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THE UNIVERSITY OF MICHIGAN
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Final Report

MACHINABILITY OF RAILROAD-CAR AXLES

L. V. Colwell
K. H. Moltrecht
J. Koivula
J. C. Mazur

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BETHLEHEM STEEL COMPANY
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ABSTRACT

The results, as shown in Table I, indicate that the average tool lives of four of the heats are close to the median at approximately four cuts. There are two heats which show greater variation from the mean. The average tool life, six cuts, for Heat Number A is well above the mean, whereas Heat Number B, at two cuts, had a tool life well below the mean.

In the preliminary work on the axle bodies, the Apex tools showed an average tool life somewhat above that of the Pullman Standard tools. The axle bodies appeared to show the same machining qualities encountered on the journals, as shown in Tables I and III.

INTRODUCTION

The machining behavior of two representative axles from each of six heats has been determined. Tests were carried out on standard AAR 6-in. x 11-in. plain bearing axles. Machinability was measured by tool life under journal finishing conditions.

TEST CONDITIONS

The axles were first cut into three pieces of approximately equal length, marked as shown in Fig. 1, and the required center holes were drilled. To assure a better grip on the headstock end of the journal, the rough forged surface at this end was removed by turning. Before taking the first roughing cut, all eccentricity and scale were removed from the journal by taking a skin cut.

The machinability tests were conducted on a 22-in. x 48-in. Model CM Monarch Engine Lathe equipped with a Reliance VR Variable Speed Drive. The work was held in a four-jaw independent chuck on the headstock end and on a dead center at the tailstock end.

Cutting tools used for the roughing cuts were of sintered carbide, Kennametal K-6 grade, which were ground with radii to conform to the radii of the journal. The finishing tools were of high-speed steel. Two styles of finishing tools were supplied. One set, used only during the preliminary work, were standard Apex tools used for finish-turning journals at the Johnstown Plant of the Bethlehem Steel Company. The second set, furnished by the Pullman Standard

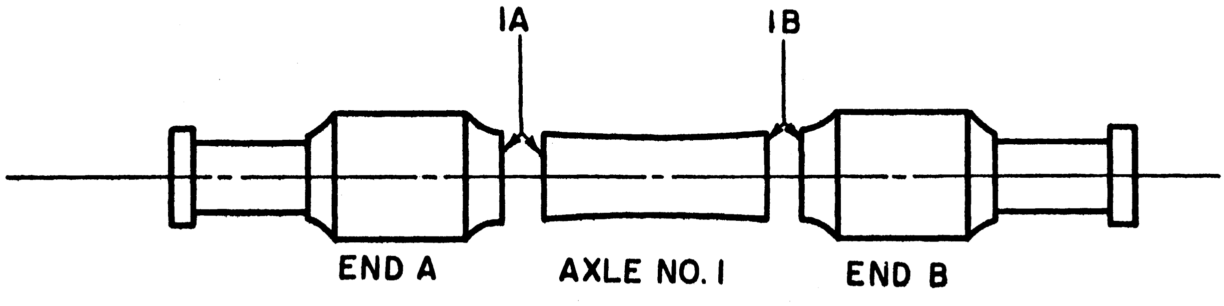
Company, consisted of two forged shanks on which were brazed high-speed steel tips. Identified as PH and P5, these latter tools were used for all the finish-turning tests on the journals.

The Pullman Standard finishing tools were reground on the face and flank after each test, maintaining correct tool shape and angles as specified by the template, sketched in Fig. 2. The tools were then hand-stoned to obtain a good surface finish and to correct minor imperfections in their contour. In the production set-up on the axle turning lathe, the tool is positioned with a back rake of approximately 5° by means of wedges or shims. This arrangement could not be used in these tests and accordingly the 5° rake angle was ground on the tool as shown in Fig. 3. Prior to the first roughing cut on each journal, the carbide roughing tools were reground using a diamond wheel and by grinding on the face only.

