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Original Research Article

Performance Evaluation of Strengthened Scrapped Mating Rings of Face Seals Used as Single Point Turning Tool

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Abstract

The scrapped mating ring of face seals has been studied and recycled into single point turning tools (SPTTs) and performed comparably with standard turning tools. Three sets of tools, namely, standard tungsten tool, strengthened and unstrengthened scrapped ring, have been studied and performed satisfactorily as SPTTs. Standard tungsten tool, strengthened and unstrengthened scrapped mating ring of face seal respectively. The tools were configured with a nose radius 2mm, positive rake angles of 3^o, 5^o and 8^o and used to perform turning operations on mild carbon steel (CS1030) with surface roughness measured. The results showed that the strengthened tools generated the best surface finish for mild carbon steel among all three tools under consideration. The statistical analysis showed that surface finish, the model, cutting speed and feed rate are significant with their P-values < 0.0001 but the depth of cut, rake angle and tool have no significant impact on surface finish at 95% confidence level. This research will provide the machine tools shop with more durable SPTT and enhance reliability, quality, minimize downtimes and accidents in machining processes.

Keywords: Face Seals, Strengthening, Auxiliary, Degreasing, Surface Finish.

INTRODUCTION

Face seals are mechanical components of equipment used for preventing leakages automatically in pipes and piping systems. The seals are extensively used in centrifugal systems such as refineries, chemical and other industries where flow of fluids are required. The mechanical face seals, contains mating ring which is made of cemented carbides. Cemented carbides are classified into tungsten carbides and titanium-tungsten carbides [3]. A lot of these non-leakage devices are used in the refinery and other piping systems. Large users agree in attributing a large proportion of process plant maintenance cost to mechanical seal failures [4].

Face seals are very expensive components of the process plant and are designed to function for about 6,000hours of operation, provided all other parameters such as operational procedures' and equipment alignment e.t.c are complied with. But incidentally, these associated conditions under which a seal functions optimally, are usually not attainable. Factors such as machinery capability, technical knowledge, operators' attitude, maintenance technicians' attitude and even management policy, limits the performance of mechanical face seals. It is on this basis that mechanical face seals hardly function for 1,000hours in operation before failure. As there is no use for the scrapped mating ring and absence of recycling companies especially in the less developed countries of the world, disposal of scrapped mechanical face seals is a serious problem [6].

Mechanical face seals are often used in rotating applications in extremely arduous conditions. It is an important machine element in the axles of heavy-duty vehicles and piping systems. Their main function is to prevent leakage and to keep contaminants from entering the system. All of them have in common that one half of the seal is rotating and the other is stationary. The separation between both halves have to be small to minimize leakage of the lubricant. Therefore, an increase of friction and wear occurs, which results in power loss and reduced life time [1].

Single point cutting tools consist of only one working cutting edge that can perform metal removal action at a time. It is to be noted that, in insert based cutting tools, multiple cutting edges may be present in a single tool; however, only one cutting edge can engage in material removal action at a time. Turning tool, also known as Single Point Turning Tool (SPTT), is an example of a single point tool. Aside turning tools, shaping, planning, slotting, boring and broaching tools are also single point tools.

MATERIALS AND METHODS

The face seal is cut using a diamond disc cutting plate to form an insert on a shank. A popular way to strengthen the cutting tips nowadays comprises the following steps, firstly, put the scrapped pieces of cutting tips in alcohol to remove grease or oil, then put it into an open container and sprinkle some urea (10% of the weight of pieces of face seal). Then, heat it to 180°C. After that, urea will melt and flow into the tungsten carbide through the blowhole. Next, keep the status for about 15minutes and then cool the tips to a temperature lower than the melting temperature of urea. At last, suddenly heated the tips to about700°C the urea would depolymerize [2]. The hardness and strength of face seal tips will be improved.

