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THE COLLEGE OF AERONAUTICS

CRANFIELD

DEPARTMENT OF PRODUCTION AND INDUSTRIAL ADMINISTRATION

MACHINE TOOL LABORATORY

Appendix A

to

Progress Report No. 2 on the investigation into grinding of nickel chrome alloy EPK31 produced by Henry Wiggins

- by -

J. Purcell

Summary of calculations for test 134

Grinding wheel specification Carborundum 5A-60-I8-V50

Coolant Metior Oil Co. Translube 150 General Purpose Cutting Oil

Maximum plunge depth of cut (E) = 0.00042 ins.

Maximum undeformed chip length (L) = 0.053 ins.

Surface area which may be ground for wheel size 7 ins. diameter by 1 inch wide = 500 sq.ins.

Modifications to conditions to enable a 15 ins. diameter wheel to be used.

Maximum plunge depth of cut E = 0.0002 ins.

Maximum underformed chip length (same) 0.053 ins.

Surface area which may be ground = 2,140 sq.ins.

In both cases the work speed is 65 feet per minute and wheel periferal speed 5,500 ft. per minute.

Note 1. External form grinding can be assumed to be exactly similar to either surface or cylinder grinding. Care must be taken to allow for any weak sections of the form length.

Note 2. Internal grinding unless it is using a very short and rigid grit has not been proved. In the case of very short quils and large bores using small grinding wheels - treat as for surface grinding.

Introduction

The work on the comparative tests of the effectiveness of coolants has continued. A wide range of soluble type coolants and straight oil coolants have been evaluated. The results of these tests are presented in a similar manner to that used in Progress Report Nos. 1 and 2, as Appendix A to Progress Report No. 2. From communications and inquiries in reference to the progress reports it may be that the clarity of the results could be improved to this end, more detailed attention to this is here included.

Explanation of test results sheet headings.

The Test Numbers, Wheel Type (specification), Coolant, are all self explanatory.

Grinding conditions

This has been fully included in the progress reports, it is as follows:

Table speed constant at 65 feet per minute
Depth of cut constant at 0.001 ins.
Gross feed constant at 0.042 ins. per table stroke
Grinding wheel diameter maximum 7 ins. minimum $6^3/_4$ ins.
Grinding wheel width 0.75 ins. constant.

The grinding wheel specification and coolant are the variables, other conditions will be varied when initial testing is completed.

The surface area ground.

This heading means the area of surface ground under the standard conditions per redress of the grinding wheel. All tests which achieve 75% of the previous test are repeated twice more. All products which achieve good results will be retested, and full calculations will be made. Full details and copies of results of any test are available on request.

Surface finish

The surface finish produced at each test is measured on the Taylor Hobson Talisurf. CLA is recorded, no trace record is made. This will be done when the most efficient products are retested.

Where necessary brief remarks on a performance are included. These will be expanded and presented in greater detail when the final tests are made.

Comments on the coolant tests

The soluble type coolants.

The results achieved when using these coolants would suggest that the task is reaching very close to their maximum capabilities. Many have proved inadequate to produce stable grinding conditions and the best performance leaves little to allow for the depreciation which may take place due to the less rigid control of the conditions which frequently occur in the factory as compared with those prevailing in the laboratory.

Tests have been carried out on the very wide range of coolants using the volume of oil to water ratios, as suggested by the coolant suppliers. The water used to dilute these coolants has been analyzed and copies of this analysis sent to the coolant suppliers. When the maximum possible effectiveness of these soluble coolants is sought the chemistry of the diluting water becomes more critical as certain elements which are found in some local water cause drop out and depreciation of the effectiveness of some addatives.

Analysis of the test results show that the most effective performance achieves 70 to 75 square inches. This figure is limited to few products, and is only improved when the oil water ratio is varied to a high oil content this causes tendency for the workpiece to heat foaming of the coolant and separation. The performance is not substantially improved by the higher concentration and it is suggested that the initial recommendation of oil water ratios are correct. There are a few samples which have done reasonably well at high ratios. these it is suggested should be tested at higher concentrations. Examples of these are the samples tested at ratios from 40 to 80 of water to one of oil to be tested at 10 and 20 to one of oil.

