ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 12 , December 2020

Control of the Accuracy of Machine Parts Machining by Effective Power Expended on Cutting

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ABSTRACT: The article discusses the determination of the shear forces generated in the machining of parts by the effective force applied to the cut and the optimization of the shear rates. Specific energy consumption was also studied. The shear strength obtained in the mathematical model was calculated and it was determined that the maximum difference when the actual shear strength was measured was 15%.

KEYWORDS: Automation, process, control, shear forces, Cutter, shear force components, effective force, rotational frequency, thrust, force, hard alloy plate, flow limit, strength limit, specific energy, shear rate, shear rate, material hardness.

I.INTRODUCTION

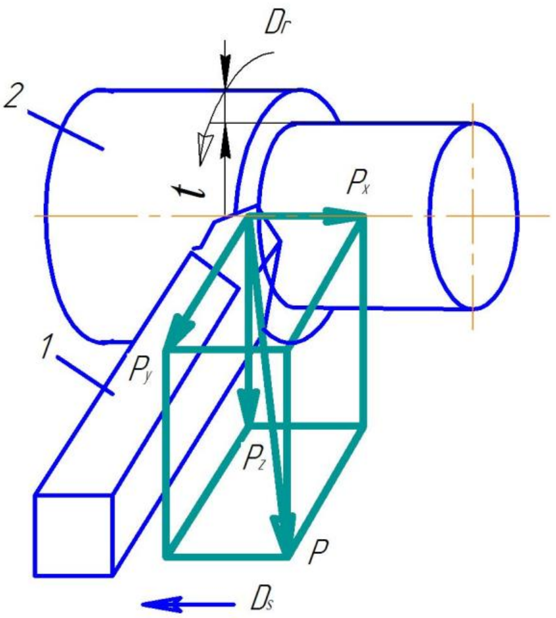
In order to manage an ongoing process in an automated production environment, it will be necessary to obtain information on how that process is progressing. This requires constant monitoring of the process.

Research shows that shear forces can be used to obtain information from the cutting process.

Figure 1 Forces acting on the cutter

1.Cutter; 2. Procurement; P-shear force;

P_y, P_x, Pz - components of shear force;



Dr is the direction of the main movement of the cut;

Ds-direction of thrust motion;t-cutting depth;

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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II.SIGNIFICANCE OF THE SYSTEM

However, the force generated works only during the cutting process. At the same time, part of the power is lost from heat re-magnetization and friction in the electric motor itself. Some of the power used is lost in the kinematic connections of the machine.

The force applied to the actual cutting process

Ne = PV, Vt (1)

where P is the shear force vector, N:

V- shear velocity vector, m / s

The effective force Ne in the general case is determined by the sum of the forces expended by the components Px, Pu, Pz.

The strength of the shear forces directed along the axes Nex is determined as follows:

$$N_{ex} = P_x nS \text{, Vt} \quad (2)$$

Here : n- the frequency of rotation of the processed workpiece, rot/s

S-push, mm/rot.

The radial shear force N_{ey} is determined as follows:

$$N_{ey} = P_y V \cos 90^\circ \text{, Vt} \quad (3)$$

$N_{ey} = 0$ because the P_y vector is perpendicular to the V vector.

The strength of the vertical shear force N_{ez} is determined as follows: $N_{ey} = P_z V$, Vt (4)

Therefore, the shear strength (2,3,4) is determined taking into account $Ne = N_{ex} + N_{ey} + N_{ez}$, Vt (5)

$$Ne = P_{xn} s + P_z V \text{, Vt} \quad (6)$$

N ex power is 1.2% of the effective power. The main effective power (98-99%) corresponds to

N_{ez}. Therefore, the following formula is used to calculate the effective power: $N_e = P_z V$, Vt (7)

The first task in the science of cutting materials is the calculation methods for determining the shear force.