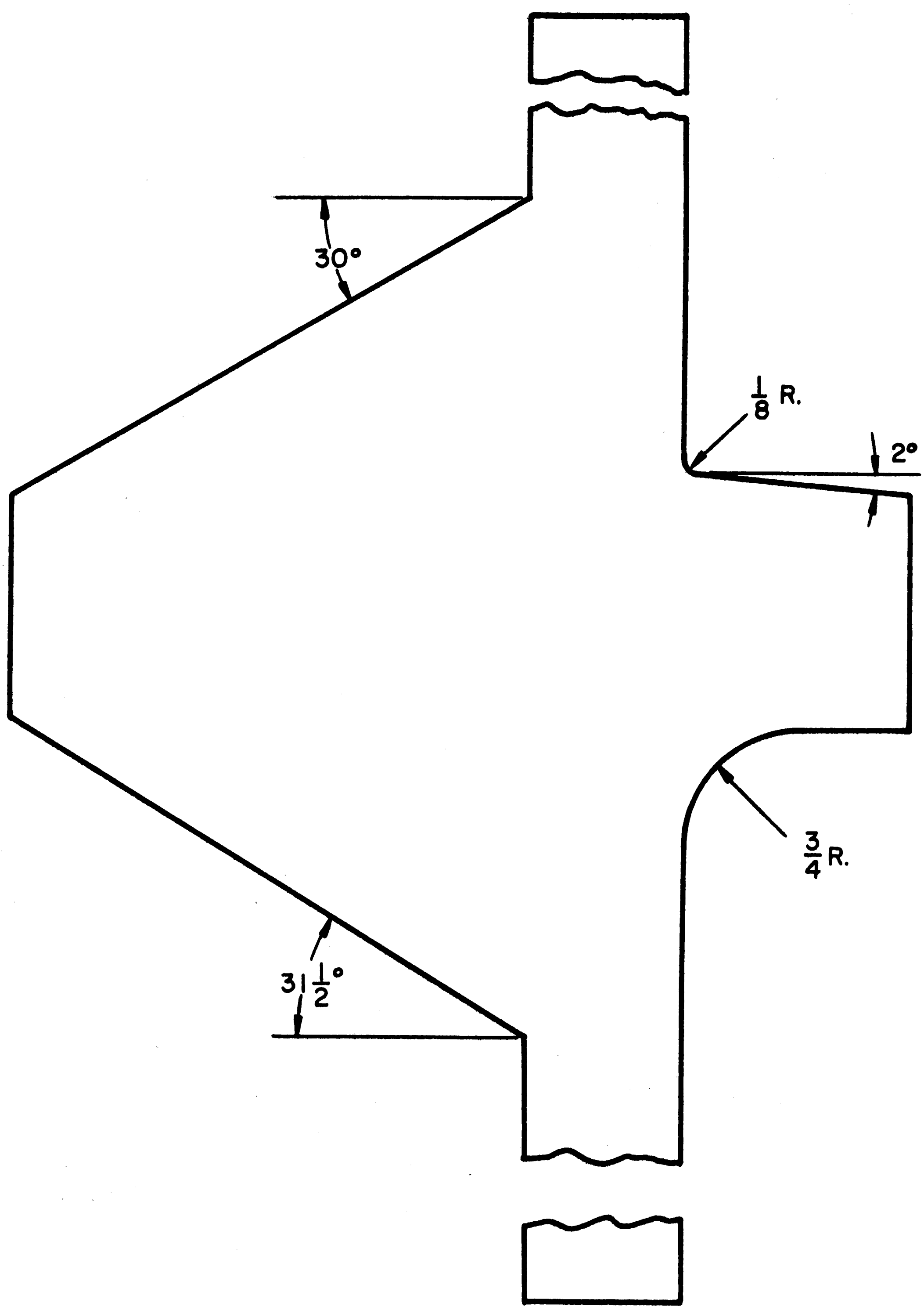
The tools were set with the cutting edge 1/4 in. to 5/16 in. above the

TABLE I

Heat	Axle No.	No. of Journals Tool Life	Surface Finish		Average Tool Life for Heat
			Start	Finish	
A	1	5	100/120	130/150	6
	2	7	100/120	110/120	
B	3	1.5	130/150	150/170	2
	4	2.5	130/170	130/170	
C	5	4.5	95/115	115/140	4.25
	6	4	100/115	150/165	
D	7	4	120/130	130/140	3.75
	8	3.5	105/115	150/165	
E	9	3.5	120/140	160/185	3.25
	10	3	110/125	150/160	
F	11	4	90/120	150/170	4.25
	12	4.5	120/140	150/160	