The product Metol 77 as originally supplied and used at the dilution rate 1 volume of oil to 10 volumes of water which has given repeated results of 72 square inches of surface area ground has been used as the basic coolant to which conditions have been returned when it has been necessary to use a new grinding wheel the wear on a wheel has been limited to a loss on diameter of 0.250 inches.

The choice of Metol 77 was made from the good performance of this product. Later tests have shown repeatability and also that when the oil water ratio falls from 1 in 10 to 1 in 7.5 there is some improvement in performance - this is true of other products tested. It is a good feature due to the use of the coolant and evaporation resulting in the loss of water. From the test results included in the Progress Reports it is shown that the correct ratio of oil and water is critical and should be checked frequently.

To support the suggestion that the soluble type coolants are only just capable of giving an acceptable performance, the chip size calculated as follows is considered, (see fig. 1) which presents the scheme of grinding wheel face wear during the test.

Test results Nos. 81, 86, 104, which are repeats of soluble oil METOL 77, show that the initial loss on the wheel leading edge (B) to form alpha the approach angle is 0.2 ins. (This figure is not shown on the summary of results included in this report).

Using this 0.2 ins. value of alpha base and the standard test conditions the maximum depth of cut (E) which is seen by the active grits is calculated thus (see fig. 1).

$$E = F \tan \text{alpha} = F \times \frac{D}{B}$$

then for the tests numbers 81, 86, 104:

$$E = 0.042 \times \frac{0.001}{0.200} = 0.00021 \text{ ins.}$$

The benefit of a large E will be evident when a change in wheel diameter is considered. (See formula). The dimensions of E is controlled by two main factors:

1. The wheel diameter
2. The effective depth of cut.

When the condition of any test is changed on application of the test results to a production machine it is necessary to maintain the chip size to the maximum or less than maximum calculated when tested, this can be condensed, to the following rules.

Rule 1

When a grinding wheel to be used for production is larger in diameter than the wheel tested then, L the arc of contact length or underformed chip length must be made equal to that found to be maximum at test. This is done by reducing (E).

Rule 2

When the production wheel is smaller than the test wheel then L must be changed to retain the E value found by test.

It can be seen from the above rules that no value for chip dimensions are used which are greater in any respect than the values proved by tests.

The E = 0.00021 achieved when using METOL 77 is the highest value achieved using soluble oil coolants, if the production machine has a wheel of 15 ins. diameter the arc of contact must be made constant and equal to or less than that proved by the test wheel and is calculated as follows:

L = the arc of wheel/work contact (or the underformed chip length)

$L = \sqrt{E \times \text{wheel diameter}}$ (close approximation)

$L^2 = E \times$ wheel diameter

For the test wheel

$L = \sqrt{0.00021 \times 7} = 0.04098$ ins. or (0.041) ins.

To retain this L value when a 15 ins. diameter wheel is used E must be adjusted to $0.0021 \times \frac{7}{15} = 0.0001$ ins.

From the above E value which is the maximum plunge infeed for form or cylinder grinding using the full grinding wheel face it will be evident that it is futile to expect a grinding machine operator to carry out infeed adjustments, on standard machines to less than one tenth of a thou, hence when using any of the tested soluble coolants or grinding wheel specifications to grind EPK31 a wheel diameter greater than 15 inches will result in failure to produce good ground surfaces. This is not so when using straight oil coolants, the tests have shown the E value is increased. Consider in detail the reason for this increase, the grinding wheel remains constant, the force necessary to break the wheel face down, is constant, hence if the wheel is able to achieve a higher penetration when using straight oil coolant the force necessary for grit penetration must have been reduced. This is reflected in the higher E value, or chip size, the breakdown value remaining constant a further rule is as follows:

When a coolant is more efficient the E value will increase provided the porosity of the wheel is adequate to accommodate the larger chip and volume of metal removed per alpha breakdown will increase.

Comments and calculations for the tests made on straight oil type coolants

The product Fletcher Miller 800 achieved 260 sq.ins. f surface area ground. This sample was fairly high viscosity, the paper filter in the Philips clarifier would not pass this coolant. The use of the MSE centrifugal equipment was necessary, due to the high viscosity when a part was finish ground a high coolant loss rate was suffered due to the thick film of coolant carried away on the finished part.

