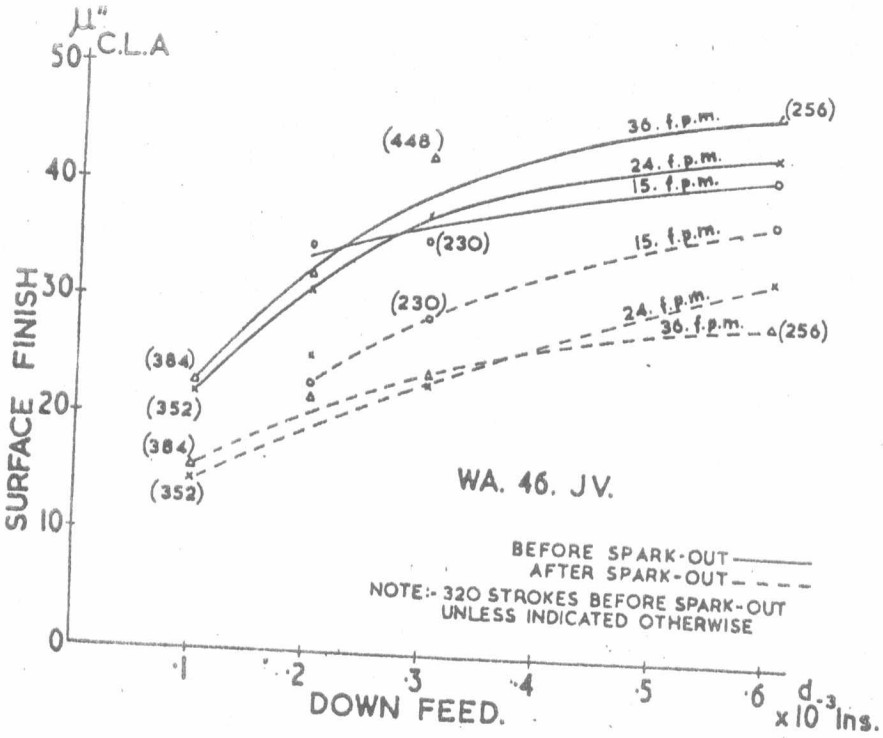


Fig. 4: Variation of Surface Roughness with Dwonfeed

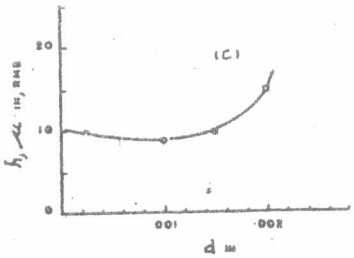


Fig. 5: Variation of Surface Roughness with Downfeed.

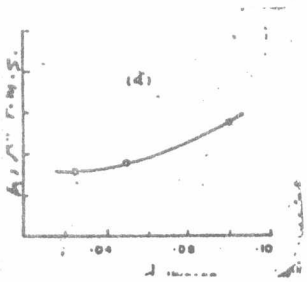


Fig. 6: Variation of Surface Roughness with Crossfeed.