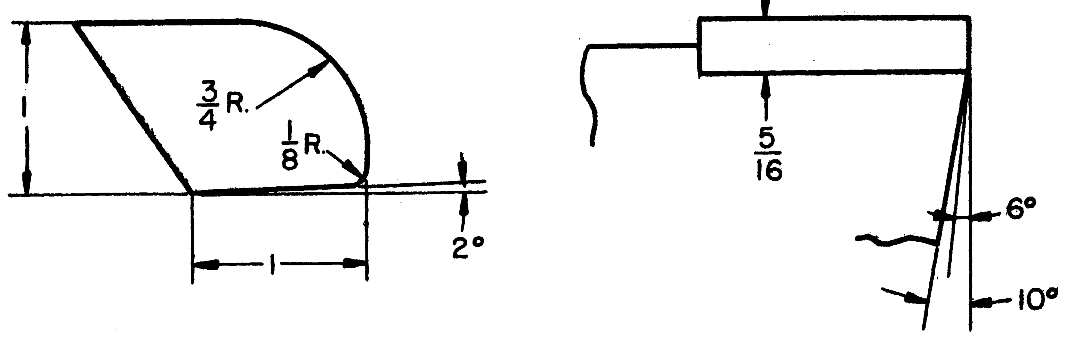


AXLE MARKINGS
FIG. I

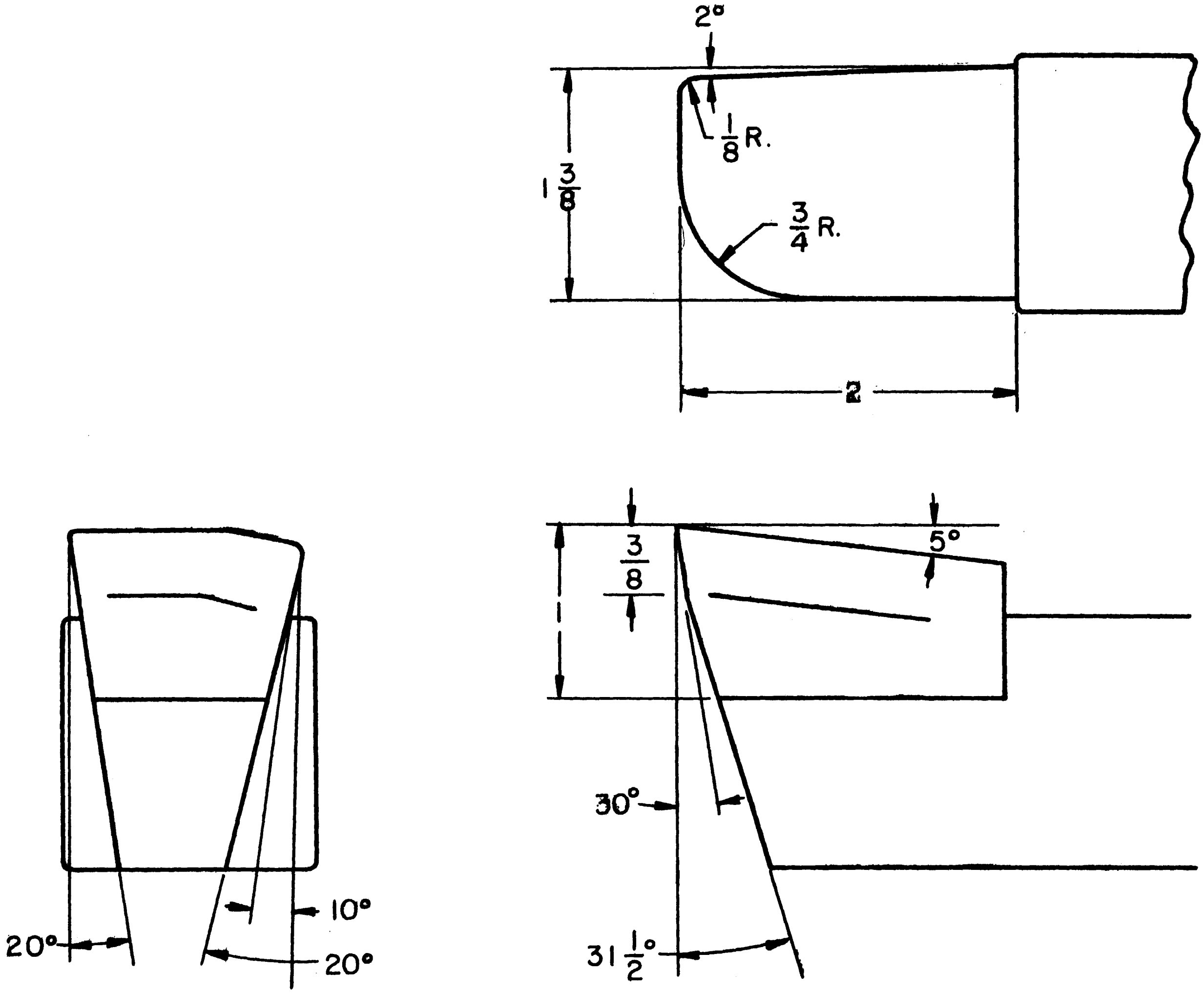


TEMPLATE FOR GRINDING TOOLS P5 & PH

FIG. 2



A-TOOL SHAPE-CARBIDE ROUGHING TOOL



B-TOOL SHAPE -H.S.S. FINISHING TOOL

FIG. 3

centerline of the journal and with an overhang of 2 in. Final adjustments to the angular position of the tool, relative to the work, were made on the basis of observations of the surface finish and the chip formation. In all cases the roughing tools were set to cut on the centerline of the journal. The cutting conditions, summarized in Table II, also corresponded to shop practice.

TABLE II

Type of Cut	Cutting Conditions					Method of Feeding		
	Cutting Tool Material	Cutting Speed, fpm	Feed, ipr	Depth of Cut, in.	Cutting Fluid	Infeed at Start of Cut	Turning 3/4-in. Radius	Turning Bearing Surface
Roughing	Kennametal K-6 Carbide	315	.043	.015	Soluble Oil (Purosol 10) 10 water 1 oil	Manual	Manual	Power
Finishing	H.S.S.	55	.063	.015	Soluble Oil (Purosol 10) 10 water 1 oil	Manual	Manual	Power

TEST PROCEDURE

The geometry of the finish-cutting tools (Fig. 3) produced a chip that was "thinned out" toward the last portion of the cut, resulting in a good surface finish until tool wear had an effect. The "thinning out" of the chip was a very important part of the problem of securing reproducible surface finishes and tool life. The proper "thinning out" of the chip was a function of the tool-setting angle and the contour of the end cutting edge. The tool setting was adjusted during the first cut of each test to obtain the optimum surface finish and chip formation. This setting was maintained for all succeeding finish cuts for any given test.

After each finishing cut the surface was wiped clean and a profilometer reading was obtained using a manual tracer. To maintain uniformity, this operation was always conducted by the same person, and the speed to move the tracer head was checked with a master plate several times daily. As a permanent record, a Fax-Film replica was made at a representative location after each cut to show the general characteristics of the surface finish, including burnishing and tearing. Estimates of the amount of burnishing, the general appearance of the surface, and the condition of the tool were recorded at this time.

Tool life was judged on the basis of tool flank wear, surface roughness, the general appearance of the surface, and the Fax-Film replicas. In general this tool life was quite reproducible. The Fax-Film replicas were extremely valuable in reviewing the individual tests and in selecting the point of tool failure.

Individual heats were represented by successive pairs of axles, i.e., 1-2, 3-4, 5-6, etc. To avoid as much as possible any tendency to carry over experience from one axle to its companion, the axles were tested in the following sequence: 1, 2, 3, 5, 7, 9, 11, 4, 6, 8, 10, and 12.

