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The College of Aeronautics
Cranfield

Department of Production and Industrial Administration

Machine Tools Laboratory

The application of the numerical method of evaluating the efficiency of grinding wheels and coolants for grinding Nickel Chromium Alloy to specification E.P.K.31 (Henry Wiggin Ltd.)

also

The evaluation of surface residual stresses induced into the material by grinding

Progress Report No. 2.

by

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SUMMARY

The material is presenting phenomena which though met and recognised previously the significance to the grinding process was on these previous occasions not critical. With this material, instead of a wheel life variation of 0.5% maximum there can be 30% to 40% reduction in expected wheel life. A detailed explanation of this element of wheel face life will be included in the final report when repeatable test results to substantiate the theory will be available. The test on soluble type coolants have not as yet been as successful as one would have hoped and it is intended to ask the supplier if an improvement can be made from the knowledge gained by the test here reported. The workpiece in all cases where soluble coolants were used remained cool, but with the very limited number of oil coolants some temperature rise in the workpiece is experienced.

This temperature rise is not very critical if the workpiece is of sufficient surface area to allow cooling to take place more rapidly. The test piece used in the laboratory is 2.5 ins x 6 ins. long, and is now 0.5 ins. thick (originally 1.0 ins).

The calculation is made and included for wheel specification

Carborundum 5A 46/54 G.8 V.50 using Fletcher Miller Product

M7/63

This is the first result which has given a performance life long enough to make these calculations and is included to enable any firm who must use results immediately to make use of our work. While not wishing to depreciate this product or to appear over enthusiastic I shall be surprised if improved life is not achieved but this fuller calculation will allow further appreciation of the numerical methods we are using.

Introduction

The material EPK.31 is an advanced Nickel Chromium Alloy designed to work at high temperatures and is very resistant to corrosion.

The chemical composition as supplied by Henry Wiggins Ltd., is as follows.

20%	Cr.	14% Co.	2.5 Ti	0.5 Al.
5%	Nb	4.5 Mo.	BAL Ni.	

The numerical method which is used to evaluate the efficiency of grinding wheels and coolants has been developed and proved at The College of Aeronautics and in a wide range of industries. The results of an evaluation enables the maximum chip size to be stated and the rate of wear on the grits when working at the maximum or any load less than maximum.

The cause of chip size limitation may be diagnosed and adjustments to wheel specification made on the basis of the measured efficiency. This also applies to coolants. These can be varied, while the wheel specification remains constant and wheel face life will then reflect the efficiency of the coolant.

Calculations for Test 46

Length of base of alpha = 0.180 ins.
Depth of cut (applied) = 0.001 ins.
Tan alpha = $\frac{.001}{.180}$ = .005 = 0° 17'

Effective maximum depth of cut as seen by any grit

(E = F crossfeed x tan alpha) =

.042 in. x .005 = 0.00021 ins.

L = underformed chip length

$= \sqrt{E \times \text{wheel diameter}} = \sqrt{.00021 \times 7} = \sqrt{.00147}$

L = .03833 ins.

Average wear on A per vol removed

= 0.053 in. for 0.016 cubic in. removed

No. of breakdowns on A = 7.0

Area ground to stabilise B = 15.6 sq. in.

Area ground for failure of A = 7 x .016 cu. in.

or 7 x 16 sq. ib. ~ 112 sq. in.

Area which is actually ground by B length to A failure = 560 sq.in.

Area ground by .180 B length = .80 sq. in.

Area which can be ground at 0.0002 E for 1 inch wheel face width

$= \frac{1.000 - 0.1}{.180} = \frac{400}{}$ sq. in.

Reduce this by 20% to allow for the wheel edge weakness then you can expect a 1" wide wheel to grind 320 sq. ins. of surface area of work at 0.0002". Plunge cut before wheel face failure.

RESULTS SHEET NO.