The most suitable metal for the shank is steel of about 0.5% carbon, in order to minimize the injurious effects of vibration and chatter on the brittle tip, the shank should be of generous cross- sectional proportion. To accommodate the tip a step or cavity is machined. Care being necessary to ensure that all surfaces are flat so that the tip is everywhere supported against pressure introduced when cutting. Failure to do this might result in bending stresses being introduced on the tip in service and its subsequent cracking/ failure [7], to affix the cutting edge to the shank. The insert is soldered using the oxy-acetylene device, after arranging the insert. Then the diamond grinding wheel is used to shape the tool to the required specification.

Three sets of tools, namely: standard tungsten tool, strengthened and unstrengthened scrapped mating ring of face seal respectively. The tools were configured witha nose radius 2mm, positive rake angles of 3^o,5^o and 8^o.

The experimental design was made using design expert software and a total of thirty- five (35) runs of experiment, with five factors at various levels as indicated in Table 1. The 35 runs of experiments is a combination five (5) factors; cutting speed, feed rate, depth of cut, rake angle and tools, and one response - surface finish.

Table 1: Process Parameters and Their Limits

				Process variables
Values in coded form	Spindle speed (N) (m/min)	Feedrate (f) (rev/mm)	Depth of cut (d) (mm)	Rake angle (°)
-1	150	0.1	0.1	3
0	170	0.2	0.17	5
+1	200	0.3	0.34	8
		0.4	0.4	
		0.5	0.5	

PHYSICAL, MECHANICAL AND CHEMICAL PROPERTIES

Physical properties

The distinguishing characteristics or qualities that are used to describe a substance such as metal or alloy are known as its physical properties. These properties encompass texture, density, mass,A material's mechanical properties refer to components' reaction to an applied load. An essential characteristic of all mechanical properties is their ability to describe the material's ability to resist deformation [8]. These mechanical properties determine the scope and limits of a material's functionality, as well as establish expected service life or performance. Among industries, materials are usually classified and identified in terms of such properties. Common mechanical properties that are considered in a wide array of materials are stiffness, toughness, strength, ductility, hardness, and impact resistance. The mechanical properties of materials are constant not; they continuously change when exposed to various conditions, such as heat or loading rate. The most common properties considered are strength, ductility, hardness, impact resistance, and fracture toughness [5].

Melting and boiling points, and electrical and thermal conductivity. All such physical properties are measurable or observable. These properties are not constant will change when subjected to certain variables such as heat. The scanning electron microscope and Rockwell hardness tester were employed.

Chemical Test: The chemical analysis was performed with X-Ray Fluorescence Analyzer, as described by Oshuoha [6].

RESULT

Table 2: Micro-Physical Test Analysis

Test Type	Cutting Tool		
	U	S	St
Hardness (HRC)	81.73	80.75	91.1
SEM			
Grain size	fine	Coarse	Coarse
Defect	numerous	minimal	minimal holesholesholes