DISCUSSION

To become acquainted with the complexities of the problem, preliminary tests were made on the body portion of several axles. Sufficient length was available to give the equivalent of two journal cuts. During this stage of the work, the variables of tool shape, elevation of the cutting edge above centerline, tool-setting angles, and tool material were studied. Table III gives a comparison of the tool life between the Pullman Standard tools and the Apex tools on two different axle bodies. These results indicate that the Apex tools on the same work material have a somewhat better tool life than do the Pullman Standard tools.

In all the tests there was a pronounced sensitivity of the surface finish to the tool shape and setting-angle factors. The optimum tool shape was determined during the preliminary testing and recorded on the template, shown in Fig. 2. The finishing tools were subsequently ground and honed to fit this template. The optimum tool-setting angle was determined experimentally at the beginning of each test by making slight adjustments of the cutting tool. In most cases it was possible to arrive at a relatively smooth surface finish during the first cut, as shown in the general summary in Table IV. Once the proper tool-setting angle and tool elevation were established, the lathe was set up in such a way that this tool setting could be reproduced easily during the several cuts which might be necessary to produce tool failure.

In arriving at the correct tool-setting angle, it was important to attain the proper "thinning out" of the chip. When this was obtained, a good surface finish resulted until the tool was worn out. The nose of the cutting tool, which removed the largest portion of the metal during the finish cut, invariably developed a small built-up edge which resulted in excessive surface roughness. This roughness appeared on the work unless it was subsequently removed by the end cutting edge of the tool in a fine shaving action, described previously as the "thinning out" of the chip.

The profilometer readings were very useful in determining that the cutting conditions were correct at the start of each test. The surface roughness, as indicated by profilometer readings, increased as the test progressed; however,

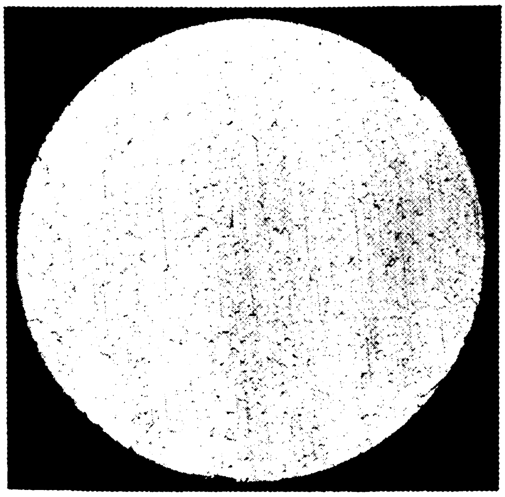
TABLE III

TYPICAL TEST RESULTS FOR MACHINING AXLE BODIES

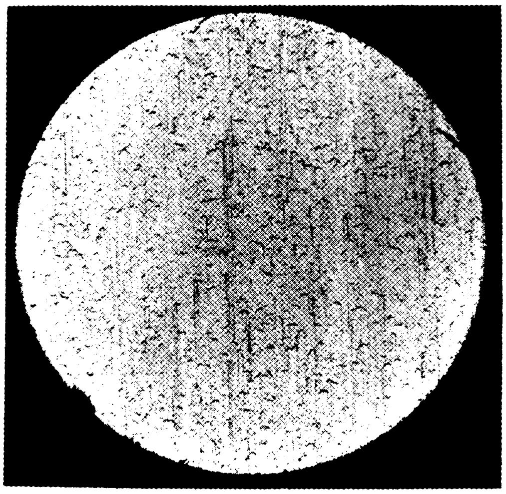
Axle No.	Cutting Tool No.	Useful Tool Life No. Cuts	No. Cuts to End of Test	Surface Finish (rms)			Estimated % Burnish		Comments
				Start of Test	End of Useful Tool Life	End of Test	End of Useful Tool Life	End of Test	
6	Apex	6	10	140/160	140/160	170/180	5%	20%	10% burnished at cut No. 7.
6	P5	5	9	120/140	120/130	130/170	5%	15%	Deep test marks appeared at cut No. 6.
11	Apex	6	10	130/140	120/140	150/170	10%	10%	Surface finish was 110/120 for second cut and 140/150 for cut No. 7. Deep tear marks appeared at cut No. 7.
11	PH	4	10	110/120	120/140	130/140	(Traces)	25%	Cut No. 5 had 15% burnish and 130/150 rms.

