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INVESTIGATION OF CUTTING TOOL INFLUENCE ON MACHINE TOOL POWER CONSUMPTION

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ABSTRACT
This paper deals with analysis of machine power consumption in case of machining 30CrNiMo8 steel by means of two different type of cutting tools, ceramic and cermets inserts. Factorial plan experiment has been performed in order to identify change of cutting forces in relation with the changes of cutting conditions. Experiment has been conducted in Laboratory for metal cutting – LORAM on University of Zenica. Kistler dynamometer Type 9265B is used to measure cutting force components Fx, Fy and Fz. Regression analysis has performed on obtained data from which appropriate mathematical models are gained.
Keywords: Cutting force, Power consumption, Regression

1. INTRODUCTION
Reducing energy consumption became one of the main goals in many researchs perform nowadays in machining materials area [1,2,3]. Beside economical effects that this reduction has, very important aspect is also its ecological impact. That is the reason for developing new systems like KERS – kinetic energy recovery system [1] or introducing new automated energy monitoring systems [2] in machining. Energy or power consumption in machining operation is a product of the main cutting force and cutting speed. It is used as one of the criterions for the selection of appropriate machine tools for cutting process performance. Determination of adequate cutting conditions, in for example turning process, is more or less starting with selection of appropriate cutting inserts to be used in that process. The producers of cutting tools gives recommended speed and feed for their cutting tools, but none of them will give information about power consumption for that tool. In literature one can found data like is specific power consumption for blunt or sharp tool. Those data are used in calculation of power consumption in relation with cutting conditions. The aim of this investigation is to give an example of establishing relationships between cutting conditions and power consumption in case of machining same material with two different type of cutting inserts, cermet and ceramic. The cutting geometries of the selected inserts are different. Hence, the change in power consumption will dependent only on the cutting inserts geometry.

2. EXPERIMENTAL SET-UP
The experiment is conducted in Laboratory for metal cutting and machine tools – LORAM on University of Zenica. Factorial plan 2^3 is used for designing experimental investigation. Table 1 shows controlled factors with their levels.

Table 1. Level of factors

Level	Factor		
	Cutting speed, v *[m/min]*	Feed, s*[mm/o]*	Depth of cut, a *[mm]*
(+1)	200	0,2	0.75
(-1)	100	0,05	0.25

Table 2. Plan matrix of experiment

Run	Plan matrix				Cutting inserts			
	X_0	X_1 (v)	X_2 (s)	X_3 (a)	CNMG (cermet)		CNGA (ceramic)	
					F	ln F	F	ln F
1.	+1	-1	-1	-1	184,145	5,216	181,734	5,2025
2.	+1	+1	-1	-1	58,223	4,064	163,817	5,099
3.	+1	-1	+1	-1	261,686	5,567	354,923	5,872
4.	+1	+1	+1	-1	213,877	5,365	213,877	5,365
5.	+1	-1	-1	+1	293,237	5,681	332,265	5,806
6.	+1	+1	-1	+1	281,084	5,639	292,83	5,68
7.	+1	-1	+1	+1	576,046	6,356	576,046	6,356
8.	+1	+1	+1	+1	644,276	6,468	644,276	6,468

3. RESULTS AND DISCUSSION

After processing these data following results are obtained:

SUMMARY OUTPUT for CERMET

Regression Statistics	
Multiple R	0,934885296
R Square	0,874010517
Adjusted R Square	0,779518405
Standard Error	0,349200515
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	3,383702	1,127901	9,249561	0,028481
Residual	4	0,487764	0,121941		
Total	7	3,871466			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	9,897086366	1,824951	5,423206	0,005605
ln v	-0,46310511	0,356233	-1,30001	0,26345
ln s	0,569143194	0,178117	3,19534	0,033047
ln a	0,89476516	0,224758	3,981013	0,016387

SUMMARY OUTPUT for CERAMIC

Regression Statistics	
Multiple R	0,965717
R Square	0,932609
Adjusted R Square	0,882066
Standard Error	0,17291
Observations	8

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1,655002	0,551667	18,45174	0,008322
Residual	4	0,119591	0,029898		
Total	7	1,774593			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	8,318321	0,903642	9,205329	0,000774
ln v	-0,22524	0,176392	-1,27693	0,270716
ln s	0,409996	0,088196	4,648684	0,009671
ln a	0,630682	0,111291	5,666957	0,004782

Since the P-value in ANOVA tables for both cases is bigger than 0.05, with 95% confidence level the cutting speed can be considered as an insignificant factor in both of regression models. For purpose of further calculations its value will be set to level 0 (v=150 m/min).