St = Standard, S = Strengthened, U = Unstrengthened

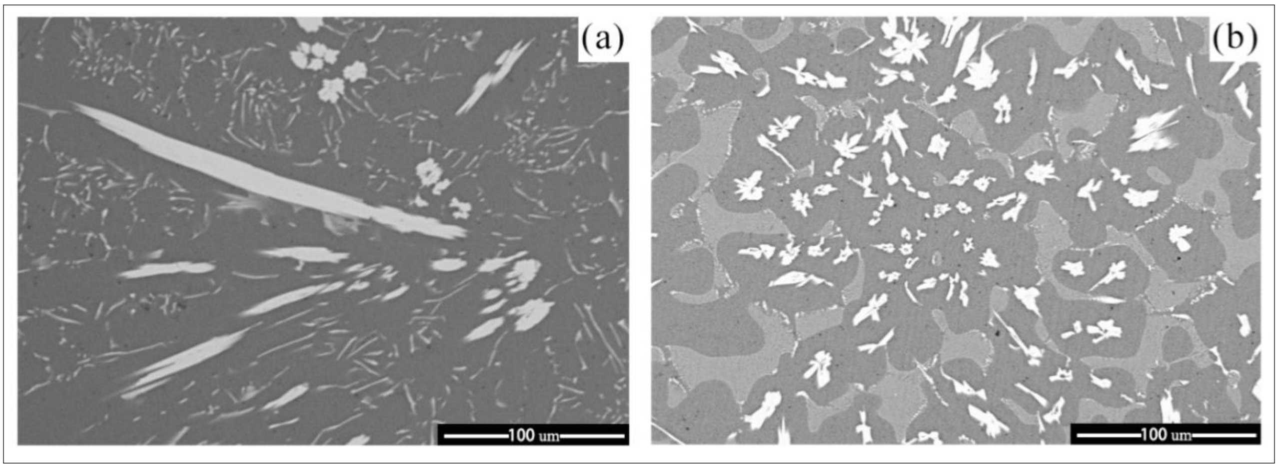

Figure 1: Scanning Electron Micrograph (SEM) for Unstrengthened Mating Ring

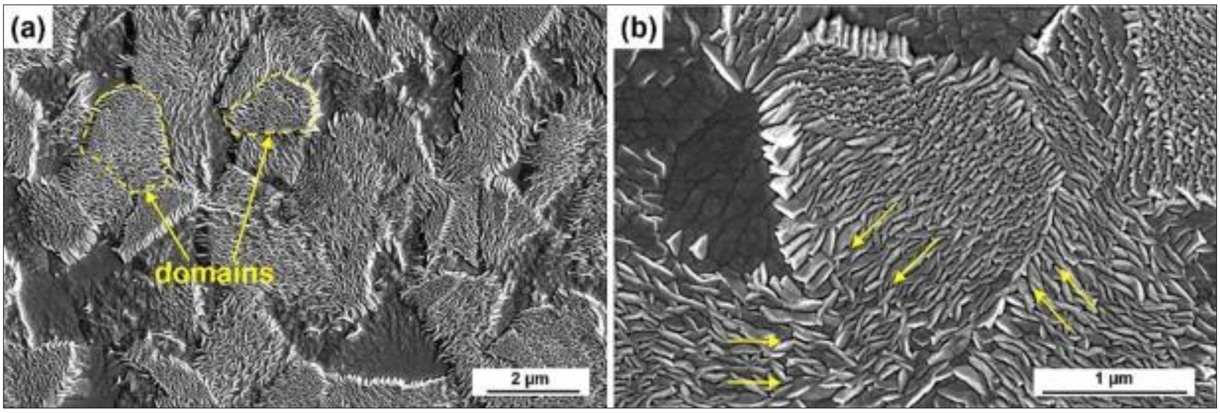

Figure 2: Scanning Electron Micrograph (SEM) for Strengthened Mating Ring

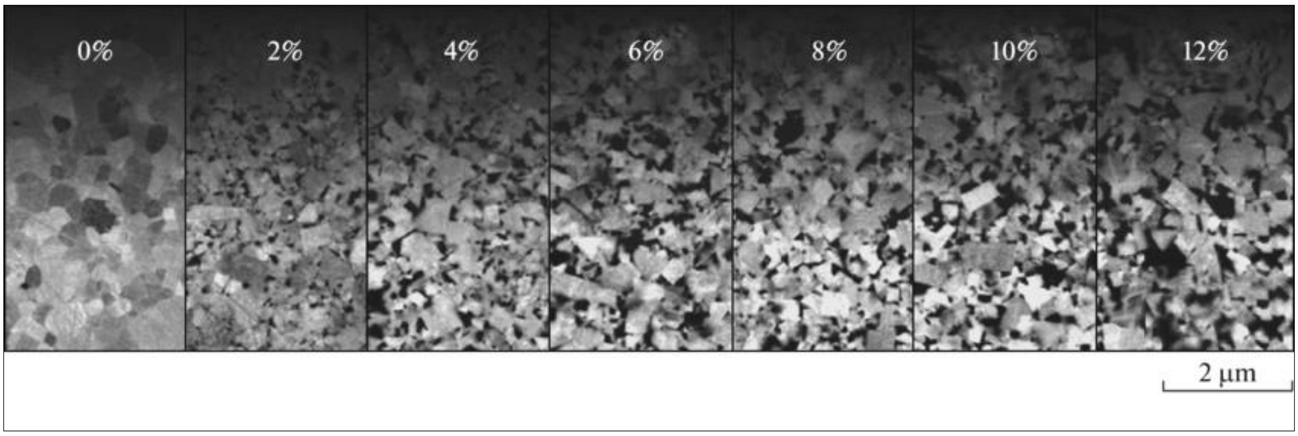

Figure 3: Scanning Electron Micrograph (SEM) for Standard Tungsten Carbide

Table 3: Chemical Test Analysis

Chemical Elements	Cutting Tool			Percentage Composition		
	U	S	St	U	U	S
Fe	0.02994	0.02823	0.0001	0.06	0.05	0.01
C	1.41	1.36	0.023	2.83	2.64	2.3
Si	0.00	0.00	0.00	0.00	0.00	0.00
Mn	15.02	14.81		30.19	28.78	
P	4.11	4.17		8.26	8.10	
S	1.15	1.68		2.31	3.26	
Cr	2.84	3.12		5.71	6.06	
Mo	1.24	1.63		2.49	3.17	
Ni	3.65	3.53		7.34	6.86	
Cu	0.00	0.00		0.00	0.00	
Al	0.378	0.740		0.76	1.44	
B	0.0258	1.03		0.05	2.00	
Co	12.75	11.85	0.10	25.62	23.03	10.00
Nb	1.82	1.92		3.66	3.73	
Pb	3.92	4.21		7.88	8.18	
Sn	0.00	0.00		0.00	0.00	
Ti	0.328	0.332		0.66	0.65	
V	0.898	0.895		1.80	1.74	
W	0.188	0.181	0.877	0.38	0.35	87.70

Table 4: Experimental Result Table

Run	Factor 1 A: cutting speed (m/min)	Factor 2 B: feed rate (mm)	Factor 3 C: depth of cut (mm)	Factor 4 D: rake angle (o)	Factor 5 E: tools	Response 1 surface finish (µm)