these readings were not as helpful in determining the end of the useful tool life. The general appearance of the surface, which included visual observations of tear marks and burnishing, was a more reliable indication of the end of the useful tool life. Under this circumstance, the Fax-Film replicas were of considerable help in judging the tool failure because they provided a record of the burnishing and tearing which could be used as a later reference. Some typical examples, pertaining to axles 6 and 8, of the finishes recorded in this manner are shown in Figs. 4 and 5. The areas shown have been enlarged about five times from the original. In these figures, the (a) enlargement illustrates surface conditions during the first cut; the (b) enlargements represent the conditions during the last cut which might be acceptable, and the (c) enlargements are typical of the surface generated after tool failure. In most cases tool life was selected as that point at which sharp changes in surface finish occurred, as illustrated in the (b) and (c) enlargements.

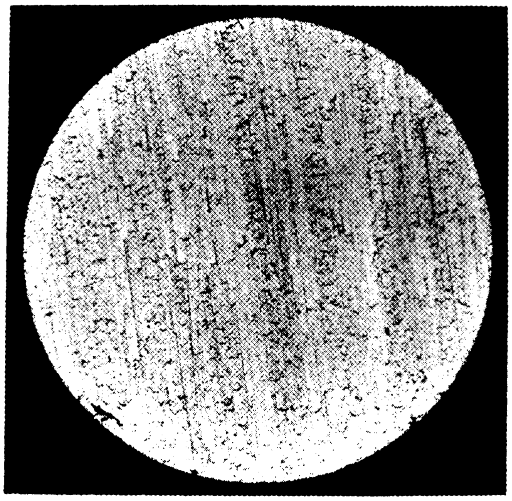
All the data pertaining to the journal have been summarized by individual axles in Table IV. These results were averaged to obtain the summary given in Table I. Heats C, D, E, and F vary in tool life from 3.25 cuts per grind to 4.25 cuts with only small variations between corresponding axles of the same heat. Heats A and B, on the other hand, are very different in their behavior. Heat A had an excellent finish at the beginning and the highest tool life. Heat B had the poorest finish at the beginning of the test and the shortest tool life.



a. Journal No. 6B. Cut No. 1.
Tool No. PH. 120/130 rms.

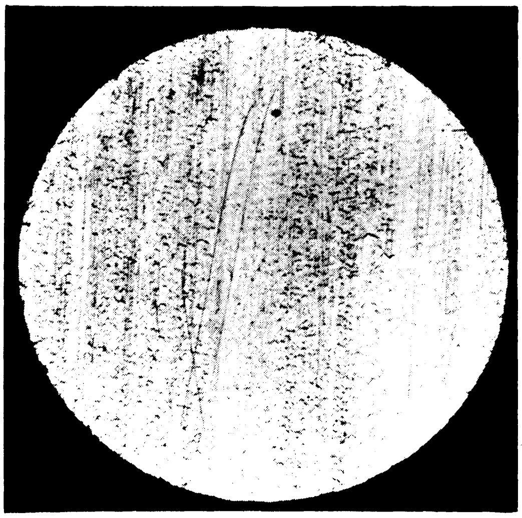


b. Journal No. 6B. Cut No. 4.
Tool No. PH. 140/160 rms. 5%
burnished.

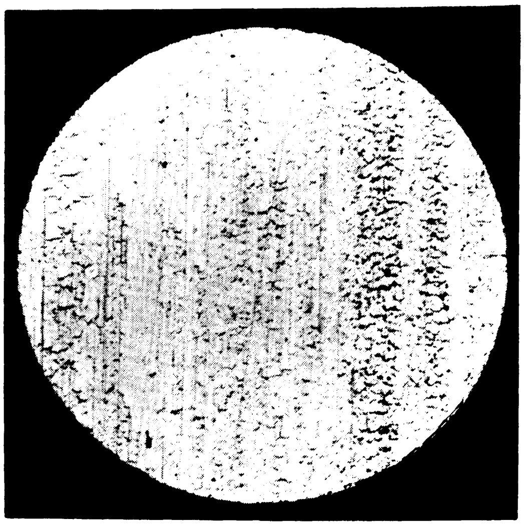


c. Journal No. 6B. Cut No. 5.
Tool No. PH. 150/170 rms. 15%
burnished.