The coolant which proved best to date is Translube 150 which achieved 231 sq.ins. of area ground, closely followed by Translube 50 and 200, all supplied by the Meteor Oil Co. Ltd. These achieved 213 sq. ins. as did the Edgar Vaughan Evco RB/SC, 300 and Metol 2200 Plus 204 sq.ins. The temperature of the workpiece tends to increase when using oil type coolant and it is interesting to note from the test results included in Appendix A, under remarks, where the efficiency of the coolant is high workpiece temperature is lower and a less efficient coolant results in higher workpiece temperature.

To allow the work carried out to date to be used, a detailed calculation of the coolant which achieved best results using the standard test equipment is presented.

The coolant is Translube 150 a reproduction of the test result sheet is shown Fig. 2.

Calculations for Test No. 134. Surface grinding.

The test piece material EPK 31 (Nickel chrome alloy Henry Wiggins)
The grinding wheel specification Carborundum 5A-60-I8-V50 grinding wheel size 7 ins. diameter $^3/_4$ ins. wide.
Grinding conditions: See Fig. 1.
Depth of cut (D) = 0.001 ins. Table speed (V) = 65 ft. per minute
Gross feed (F) = 0.042 ins. per table stroke
The coolant Metior Oil Cos Translube 150.
General Purpose Cutting Oil
Surface area ground to stabalize alpha = 9.27 sq.ins.
Loss on wheel face at alpha stable = 0.100 ins. = (B)

$$\text{Tan alpha} = \frac{D}{B} = \frac{0.001}{0.100} = 0.01 = 0^\circ\ 34'$$

$$E = F \tan \text{alpha} = F\frac{D}{B} = 0.042 \times 0.01 = 0.00042 \text{ ins.}$$

$$L = \sqrt{E \times \text{wheel diameter}} = \sqrt{0.00042 \times 7} = 0.053 \text{ ins.}$$

See Talisurf trace of alpha Fig. 3 showing D.B.E.F.L.T.V. and M.
The surface area ground between each wheel face loss or wear is approximately 23 square inches. This loss is given the letter A (Fig. 1) and the area ground provides the data on which form and cylinder grinding wheel prediction is made, in the case being considered Test 134.

The value of E is 0.00042 ins. This is the thickness of metal which is seen by the grits on the hypotenuse of alpha and the true area ground by these active grits is proportional to surface ground x $\frac{D}{E}$ as shown in scheme in Fig. 4.

For test 134

Actual area ground per alpha breakdown surface area ground (see test result sheet fig. 2).

= 23 square inches.

E = 0.00042 D = 0.001

$$23 \times \frac{0.001}{0.00042} = 54.76 \text{ sq.ins.}$$

This calculation giving 54.76 sq.ins. is the surface area which can be ground at 0.00042 ins. depth of cut using a 0.100 ins. of wheel width which is 7 ins. diameter. A wheel width which is a multiple of the above will remove a proportional area of metal, i.e. 1.000 ins. wide would cover 547.6 sq.ins. Care should be taken when calculating the expected performance of a wheel face to allow for any weak sections, i.e. the edges of the wheel, allow in the test case 134. The 47.6 sq.ins. for wheel edge weakness, leaving 500 sq.ins. for a 1.000 ins. wheel face width. A further adjustment must be made if the wheel diameter is changed from the 7 ins. as tested, consider a 15 ins. diameter cylinder grinding wheel.

Rule 1 above applies i.e. E is reduced to maintain L(chip length) constant, as follows:

$$\text{Now } E = \text{original } E \times \frac{\text{original diameter}}{\text{new diameter}}$$

$$= 0.00042 \times \frac{7}{15} = 0.0002 \text{ ins.}$$

The maximum depth of cut to maintain chip size not greater in any dimension than that proved by the test is 0.0002 ins. This condition will also maintain T (Fig. 1) constant, and the maximum grit penetration M will not increase.

The larger diameter wheel will present a proportionally larger number of active grits, which will be called upon to cut a reduced number of times, for 15 ins. diameter wheel this will be as 7 the original wheel is to be 15, the new wheel. This will extend the grit life in this ratio which will give a surface area ground for a 1 inch wide wheel. 15 ins. diameter. $500 \times \frac{15}{7} = 1070$ sq.ins.

This area of 1070 sq.ins. is based on an E value of .00043 which was reduced to maintain L constant. The effect of this E adjustment will be to increase wheel face life by a ratio or slightly more than as 2 is to 1, which results in a total surface area which may be ground 2140 sq.ins.