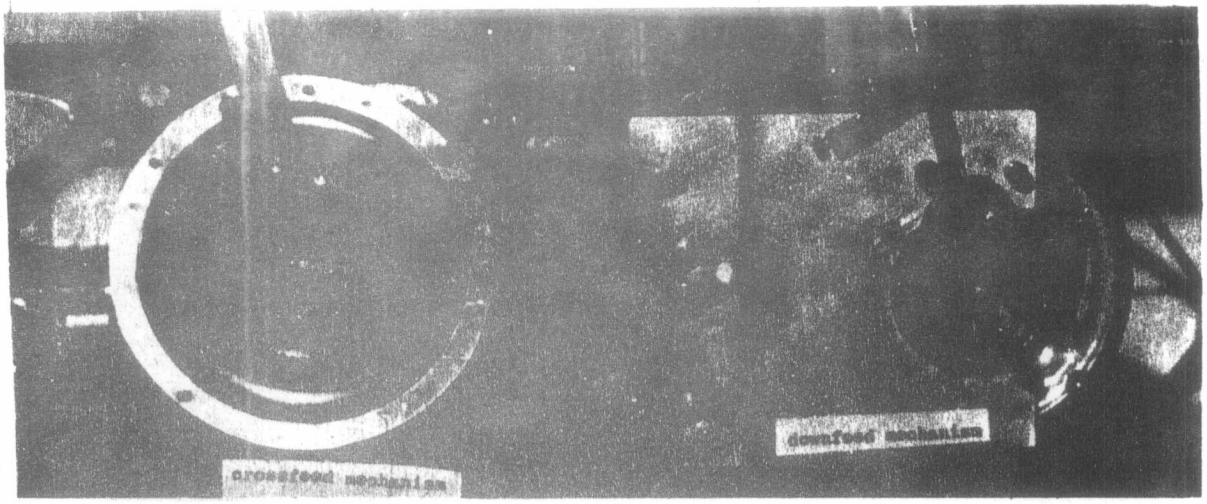


Fig. 7: Ratchet Mechanisms.

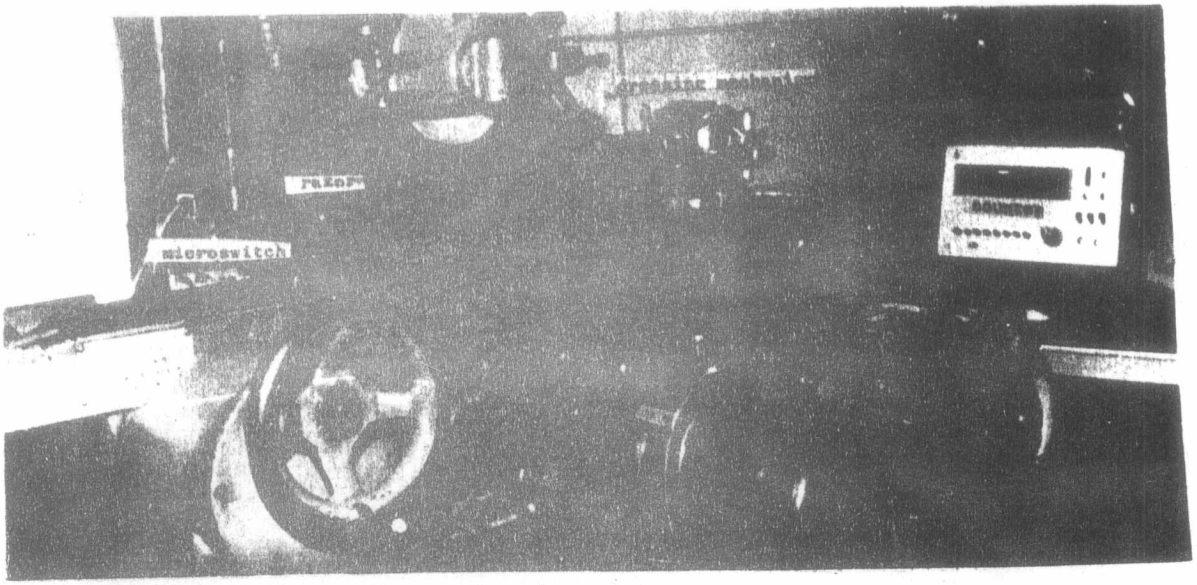


Fig. 8: General Setup.