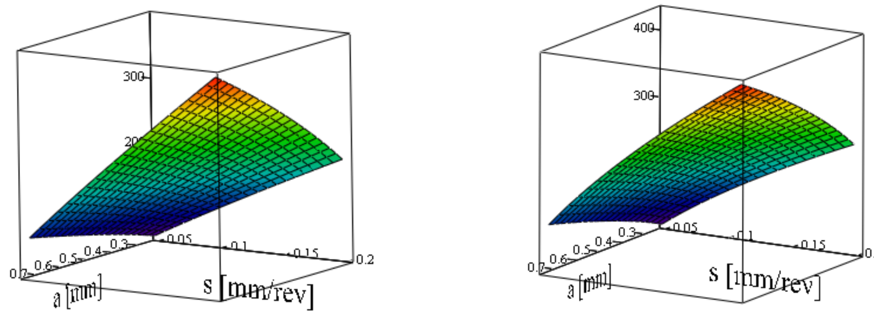
After decoding linear regression models, following polynomial functions are gained:

CNMG cermets: $$F_{cermet} = 19870.67 \frac{s^{0.5694} \cdot a^{0.8945}}{v^{0.4631}} \quad \ldots(1)$$

CNGA ceramic: $$F_{ceramic} = 4098.187 \frac{s^{0.4099} \cdot a^{0.6307}}{v^{0.2252}} \quad \ldots(2)$$

For v=150 m/min the models became:

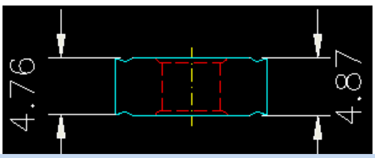
$$F_{cermet} = 1921.932 \cdot a^{0.8945} \cdot s^{0.5694} \qquad F_{ceramic} = 1325.977 \cdot a^{0.6307} \cdot s^{0.4099}$$



$$\int_{0.25}^{0.75} \int_{0.05}^{0.2} F_{cermet}(s,a)\, ds\, da = 23.625 \qquad \int_{0.25}^{0.75} \int_{0.05}^{0.2} F_{ceramic}(s,a)\, ds\, da = 26.683$$

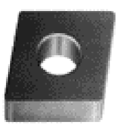
Figure 1. 3D plot of cutting forces for cermet and ceramic inserts

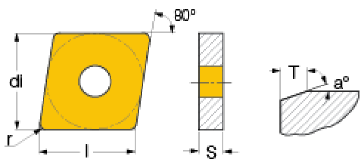
Obviously, ceramic cutting inserts, in comparing with cermets inserts, require more energy to be spent in machining process.



CERMET cutting inserts

l	di	S	r	ft(min)	ft(max)	ap(min)	ap(max)
12.90	12.70	4.76	0.80	0.12	0.35	1.00	4.00





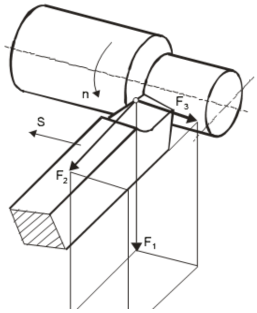
CERAMIC cutting inserts

l	di	S	r	Txa°	ap(min)	ap(max)	ft(min)	ft(max)
12.90	12.70	4.76	0.80	0.20X25	0.07	0.40	0.05	0.20

Figure 2. Cutting inserts data [5]

Cutting power consumption calculation is based on cutting force components measurement, figure 1. Roughly, one can state that cutting power is product of cutting force and cutting speed. In this case, that power consumption can be expressed by Equations (3) and (4). Equation (5) is used to calculate difference between the two cases. Its graphical interpretation is shown in figure 3.

AUTHORS



$$P_{cermet}(s,a)=\frac{F_{cermet}(s,a)\cdot v}{6\cdot 10^4}\;[W] \qquad \ldots(3)$$

$$P_{ceramic}(s,a)=\frac{F_{ceramic}(s,a)\cdot v}{6\cdot 10^4}\;[W] \qquad \ldots(4)$$

$$\Delta P(s,a)= P_{ceramic}(s,a)-P_{cermet}(s,a),\;[W] \qquad \ldots(5)$$

Figure 2. Cutting force components direction

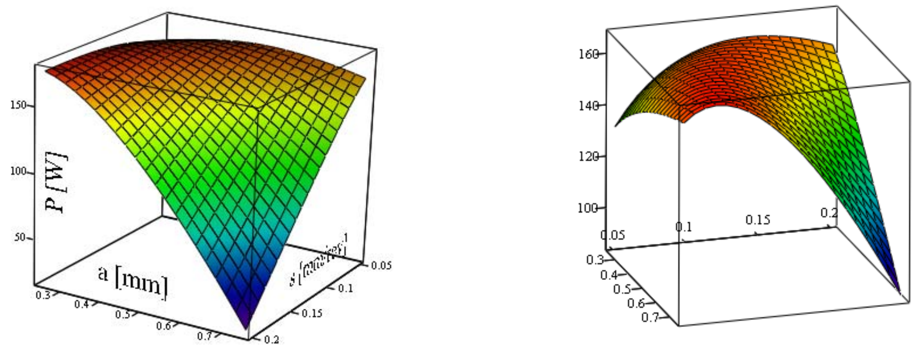


Figure 3. Difference in power consumption for different cutting tools

4. CONCLUSION

The results shows that power consumption depend not only on cutting conditions but also on cutting insert geometry. In presented investigation machining with ceramic inserts consume more energy than machining with cermet inserts. Main reason is notable in figure 2. – cutting insert data, and it is the fact that ceramic inserts is suppose to cut in with depths more than 1mm, which is actually bigger then upper depth of cut's level used in experiment. That means, bigger the depth of cut (as well as feed) smaller the difference between energy consumption. On the other hand, at the same time, bigger feed and bigger depth of cut means higher cutting force and consequently higher the absolute value of energy consumption. By coupling presented methodology and additional machinability parameters like surface roughness, for example, it is should be possible to optimize energy consumption in machining processes and make an environmentally friendly choice of cutting inserts geometry.

6. REFERENCES

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