COOLANT SELECTION TEST

COOLANT:

Surface area ground sq. ins.	0	15.6	36.3	43.9	56.0	68.1	88.2
Width of wheel lost in ins.	0	0.180	0.060	0.030	0.060	0.040	0.120
Width of wheel left in ins.	0.740	0.560	0.500	0.470	0.410	0.370	0.250
Surface finish micro ins. CLA		7.5	7.5		7.5		7.5

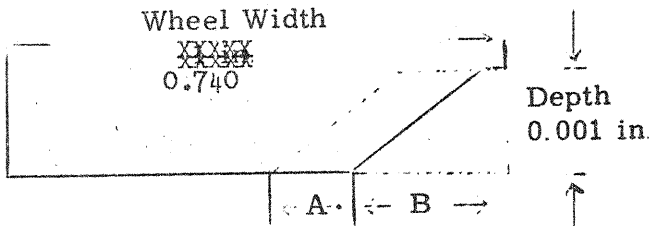
15.6 * = work done to stabilise approach angle α and wear in Zone B
165 sq. in.* the surface area at constant depth of 0.001 in. taken as one unit volume of stock removed.

Summary of results

Loss on B to point	=	0.180 in.
Loss on A per unit volume of stock removed	=	0.054 in.
Total volume of stock removed for tests	=	0.1246 cub. in.
Loss of wheel in Zone B	=	0.00198 " "
Stock removed for loss in Zone B	=	0.0156 " "
Loss of wheel in Zone A	=	0.1245 " "
Stock removed for loss in Zone A	=	0.1088 " "
Ratio of work loss to wheel loss Zone B	=	7.9 to 1
Ratio of work loss to wheel loss Zone A	=	8.6 to 1
Number of unit volume lengths on A	=	7.2
Estimated life of wheel face in Zone B	=	0.0156 cub. in.
Estimated life of wheel face in Zone A	=	0.1088 " "
Total estimated life = Zone A + Zone B	=	0.0156 + 0.1088 cub.in.
	=	0.1244 cub. in.

Surface finish micro ins. = 7.5

E = 00021 in.
L = 0.0383 in.
alpha = 0° 17'



A = 0.053 in. B = 0.180 in.
actual life of wheel as found by actual test = 0.1250 cub. in.

SUMMARY OF RESULTS

Standard grinding conditions are:-

Depth of cut = .001 in.
Cross feed = .042 in. /pass
Table speed = 62.5 ft/min
Wheel dia. = 7 in. Wheel width = .750 in.

Material is:-

PK.31 (Henry Wiggin)

Heat treatment:-

Solution treated and age hardened

*Figures marked thus refer to wheels 1 inch wide others are $\frac{3}{4}$ ins. wide.

Introduction

The material E.P.K. 31 is an advanced nickel based alloy produced by Henry Wiggin Ltd. The material is designed to work at high temperatures and has very marked resistance to corrosion. The chemical composition of this material is

20 Cr.	14 Co.	2.5 Ti.	0.5 AL
5 N6	4.5 Mo.	Bal. Ni.	

(This information is supplied by Henry Wiggin Ltd.)

The numerical method which is used to evaluate the efficiency of grinding wheels and coolants has been developed and proved at the College of Aeronautics during a period of five years. The results of an evaluation enables the maximum chip size per active grit in the grinding wheel face to be found and the rate of wear on the grits at maximum chip or less to be stated. The effect of any coolant on maximum chip size and grit wear may also be determined.

Method

The efficiency of the available grinding wheel specification will be evaluated and any which prove to be capable of a repeatable and reasonable performance will be fully tested and its maximum metal removal rate and rate of wear calculated.

Any coolant which will give a reasonable wheel life may be used for the initial grinding wheel specification tests. Other coolants will then be compared to this initial coolant when the wheels have been evaluated.

Results of tests carried out

The coolant used initially was Shell Mex B.P. Dromuc E a soluble oil. 1 vol in 40 Vols of water, this being the only coolant immediately available. The results of tests carried out using this coolant are included in the summary sheet as tests No. 1 to 3 inclusive. No calculations are made for these tests as the life was unsatisfactory and the coolant was changed. The replacement coolant was Manchester Oil Refinery Dolphin No. 1 a grinding oil This was chosen as it had been used on Stainless Steel (REX 448) and proved excellent. Tests No. 4 to No. 12 inclusive on the summary sheets show that this coolant gave improved results and surface finishes of 8 to 10 micro inches CLA (measured at full metal removal rate and no spark out). The workpiece temperature increased to approximately 60°C during some of the tests. This led to a further coolant change Meteor Oil Companys Metol 77 soluble oil 1 vol in 10 vols water. Manchester Oil Refinery have been informed of the results of these initial tests on Dolphin No. 1. Tests Nos. 13 to 24 inclusive produced the data as included on the summary sheet. The total volume of metal removed was not significantly increased and it is not