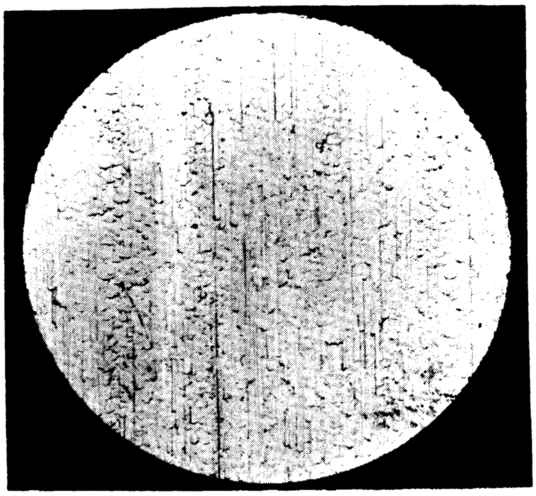
Fig. 4



a. Journal No. 8A. Cut No. 1. Tool No. P5. 90/100 rms.



b. Journal No. 8B. Cut No. 4. Tool No. P5. 150/160 rms. 10% burnished.



c. Journal No. 8B. Cut No. 5. Tool No. P5. 150/160 rms. 10% burnished.

Fig. 5

TABLE IV

Axle No.	Cutting Tool No.	Journal Diameter		Useful Tool Life No. Cuts	No. Cuts at End of Test	Surface Finish			Estimated % Burnish		Comments
		Start	End			Start of Test	End of Useful Tool Life	End of Test	End of Useful Tool Life	End of Test	
1A to 1B	P5		A-5.88	5	8	100/120	130/150	130/180	10	20	
			B-5.81								
2A to 2B	PH	A-6.18	A-5.84	7	10	100/120	110/120	110/140	< 5	25	
		B-6.10	B-5.91								
3A	PH	6.17	5.97	1-2	3	130/150	130/150	150/180	< 5,10	< 5	Cut No. 2 has
							150/170				10% burnish
3B	P5	6.10	5.94	1	3	130/170	130/170	180/210	-	10	
4A	PH	6.18	5.78	2	7	130/140	150/160	180/210	< 5	10	
4B	P5	6.19	5.78	3	7	130/140	150/160	160/180	5	20	
5A	PH	6.15	5.81	4	6	110/140	140/180	130/155	5	10	Cut No. 4
											rms = 140/180
5B	P5	6.13	5.59	5(4-6)	9	80/90	90/100	110/130	< 10	30	Cut No. 7
							4-100/120		4-5		rms = 120/140
							6-120/130		6-10		
6A	P5	6.17	5.81	4	6	80/100	160/170	140/170	10	15	Cut No. 5
											rms = 160/180
6B	PH	6.14	5.81	4	6	120/130	140/160	160/180	5	10	15% burnish
											at cut No. 5
7A to 7B		A-5.84	A-5.75	4	5	120/130	130/140	130/150	10	15	
		B-6.20	B-5.89								
8A	PH	6.14	5.91	3	4	120/130	150/170	160/180	10	10	
8A to 8B	P5	A-5.90	A-5.75	3-4	6	90/100	3-140/150	150/170	3-10	20	
		B-6.20	B-6.06				4-150/160		4-10		
9A	PH	6.18	5.84	3	6	110/130	150/170	180/200	5	10	
9B	P5	6.15	5.84	4	5	130/160	170/200	180/210	15	20	
10A	P5	6.18	5.91	3	5	100/120	140/150	160/170	5	15	Cut No. 4
											rms = 160/180
10B	PH	6.02	5.75	3	5	120/130	150/160	140/150	10	15	
11A to 11B	P5	A-5.98	A-5.81				4-150/170	150/180	4-10	20	
		B-6.16	B-5.94	4-5	7	90/120	5-150/170		5-10	20	
12A	PH	6.15	5.81	5	6	120/130	140/150	130/140	5	10	Cut No. 4
											rms = 150/160
12B	P5	6.17	5.78	4	7	130/150	150/170	140/160	< 10	10	Cut No. 5
											rms = 150/180