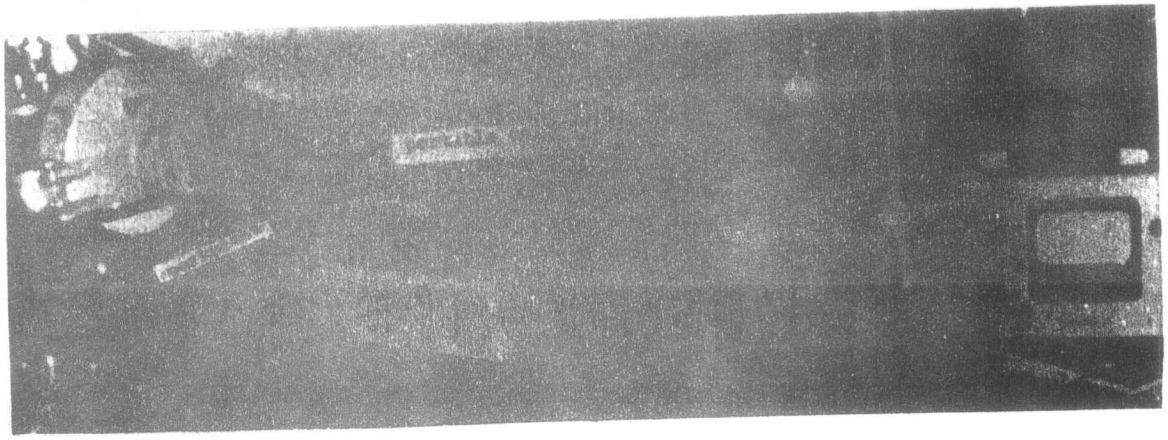
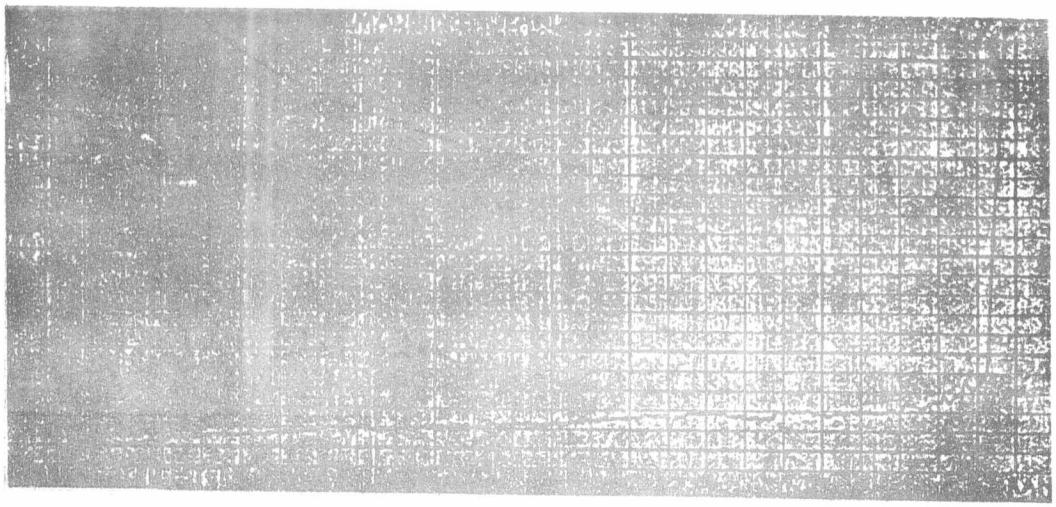
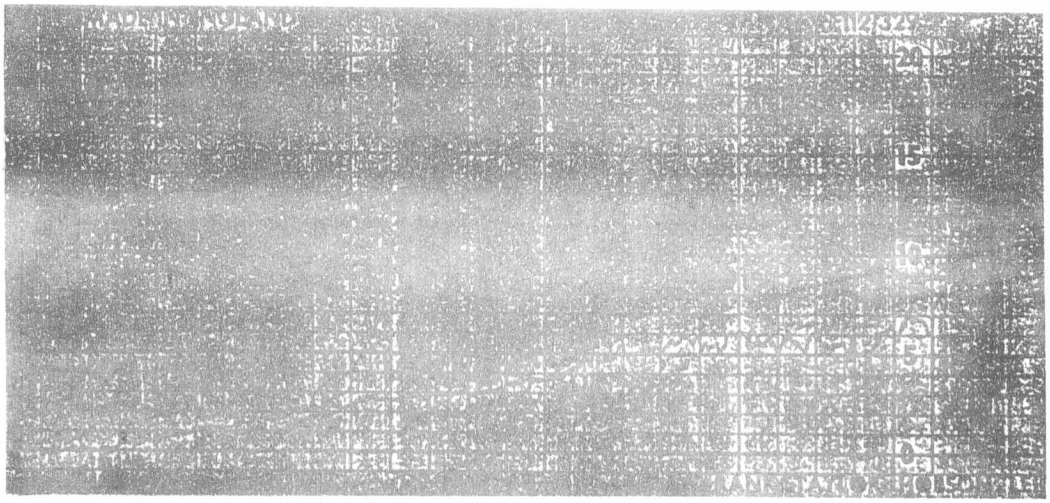


Fig. 9: Surface Roughness Measurement With Portable Talysurf.



(a) Initial Wheel Wear



(b) Final Wheel Wear.

Fig. 10: Wheel Wear.