Test No.	Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface Finish C.L.A. min.	Remarks
1	Universal WA 60 IV277608 (No. 2 White)	Shell Dromus E	Standard	-		Poor performance. Wheel face soon became washed
2	Universal C60IV277612 (No. 1 Green)	" "(1:40)	"	-		Very poor performance
3	Carborundum jDA60J5 VF BLU (Blue)	"	"	- *		Reasonable performance but test not taken far because it was obvious that the coolant was not good enough
4	Carborundum 7DA60J5 VF BLU (Blue)	Manchester Dolphin No. 1 (Neat)	"	52 for .500in wheel lost		Good performance but test not completed because it is no longer possible to obtain these wheels in this country. Compare Test 3.
5A	Universal WA60IV277608 (No. 2 White)	"	"	47		Reasonable performance. Compare Test 1.
B	" "	"	"	50		" "
C	" "	"	"	42		" "
6A	Universal WA60HV277609 (No. 3 White)	"	"	69	10	Good performance
B	" "	"	"	54		" "
C	" "	"	"	65		" "
7A	Universal WA46IV277610 (No. 1 White)	"	"	60		Tending to cut warm
B	" "Q HPE	"	"	44		" "
8A	Universal WA60HV712100 (No. 1 Brown)	"	"	61	8	Reasonable performance
B	" "	"	"	48		
9A	Universal WA60IV699342 (No. 1 Blue)	"	"	61		Tending to cut warm
B	" "	"	Table speed = 42.5ft/min	73	9.5	" "

Test No.	Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface Finish C.L.A. min.		Remarks
9C	Universal MA60IV699342 (No. 1 Blue)	Manchester Dolphin No. 1 (Neat)	Table speed = 42.5ft/min	73			Produced heat early on Did not cut very well .100" left on wheel face when test stopped
10A	Carborundum 5AV50 I Grade (Red)	"	Wheel dia.=6.5"	66 97*	8		Tending to cut hot
B	" "	"	Table speed = 42.5ft/min Wheel dia. = 6.5 in.	126 170*			Tending to cut really hot. Did not cut very well after 60 in^2. Workpiece was slowing down wheel.
11	Sulphorised Carborundum 7DA60J5 VF I LU (No. 3 Blue)	"	Standard	48 for .270 in. wheel list*			Check on Talysurf showed wheel was not cutting properly. Test discontinued.
12	Universal C60IV277612 (No. 1 Green)	"	"	18 for .260 in. wheel list			Not cutting properly. Test discontinued. Compare Test 2.
13A	Universal WA60HV277609 (No. 3 White)	Metol 77	"	52		Ø	Reasonable performance
B	" "	" (1:10)	"	61		Ø	" "
C	" "	"	"	56	7	Ø	" "
						Ø	but not as good as with Manchester Dolphin No.1. See Test 6.
D	" "	"	Table speed = 42.5ft/min	44			Not cutting very well
E	" "	"	"	36			" "

Test No.	Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface finish C.L.A. min.	Remarks
14A	Carborundum 5AV50 Probably I Grade (Red)	Metol 77	Wheel dia.= 6.5"	66 85*		Good performance. Cutting cool. Compare Test 10
B	" "	"	Table speed = 42.5ft/min Wheel dia. = 6.5 in.	66 97*	15.5	Cutting a little warm. Workpiece was slowing down wheel.
15A	Universal WA60IV277608 (No. 2 White)	"	Standard	48		Reasonable performance. Compare Test 5.
B	" "	"	"	48		" "
16A	Universal MA60IV 699342 (No.1 Blue)		Standard	61		Not cutting very well. Not breaking down. Cutting warm
B	" "	" (1:10)	"	61	5.5	" " Compare Test 9.
17A	Universal MA60HV HPE 712100 (No.1 Brown)	"	"	73		Reasonable performance but cutting a little warm. See Test 8.
B	" "	"	"	97	15	" "
18A	Extra porosity Carborundum 7A60J16 VFBP (No. 1 White)	"	"	48 97*		Reasonable performance
B	" "	"	"	48 97*		" "
19A	Extra porosity Carborundum 7A60I16 VFBP (No.1 White)	"	"	48 114*		Reasonable performance
B	" "	"	"	42 73*	9	" "
C	" "	"	"	54 73*		" "
20 A	Extra porosity Norton 38A46H12VBEP (White)	"	"	36		Cut well but short life.