Calculations for Coolant Test (Continued)

The following calculations are made for the second best coolant performance which achieved 213 sq.inches. There were 3 results with similar area ground and the E.L. and total area ground using a 15 inches diameter wheel 1 inch wide will apply to the Translube Coolants Test No. 125 was for Edgar Vaughan EVCO RB/SC 300.

Calculations

Loss of wheel face to stabilize alpha B = 0.130 ins. depth of cut
Depth of cut D = 0.001 ins.

$$E = F \tan \text{alpha} = F \text{ Tan } \frac{D}{B}$$

$$= 0.042 \times \frac{0.001}{0.130} = 0.00032 \text{ ins.}$$

$$L = \sqrt{E \times \text{wheel diameter}} = \sqrt{.00032 \times 7} = \sqrt{.00224} = 0.0475 \text{ ins.}$$

The above is the chip size as seen by the 7 inches diameter wheel. The total area ground by the grits on the hypotenuse of the alpha angle is

$$213 \times \frac{D}{E} = 213 \times \frac{001}{00032} \quad 709 \text{ sq.ins.}$$

Total area ground by a row of grits 0.130 ins. wide and round the circumference of a 7 inch diameter wheel (E depth of cut = 0.00032 inches =

Average work done between each failure

$$= 9.27 \text{ sq.ins.} \quad \text{This time the ratio of } \frac{D}{E} = 9.27 \times 3.125 = 28.68 \text{ sq.ins.}$$

Now using a 15 inch diameter wheel

E must be reduced to $0.00032 \times \frac{7}{15}$ inches. .00015 inches the increase in grit life at this reduced loading will just exceed a ratio of 2 to 1, showing 28.68 x 2 = 57.36 sq.ins. This will again increase by the number of grits round the wheel to:

$$57.36 \times \frac{15}{7} = 108.5 \text{ sq.ins.}$$

This is for a wheel width of 0.13 inches. The area which would be ground by a 1 inch wide wheel would be:

$$108.5 \times \frac{0.9}{0.13} = 750 \text{ sq.ins.}$$

The reduction of the wheel width from 1 inch to 0.9 in. is to allow for wheel corner weakness.

Note 3

The development of equipment for analysing the induced surface residual stress due to grinding is continuing and confidence is felt that this equipment and the technique for its use will be ready when it is needed at the completion of the grinding wheel and coolant tests.

Note 4

The contamination of the material EPK 31 by coolant addatives such as sulphur may for some particular applications be undesirable to ensure freedom from any contamination. A spectro analysis of a sample from the test piece surface after grinding is to be included in the final test programmes.

Reference

The addresses of the suppliers of the coolants described in this appendix are:

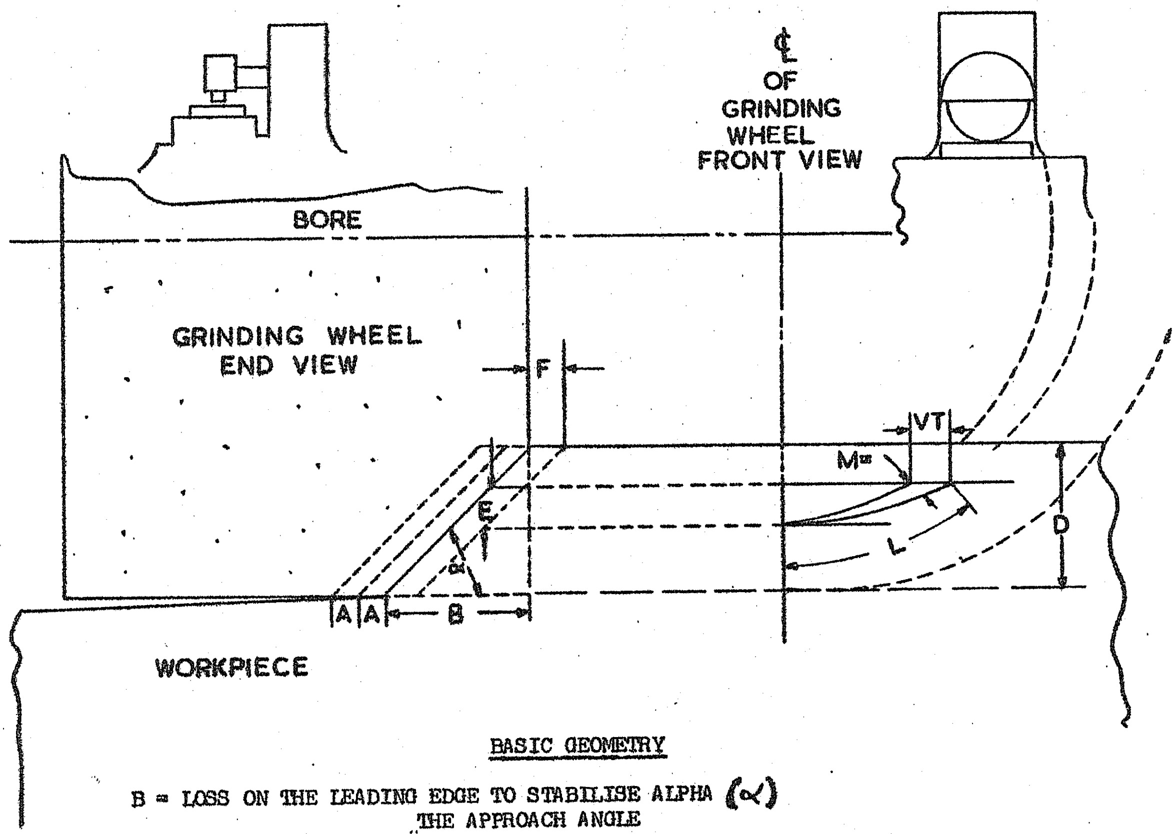
Metior Oil Co.,
Poplar Road,
Dorridge, Solihull, Warwickshire.