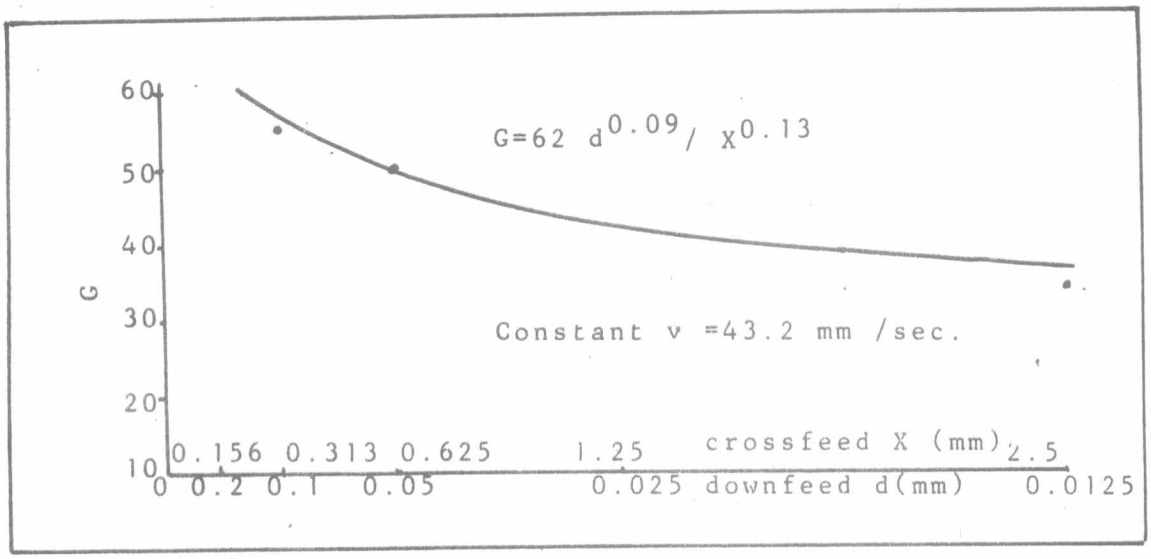


Fig.11. Change of G with X and d under constant v

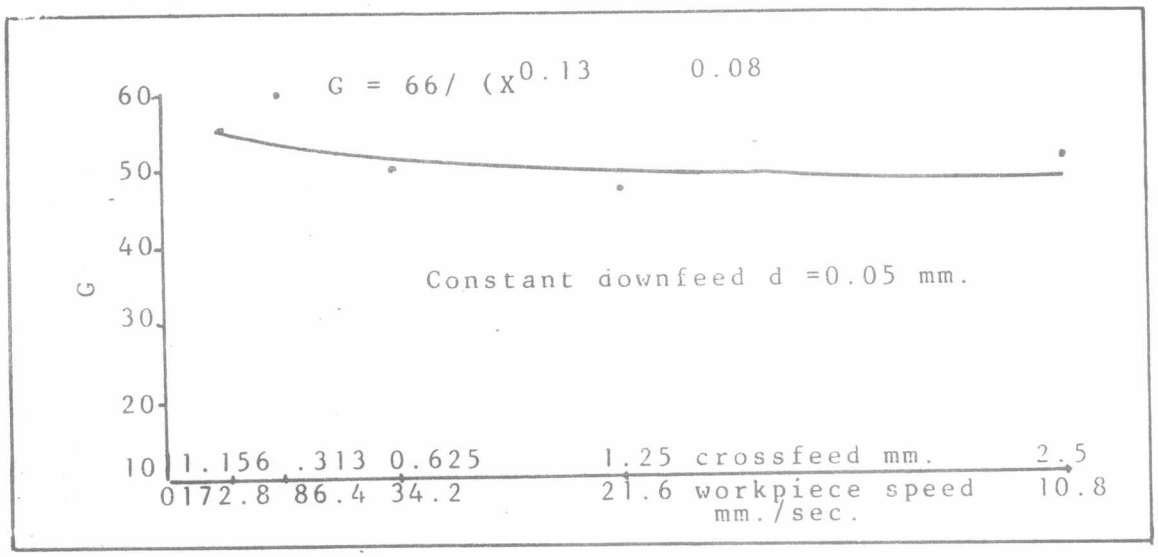


Fig.12.Change of G with X and v under constant d.