1	150	0.1	0.5	8	strengthened	0.79
2	150	0.1	0.1	8	strengthened	0.75
3	150	0.5	0.1	3	standard	0.90
4	170	0.5	0.17	5	unstrengthened	0.74
5	170	0.1	0.17	5	standard	0.71
6	200	0.5	0.17	3	strengthened	0.64
7	200	0.1	0.1	8	strengthened	0.55
8	200	0.5	0.1	8	standard	0.64
9	150	0.3	0.1	5	standard	0.82
10	170	0.5	0.5	8	standard	0.70
11	150	0.4	0.5	8	unstrengthened	0.92
12	150	0.4	0.4	3	standard	0.88
13	200	0.4	0.34	5	standard	0.61
14	200	0.1	0.5	8	standard	0.58
15	170	0.2	0.17	8	unstrengthened	0.68
16	200	0.4	0.34	5	standard	0.61
17	170	0.3	0.4	3	unstrengthened	0.73
18	200	0.5	0.5	5	unstrengthened	0.65
19	170	0.3	0.1	5	strengthened	0.69
20	170	0.2	0.17	8	unstrengthened	0.68
21	200	0.1	0.5	3	strengthened	0.56
22	150	0.1	0.4	5	unstrengthened	0.85
23	150	0.2	0.1	3	unstrengthened	0.86
24	150	0.1	0.34	3	strengthened	0.81
25	150	0.1	0.5	3	standard	0.84
26	200	0.1	0.1	3	standard	0.55
27	170	0.3	0.1	5	strengthened	0.69
28	150	0.3	0.34	8	standard	0.85
29	200	0.2	0.17	5	unstrengthened	0.57
30	150	0.4	0.5	5	strengthened	0.87
31	170	0.5	0.34	3	strengthened	0.72
32	170	0.3	0.4	3	unstrengthened	0.73
33	200	0.4	0.34	8	strengthened	0.62
34	170	0.5	0.17	5	unstrengthened	0.74
35	150	0.5	0.17	8	strengthened	0.91