Fletcher Miller Ltd.,
Alma Mills,
Hyde, Cheshire.

Carborundum Company Ltd.,
Trafford Park,
Manchester, 17.

Edgar Vaughan and Co. Ltd.,
Legge Street,
Birmingham, 4.

SCHEME OF THE LEADING EDGE SELF ADJUSTMENT
OF A SURFACE GRINDING WHEEL



BASIC GEOMETRY

B = LOSS ON THE LEADING EDGE TO STABILISE ALPHA (α)
THE APPROACH ANGLE

D = THE APPLIED DEPTH OF CUT. E = SELF ADJUSTED DEPTH OF CUT PER GRIT.
L = LENGTH OF WHEEL WORK ARC OF CONTACT = CHIP LENGTH (UNDERFORMED)
T = TIME IN MINUTES FOR A GRIT TO ROTATE L LENGTH OF ARC.
V = WORK TABLE SPEED IN INCHES PER MINUTE.
M = THE MAXIMUM POSSIBLE GRIT PENETRATION.
A = THE LOSS OF GRINDING WHEEL FACE FOR EACH UNIT
VOLUME OF METAL REMOVED FROM THE WORKPIECE.

Fig. 1

FIG 2

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EXPERIMENTAL RECORD

TEST No 134
AND REPEATS

TEST PIECE MATERIAL. EPK 31.
NICKEL CHROME ALLOY. (HENRY WIGGINS)

ALL TEST CONDITIONS ARE STANDARD
THE GRINDING WHEEL SPECIFICATION
CARBORUNDUM. 5.A.60. I.8. V50 (RUBY)