Russian scientist K.A. Zvorikin, the founder of the theory of metal cutting, said that the cutting force is equal to the resistance of the metal, the plastic deformation in the cutting separation and the frictional force on the cutting surfaces. This conclusion is based on the scheme of operation, which describes the sliding of the planer cutter along the workpiece at a speed of V. K.A. Zvorikin derived the theoretical equation of shear force from the equation of equilibrium of forces acting simultaneously on the cutting surface.

$$P = \frac{ab\tau\left[\left(1 - f_1^2\right)\cos\gamma + 2 f_1 \sin\gamma\right]}{\sin\Theta\left[\left(1 - f_1 f_2\right)\cos(\gamma - \Theta) + \left(f_1 + f_2\right)\sin(\gamma - \Theta)\right]} \text{,H} \quad (8)$$

Russian scientists A.M. Rosenburg, I.M. Klushkina, N.N. Zoreva, M.F. Poletika, V.A. Krivoukhova and others have expanded the idea of the given systems of forces influenced by cocktails. The specification of plastic deformation of shavings formation is also improved by the image of maximum plastic deformation surfaces. The equations given by these authors are not clear because these formulas contain factors that are not taken into account when analyzing the physical and mechanical processes in the cutting zone, and the structure of the formula is more complex and difficult to apply. Therefore, these formulas are not widely used.

G.I. Granovsky proposed a simple equation of shear force.

$$P = K\rho\delta_{\hat{A}} f_H \text{, H} \quad (9)$$

where: - the allowable tensile stress of the material to be processed;

- cross-sectional area of the cut layer, mm^2.

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International Journal of Advanced Research in Science, Engineering and Technology
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The product of KrdV is the resistance to cutting of the workpiece being machined.

Experiments show that when cutting carbon structural steels, Kr≈2.5. For other structural steels, taking into account their chemical composition, composition and mechanical properties, Kr≈2.3-2.8.

The proposed formula allows to determine the amount of forces in the cutting process only at the first approximation, but can not be used in precise calculations.

VF Bobrov proposed an empirically generalized formula for calculating shear forces. Given the effect of these cutting rhythms on the forces generated, it is not difficult to determine under production conditions. The general view of this formula is as follows. $P = C_p t^{xp} S^{up} V^{zp} K_p$, H (10)

This formula is quite convenient and is widely used in engineering calculations. But it is not advisable to use it in adaptive control as it gives approximate and average values.

In this regard, we can draw very close results with the theoretical analysis that the effective cutting force depends on the cutting rhythms and the hardness of the material being processed.

On the basis of experimental studies, the aim was to verify the accuracy of the dependencies in the process of grinding structural steels with a cutting tool mounted on a hard alloy plate and to compile an equation of additional effective strength.

III. METHODOLOGY

Experimental studies were performed on a 16A20Ф3 device controlled by a MIKROS 12T CNC device and recorded on a computer. The power of the main drive motor was measured directly using the K505 instrument.

Effective power is obtained when the machine is working and as a difference of power at idle.

In the processing of structural steels, the sharp rhythms V, S, t are taken as undesirable variables. Ne effective shear force was obtained as the output size. Under the experimental conditions, it was possible to mix the incoming variables at four levels.

Xj = [-2,-1,+1,+2]

Their values :V=[1.6; 2.3;3.5;4.1 m/s].

S=[0.1,0.15;0.25;03mm/rot]

t=[0.1;0.15;0,25;0.3 mm]

20,45, 40 X 35 XГC A steels were machined. Their mechanical properties are given in Table 1.

Table 1

Steel grade	Hardness, HB	Leakage limit, GPa	Strength limit, σ_B,GPa	Relative elongation δ, %
20	156	0,22	0,44	25
45	217	0,36	0,75	16
40X	187	0,785	0,95	10
35XГCA	285	0,92	1,10	9

Table 2

№	S	t	V	S, mm/rot	t, mm	V, m/s	HB	N_e, W
1	-1	-1	-1	0,05	0,14	2,3	187	90
2	+2	-1	-2	0,125	0,14	1,7	217	131
3	-2	+2	-2	0,025	0,40	1,7	285	79,5
4	+1	+2	-1	0,1	0,40	2,3	156	157,5
5	-1	-2	+1	0,05	0,05	3,5	285	112,5
6	+2	-2	+2	0,125	0,05	4,1	156	217,5
7	-2	+1	+2	0,025	0,31	4,1	187	172,5
8	+1	+1	+1	0,1	0,31	3,5	217	285