Test No.	Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface Finish C.L.A. min	Remarks
	Extra porosity					
20B	Norton 38A46H12VBEP	Metol 77	Standard	30		Cut well but short life
C	" "	"	"	36		" "
D	" "	"	Table speed = 42.5ft/min	52		" "
E	" "	"	"	36	10	" "
21 A	Universal MA80JV699347 (No. 1 Blue)	"	Standard	40		Too hard or not sufficient porosity. Wheel loading but not breaking down.
B	" "	"	"	28		
22 A	Universal MA80IV699344 (No. 1 Blue)	"	"	48		" " but better than Test 21
B	" "	"	"	61		
23 A	Carborundum AA46/54 H16 VE 3	"	"	32		Cutting harshly and not very well.
B	P01 (White) Extra pos porosity. Aloxite. (Supplied by Matchless)	"	"	36		" "
24 A	Winterthur 46L417637 Vitoneva	"	"	36		Started off cutting well but deteriorated
B	(Supplied by Matchless)	"	"	48		Began to cut harshly and became a little warm.

Test No.	Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface Finish C.L.A. min.	Remarks
25 A	Carborundum 5AV50 I Grade (Red)	Metol 77	Wheel dia. = 6.5 in.	85		Good performance. Cutting cool. Repeat of Test 14
B	" "	"	" "	61		Slight slowing down of wheel by workpiece.
C	" " Extra porosity	"	" "	54	4	" "
26	Universal MA606V (Brown)	"	Standard	36		Two soft
27 A	Universal A60HV (Brown)	"	" "	56		)
B	" "	"	" "	40		) Slightly hard. Cutting hard near end of tests.
C	" "	"	" "	40		)
28 A	Norton 38A60J5VBE(White)	"	" "	36*		)
B	" "	"	" "	36*		) Reasonable performance
C	" "	"	" "	36*	7	)
29 A	Norton 38A60K5VBE(White)	"	" "	32*		)
B	" "	"	" "	32*		) Too hard
C	" " HPE	"	" "	36*	9	)
30 A	Universal MA60HV712100 (Brown)	No.1 Manchester Oil Refinery Transparent Grinding Fluid.	Standard	32		))))) Cutting well while it lasted
B	" "	"	" "	32	12	)
31 A	Universal WA60HV277609 (White)	No. 2 " "	" "	36		)
B	" "	"	" "	32		) Cutting rather harshly

Test No.		Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface Finish C.L.A. min.	Remarks
		Extra porosity					
32	A	Universal A60IP4V (Grey)	Meteor Oil Co. Metol 77	Standard	61		Grinding a little harsh but in the main cool and well
	B	" "	"	"	61		
	C	" "	"	"	56	16	
33	A	Carborundum 5A46/54 GBV50 (Red)	"	"	76		Cutting cool and well despite scatter of results. Producing just a little heat near the end of the tests and wheel showing slight hesitancy to break down when it should have done.
	B	" "	"	"	61		
	C	" "	"	"	61	8	
34	A	Carborundum 5A60I8V50 (Red)	"	"	73		Good performance
	B	" "	"	"	73	6	
35		Carborundum 5A60I8V50 (Red)	"	"	-		Material - 582 Case hardened to 750 - 800 V.P.N. Test to determine whether porosity is at fault in this wheel
36		Carborundum 5A60J8V50 (Red)	"	"	32		
37		Carborundum BA60K5 BLU (Blue)	"	"	(36)		Test discontinued because wheel too hard
38		Carborundum BA60J5VF BLU (Blue)	"	"	76		Good performance
39		Carborundum AA60H5VF8 (White)	"	"	48		Reasonable performance