EXPERIMENT: TO EVALUATE COOLANT EFFICIENCY

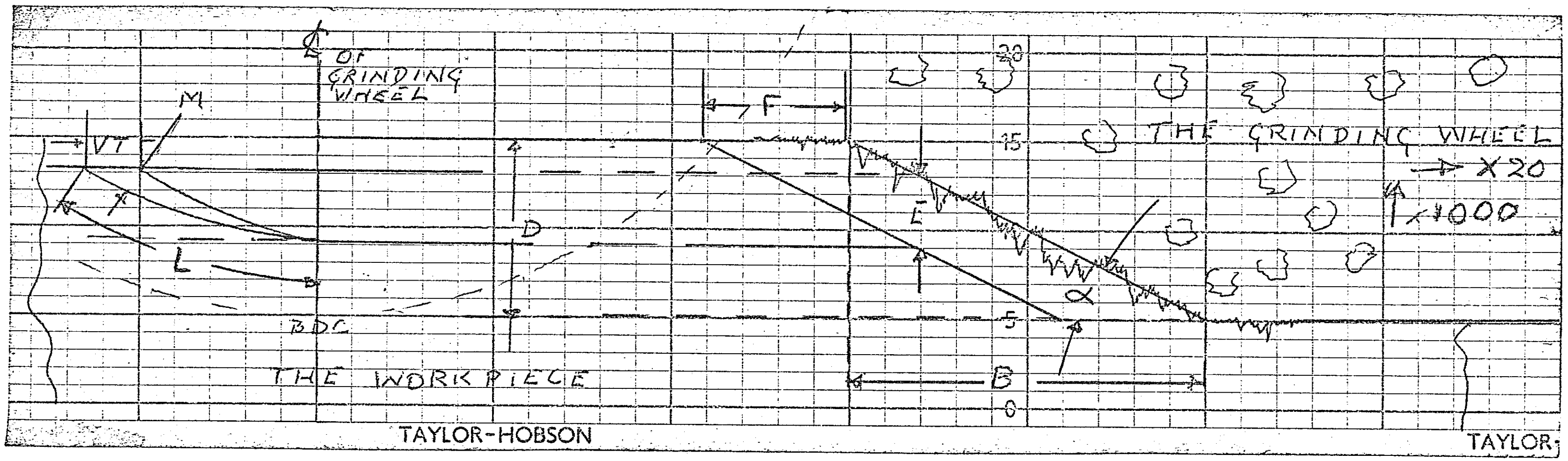
NAME J. PURCELL

REMARKS: COOLANT METEOR OIL Co. TRANSLUBE 150

DATE APRIL 1964

SURFACE AREA GROUND SQ INS	WHEEL FACE WIDTH INS	WHEEL FACE WEAR INS		SURFACE AREA GROUND SQ INS	WHEEL FACE WIDTH INS	WHEEL FACE WEAR INS		SURFACE AREA GROUND SQ INS	WHEEL FACE WIDTH INS	WHEEL FACE WEAR INS				
0	·750	0		101·97	·370	·070		198·90	·100	·060				
4·23	·650	·080		106·2	"	NONE		203·94	"	NONE				
9·27	·630	·020	*ALPHA	111·24	"	NONE		218·17	"	"				
13·5	"	NONE	STABLE	115·47	"	"		213·21	"	"				
18·54	"	"		120·51	"	"		217·44	"	"				
22·77	"	"		124·74	·280	·090		222·48	·020	·080				
32·04	"	"		129·78	"	NONE		226·71	"	NONE				
37·08	·580	·070		131·01	"	"		231·75	0	020				
41·31	"	NONE		139·05	"	"								
46·35	"	"		143·28	"	"		END OF TEST						
50·58	"	"		148·32	·240	·040		2 REPEATS SHOW SIMILAR RESULTS						
55·62	"	"		152·55	·200	·040		SEE TAYLOR TAYLOR HOBSON TALISURF TRACE						
59·82	·510	·070		157·59	"	NONE		OF APPROACH ANGLE.						
64·89	"	NONE		161·82	"	"								
69·12	"	"		166·86	"	"								
74·16	"	"		171·09	"	"								
78·39	"	"		176·13	·160	·040								
83·43	·440	·070		180·36	"	NONE								
87·66	"	NONE		185·40	"	"								
92·7	"	"		189·63	"	"								
96·93	"	"		194·64	"	"								

Taylor Hobson Talisurf Trace of the leading edge of the grinding wheel showing stable alpha angle and the maximum chip proportions.



V = Work speed = 65 ft/min. T = Time for a grit to rotate arc L.
D = The applied depth of cut = 0.001 ins.
B = Wear on the leading edge of the wheel to form alpha = 0.100 ins.
F = Cross feed per table stroke = 0.042 ins.
E = Maximum effective grit depth of cut = 0.00042 ins.
L = Underformed chip length = 0.053 ins.
Work piece material nickel chrom. alloy by Henry Wiggins E.P.K.31.
Coolant Meteor Oil Company Translube 150 General Purpose Cutting Oil
Grinding wheel specification carborundum 5A-60-I8-V50.
Grinding wheel size 7 ins. diameter $^3/_4$ ins. wide.