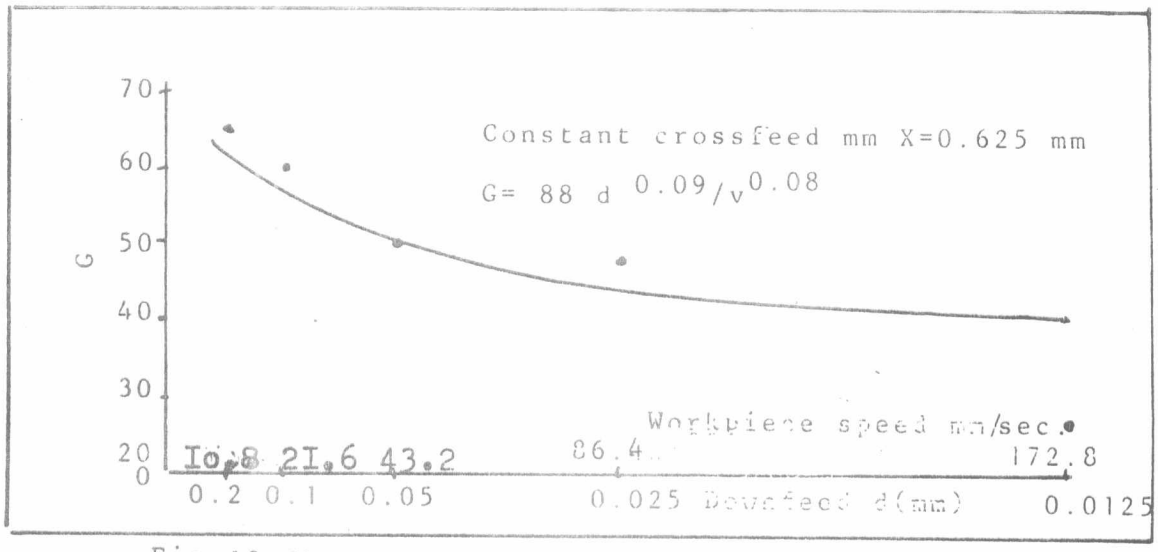


Fig.13.Change of G with v and d under constant X

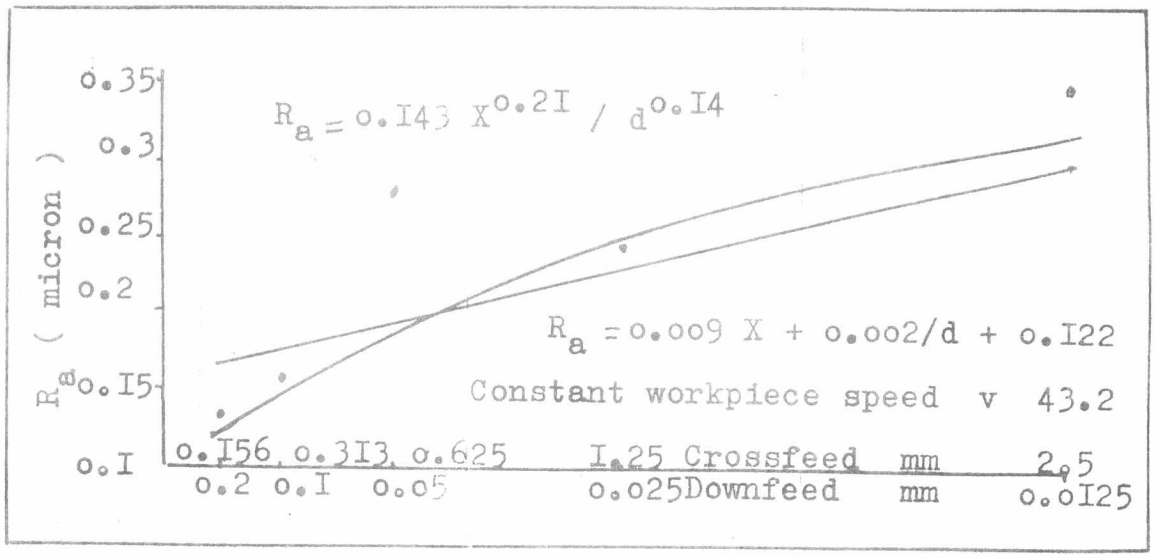


Fig. I4. Change of R_a with X and d