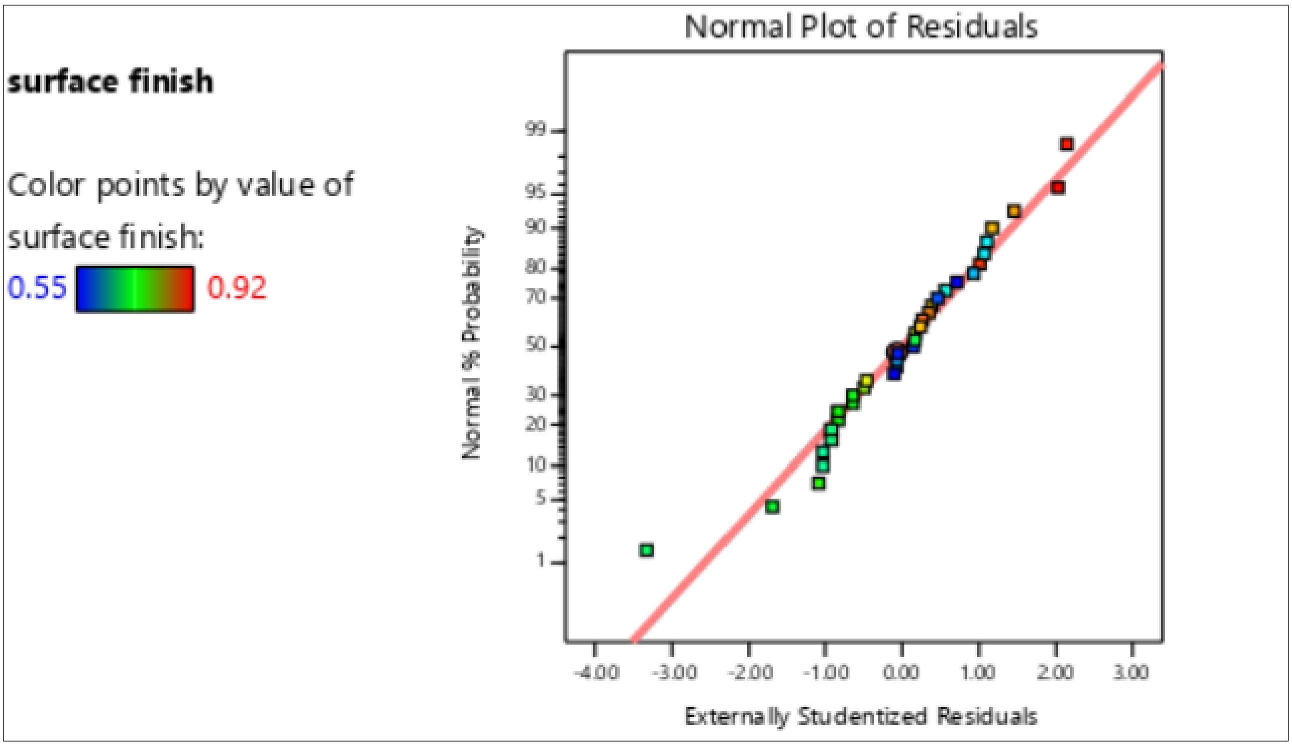

Figure 4: Normal Plot of Residuals

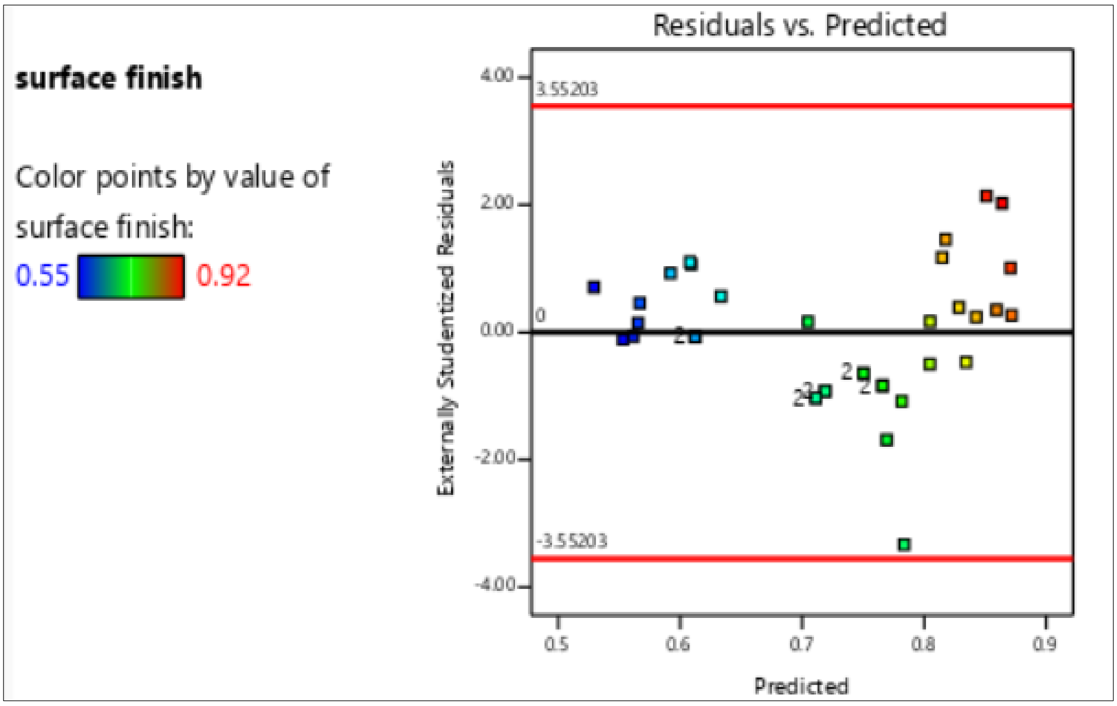

Figure 5: Residuals vs Predicted

Table 5: Fit Summary
Response 1: surface finish

Source	Sequential p-value	Lack of Fit p-value	Adjusted R^2	Predicted R^2	
Linear	**< 0.0001**		**0.9119**	**0.8828**	**Suggested**
2FI	0.7704		0.8943	0.4326	
Quadratic	0.0052		0.9620	0.5478	Suggested
Cubic			1.0000		Aliased

Sequential Model Sum of Squares [Type I]

Response 1: surface finish

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Mean vs Total	18.49	1	18.49			
Linear vs Mean	0.3993	6	0.0666	59.64	< 0.0001	Suggested
2FI vs Linear	0.0125	14	0.0009	0.6676	0.7704	
Quadratic vs 2FI	0.0139	4	0.0035	7.24	0.0052	Suggested
Cubic vs Quadratic	0.0048	5	0.0010			Aliased
Residual	0.0000	5	0.0000			
Total	18.92	35	0.5406			

Select the highest order polynomial where the additional terms are significant and the model is not aliased.

Table 6: Model Summary Statistics

Source	Std. Dev.	R^2	Adjusted R^2	Predicted R^2	PRESS	
Linear	0.0334	0.9274	0.9119	0.8828	0.0505	Suggested
2FI	0.0366	0.9565	0.8943	0.4326	0.2443	
Quadratic	0.0219	0.9888	0.9620	0.5478	0.1947	Suggested
Cubic	0.0000	1.0000	1.0000		*	Aliased

- Case(s) with leverage of 1.0000: PRESS statistic not defined.