Figure 3

SCHEME OF ACTUAL AREA SEEN BY THE GRITS ON THE APPROACH ANGLE ALPHA

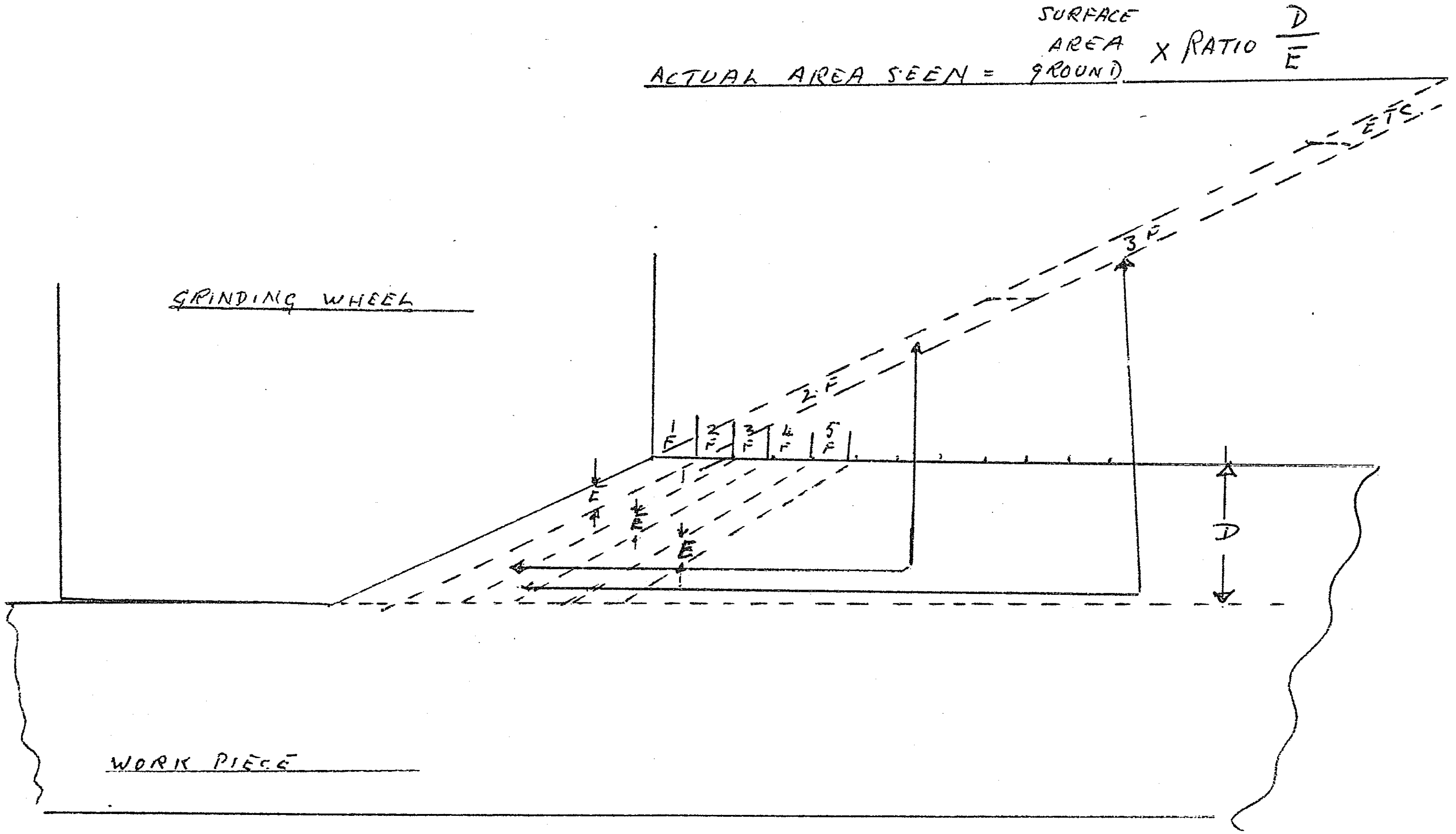


FIG 4

TEST No 125

FIG 5.

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EXPERIMENTAL RECORD

EXPERIMENT: COOLANT:- EDGAR VAUGHAN EVCO RB/SC 300
WHEEL - 5A60-I8-V50

NAME S. C. Drinkwater.