Test No.	Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface Finish C.L.A. min.	Remarks
40	Carborundum AA60J5VFE (White)	Meteor Oil Co. Metol 77	Standard	52		Reasonable performance
41	Carborundum AA60K5VFE (White)	"	"	(32)		Test discontinued because wheel too hard.
42	Universal MA60HV322607 (Brown)	No. 2 Manchester Oil Refinery Solumor NCl (1:30)	"	32	11	Poor performance
43	Extra porosity Universal A60IP4V(Grey)	"	"	20		Poor performance
44	Carborundum 5A 46/54V50 (Red)	"	"	32		Poor performance
45	Carborundum 5A 46/54G8 V50 (Red)	Manchester Oil Refinery Suprumor Special EP	"	43		Reasonable performance
46	Universal MA60HV322607 (Brown)	No. 2 (1:30)	"	(36)		Test discontinued because of poor performance
47	Universal MA60HV 322607 (Brown)	No. 2 Edgar Vaughan Hocut G	"	36		Poor life but cutting cool and well
48	Carborundum 5A 46%54 6BV50 (Red)	(1:60)	"	32		Poor life
49	Carborundum 5A 46/54 G8 V50 (Red)	Edgar Vaughan Hocut 237 (1:25)	"	(12)		Test discontinued because of poor performance
50	Carborundum 5A 46/54 G8 V50 (Red)	Edgar Vaughan Hocut 3210 (1:10)	"	61		Good performance
51	Universal MA60 HV 322607 (Brown)	No. 2 "	"	56		Good performance
52A	Universal MA60 322607 (Brown)	No. 2 Meteor Oil Co. Metol 77 EP	"	56		Good performance

Test No.	Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface Finish C.L.A. min.	Remarks
52 B	Universal MA60 322607 (Brown)	No. 2 Meteor Oil Co. Metol 77 EP (1:10)	Standard	56		Good performance
53	Carborundum 5A 46/54 G8V50(Red)	"	"	61		Good performance
54	Universal A60IP4V(Grey) Extra Porosity	"	"	24		Poor performance
55	Carborundum 5A 46/54G8 V50 (Red)	Fletcher Miller Products M16/62	"	40		
56 A	Universal MA60HV322607 (Brown)	No.2 (1:50)	"	32		
B	" "	"	"	40		
57 A	Universal MA60HV 322607 (Brown)	No. 2 Fletcher Miller Product M16/62	"	56		
B	" "	)1:10)	"	52		
58	Universal MA60HV322607 (Brown)	No. 2 "	"	56		
59	Carborundum 5A 46/54 G8V50 (Red)	Sternol Sternopal(1:40)	"	44		
60	Universal MA60HV322607 (Brown)	No. 2 "	"	40		
61	Universal MA60HV322607 (Brown)	Fletcher Miller No.2 Swift Cutting Oil No.4 (Neat)	"	52		
62	Universal A60IP4V (Grey) Extra porosity)	"	"	40		
63 A	Carborundum 5A 46/54 GBV50 (Red)	"	"	61		

Test No.	Wheel Type	Coolants	Grinding Conditions	Surface Area Ground in^2	Surface Finish C.L.A. min.	Remarks
63 B	Carborundum 5A 46/54 GB V50 (Red)	Fletcher Miller Swift Cutting Oil No. 4 (Neat)	Standard	48		
64	Carborundum 5A 46/54 GB V50(Red)	Fletcher Miller Product M.7/63(Neat)	"	125	7.5	
65	Universal MA 60 HV 322607 (Brown)	No. 2 "	"	92		
66 A	Carborundum 5A 46/54 GB V50 (Red)	Meteor Oil Co. Metol 77 EP (A)	"	64		
B	" "	"	"	56		
67	Carborundum 5A 46/54 GE V50 (Red)	Plus Gas Formula C (Neat)	"	64		
68	Universal MA60HV 322607 (Brown)	No. 2 "	"	36		
69	Universal MA60HV 712100(Brown)	No. 1 "	"	44	(10)	