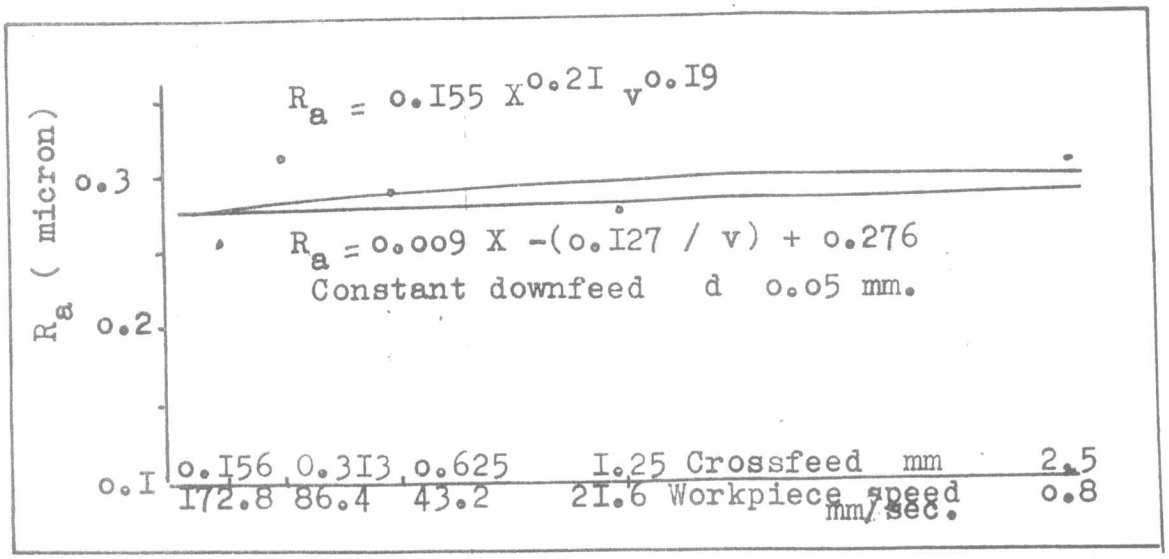


Fig. 15. Change of R_a with X and v

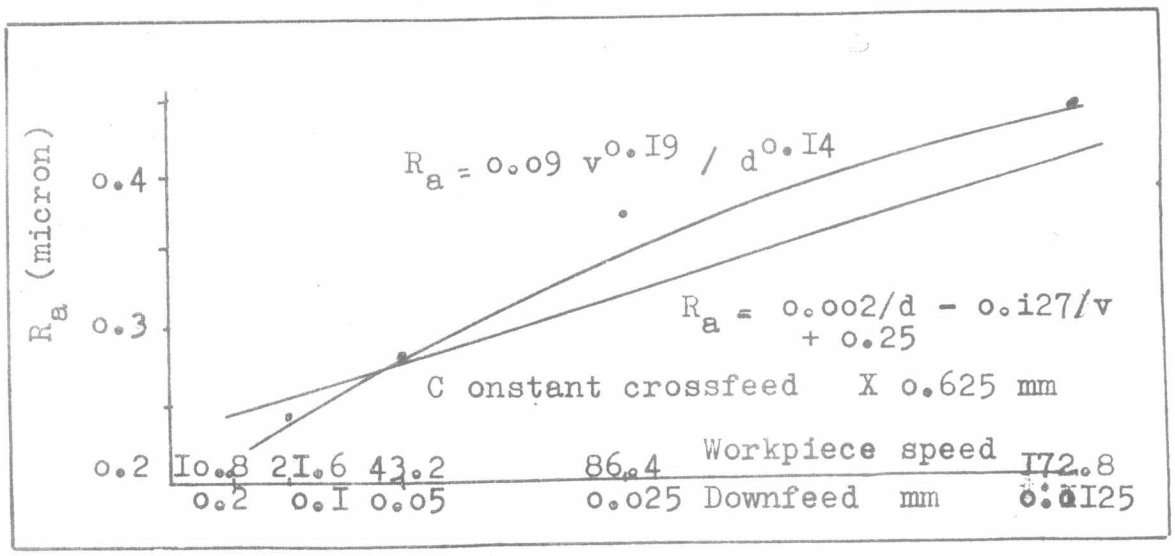


Fig. 16. Change of R_a with v and d