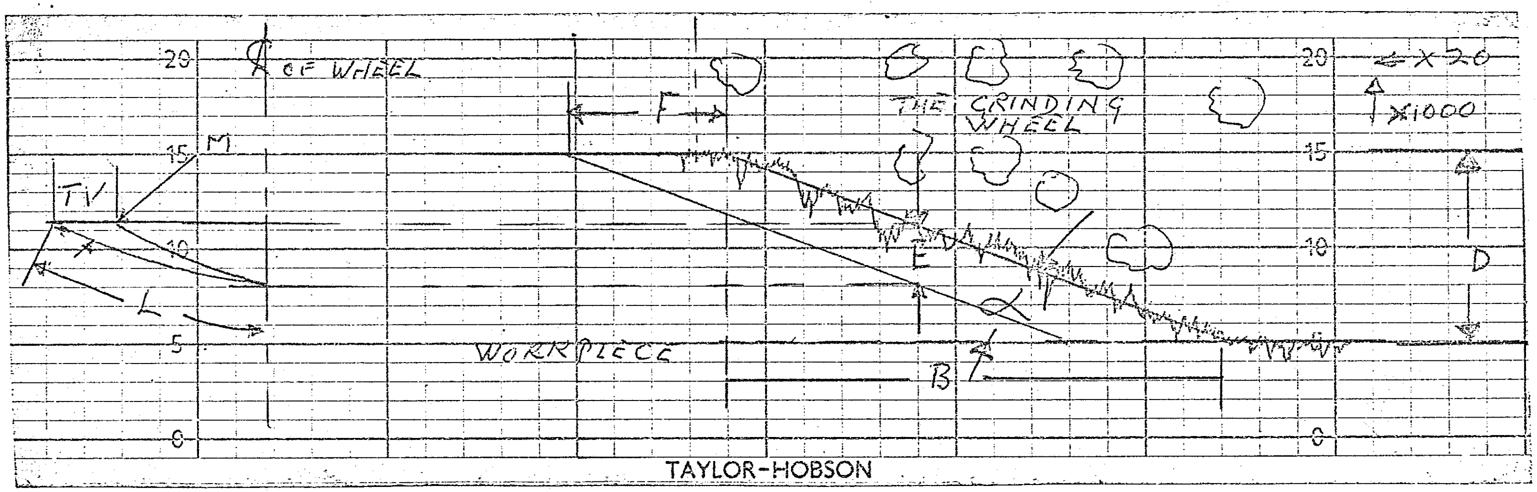
REMARKS: MATERIAL - EPK - 31.

DATE

SURFACE GROUND	AREA INS²	WHEEL	WIDTH INS	WHEEL	LOST INS			
	0		·750		0			
	4·23	}	·680		·070			
	9·27	}	·620		·060			
	13·5	}	·620		–			
	18·54	}	·620		–			
	22·77	}	·600		·020			
	27·81	}	·570		·030			
	32·04	}	·570		–			
	37·08	}	·550		·020			
	41·31	}	·550		–			
	46·34	}	·530		·020			
	50·58	}	·530		–			
	55·62	}	·480		·050			
	59·85	}	·480		–	WORKPIECE GETTING		
	64·89	}	·450		·030	HOT		
	69·12	}	·450		–			
	74·16	}	·450		–			
	78·39	}	·400		·050			
	83·43	}	·400		–			
	87·66	}	·360		·040			
	92·7	}	·350		·010			

SURFACE GROUND	AREA INS²	WHEEL	WIDTH INS	WHEEL	LOST INS
	96·93	}	·350		–
	101·97	}	·320		·030
	106·2	}	·300		·020
	111·24	}	·300		–
	115·47	}	·300		–
	120·51	}	·260		·040
	124·74	}	·250		·010
	129·78	}	·250		–
	134·01	}	·230		·020
	139·05	}	·200		·030
	143·28	}	·200		–
	148·32	}	·200		–
	152·55	}	·170		·030
	157·59	}	·170		–
	161·82	}	·150		·020
	166·86	}	·150		–
	171·09	}	·130		·020
	176·13	}	·100		
	180·36	}	·100		–
	185·40	}	·100		–
	189·23	}	·080		·020
	194·67	}	·080		

Taylor Hobson Talisurf trace of stable alpha angle when using Edgar Vaughan Evco RB/SC 300 Oil Coolant.



The grinding conditions are constant.
The grinding wheel specification is
Carborundum 5A-60-I8-V50.

B = 0.130 ins. Alpha = $0^{\circ}26'$
E = 0.00032 ins. L = 0.0475 ins.

Figure 6