Focus on the model maximizing the Adjusted R^2 and the Predicted R^2**.**

Table 7: ANOVA for Linear Model

Response 1: surface finish

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.3993	6	0.0666	59.64	< 0.0001	Significant
A-cutting speed	0.3750	1	0.3750	336.06	< 0.0001	Significant
B-feed rate	0.0227	1	0.0227	20.34	0.0001	Significant
C-depth of cut	0.0028	1	0.0028	2.52	0.1236	Not significant
D-rake angle	0.0005	1	0.0005	0.4573	0.5045	Not significant
E-tools	0.0013	2	0.0007	0.5844	0.5641	Not significant
Residual	0.0312	28	0.0011			
Lack of Fit	0.0312	23	0.0014			
Pure Error	0.0000	5	0.0000			
Cor Total	0.4306	34				

Factor coding is coded

Sum of squares is Type II Classical

The Model F-value of 59.64 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

P-values less than 0.0500 indicate model terms are significant. In this case A, B are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

Table 8: Fit Statistics

Std. Dev.	0.0334	R^2	0.9274
Mean	0.7269	Adjusted R^2	0.9119
C.V. %	4.60	Predicted R^2	0.8828
		Adeq Precision	22.9220

The Predicted R^2 of 0.8828 is in reasonable agreement with the Adjusted R^2 of 0.9119; i.e. the difference is less than 0.2.

Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 22.922 indicates an adequate signal. This model can be used to navigate the design space.

Table 9: Final Equation for Surface Finish in Terms of Actual Factors

TOOL TYPE	VALUE	CUTTING PARAMETER
Unstrengthened	surface finish=	
	+1.54171	
	-0.005047	cutting speed
	+0.163384	feed rate
	+0.057553	depth of cut
	-0.001872	rake angle
Strengthened	+1.53151	
	-0.005047	cutting speed
	+0.163384	feed rate
	+0.057553	depth of cut
	-0.001872	rake angle
Standard	+1.54597	
	-0.005047	cutting speed
	+0.163384	feed rate
	+0.057553	depth of cut
	-0.001872	rake angle

DISCUSSION

From Table 6, the models developed for all three tools, fit in for both linear and quadratic models. The values of R^2 are: R^2 = 0.9274, adjusted = 0.9119 and predicted = 0.8828, for linear model. Whereas, the values of R^2 for the quadratic model are: R^2 = 0.9888, adjusted = 0.9620 and the predicted =0.5478 respectively. Considering the above information, the linear model was chosen, as it will minimize the variation the actual value of surface finish and the predicted results (R^2 = 0.9274 and R^2 predicted = 0.8828), are more reliable.

According to results, from the Analysis of Variance (ANOVA), the linear model generated: the model have F-value 59.64 and P-value less than 0.0001, this makes it significant; cutting speed, have F-value 336.06 and P-value less than 0.0001, this makes it significant; the federate have F-value of 20.34 and P-value is less than 0.0001, which also makes it significant. While, the depth of cut, rake angle and tools have F-values of 2,52, 0.4573 and 0.5844 respectively, with all their P-values greater than 0.0001. This makes them not significant.

From Table 8; the Adeq precision of 22.922 is greater than the standard value of 4.00. As any signal to noise ratio greater than 4, is adequate signal for the modeling process. From Table 9, the modeled equations for the surface finish in terms of actual factors showed that the tools showed comparable performances. The scrapped mating ring of face seals have been studied and performed satisfactorily as single point turning tools (SPTTs). The strengthened mating ring of face seals, have ensured a better performance of SPTT, when both are compared alongside with standard tungsten carbide tool.

CONCLUSION

The turning operations' models for surface finish profile for all three tools under consideration showed excellent correlation. The statistical analysis showed that surface finish, the model, cutting speed and feed rate are significant. But the depth of cut, rake angle and tool have no significant impact on surface finish at 95% confidence level.

The strengthening of the scrapped mating ring of face seals and used to produce SPTTs generated better surface finish than scrapped mating rings and tungsten carbide tools. This research, will provide the machine tools' shop with more durable SPTTs. And in turn will enhance reliability, quality, minimize downtimes and accidents in machining processes. It will ensure better surface finish, durability and longer life span of SPTT. The mechanical properties of the recycled mating ring, suggests it can be used for other applications: for making other single point operations' tool such as shaping, planning, slotting, boring and broaching.

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