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

Vol. 7, Issue 12 , December 2020

IV. EXPERIMENTAL RESULTS

Table 3

№	The components of the shear forces are Px, Py, Pz [H] dependence
1	$Px=4.604+1091.5St-29943(tVHB)^{-1}-1.427 \cdot 10^{-3}t^{-3}$
2	$Px=2.056+1396.4St-1.681 \cdot 10^{6}S(V \cdot HB)^{-1}-0.360S^{-2}HB^{-1}$
3	$Px=1.162+1232.4St-6.173St-1-5.531 \cdot 10^{-4}V \cdot HB^{-1}$
4	$Px=4.910+1107.4St-30378(tVHB)^{-1}-8.073 \cdot 10^{-4}HB \cdot t^{-1}$
5	$Px=-0.984+1092.3St-9.376t^{-2}HB^{-1}-4.968 \cdot 10^{-6}V^{2}$
6	$Py=-15.813+2.929 \cdot 10^{5}StHB^{-1}+0.106 \cdot HB+1.107 \cdot 10^{-5}t^{-1}HBV^{-1}$
7	$Py=-1.872+2.723 \cdot 10^{5}StHB^{-1}+2.239 \cdot 10^{-4}HB^{2}+6.298 \cdot 10^{-4}HB^{2}S$
8	$Py=-13.264+2.874 \cdot 10^{5}StHB^{-1}+0.104HB+9.292 \cdot 10^{-4}HBS^{-1}$
9	$Py=-11.030+2.883 \cdot 10^{5}StHB^{-1}+0.104HB-1.418 \cdot 10^{3}tHB^{-1}$
10	$Py=-10.97+2.731 \cdot 105StHB-1+9.884 \cdot 10-2HB^{-1}+5.659 \cdot 10^{-2}SHB$
11	$Pz=13.272+7.483 \cdot 10^{5}StHB^{-1}-3.794 \cdot 10^{4}SHB^{-1}+5.691 \cdot 10^{-3}HBt^{-1}$
12	$Pz=49.253+6.948 \cdot 10^{5}StHB^{-1}-9.482 \cdot 10^{3}HB^{-1}+3.514 \cdot 10^{4}V^{-2}$
13	$Pz=48.569+6.917 \cdot 10^{5}StHB^{-1}-9.440 \cdot 10^{3}HB^{-1}+1.106 \cdot 10^{7}V^{-2}HB^{-1}$
14	$Pz=37.954+7.001 \cdot 10^{5}StHB^{-1}-7.958 \cdot 10^{3}S^{3}-4.720 \cdot 10^{3}HB^{-1}$
15	$Pz=35.910+6.728 \cdot 10^{5}StHB^{-1}-9.151 \cdot 10^{5}HB^{-2}-1.868 \cdot 10^{-4}V \cdot HB$

Table 4

№ experiencea	S	t	V	HB	S, mm/tur	t, mm	V, m/s	HB	P_z, H	P_y, H	P_x, H
1	-1	-1	-1	-1	0.05	0.15	140	187	33	13	8
2	+2	-1	-2	+1	0.125	0.15	100	217	71	36	16
3	-2	+2	-2	+2	0.025	0.3	100	285	36	25	9
4	+1	+2	-1	-2	0.1	0.3	140	156	130	57	35
5	-1	-2	+1	+2	0.05	0.1	210	285	31	26	6
6	+2	-2	+2	-2	0.125	0.1	250	156	46	27	9
7	-2	+1	+2	-1	0.025	0.25	250	187	31	18	12
8	+1	+1	+1	+1	0.1	0.25	210	217	85	43	29

Table 5

№ experienc e a	S	t	V	HB	S, mm/tur	t, mm	V, m/s	HB	N_e, W
1	-1	-1	-1	-1	0.05	0.15	2,3	187	67.5
2	+2	-1	-2	+1	0.125	0.15	1,7	217	135
3	-2	+2	-2	+2	0.025	0.3	1,7	285	60
4	+1	+2	-1	-2	0.1	0.3	2,3	156	272.5
5	-1	-2	+1	+2	0.05	0.1	3,5	285	119
6	+2	-2	+2	-2	0.125	0.1	4,1	156	220
7	-2	+1	+2	-1	0.025	0.25	4,1	187	157.5
8	+1	+1	+1	+1	0.1	0.25	3,5	217	337.5

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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Dependence of effective force Ne on cutting of structural steels, [W]
N_e=16.954+7.332·10^4S^2t+9.501·$10^{-6}V^3$-7.915·$10^{-2}V^{-2}HB^{-1}$
N_e=-84.532+7.169·10^4S^2t+1.11^{3}V-1.295·$10^{-4}V^2t^{-1}$
N_e=58.053+6.054·10^4S^2t+7.8443·$10^{-6}V^3$-0.298$S^{-1}t^{-1}$
N_e=-222.15+8.125·10^4S^2t+1.261V+40.864HB·V^{-1}
N_e=-33.308+5.612·10^4S^2t+0.871V-0.193$S^{-1}t^{-1}$
N_e=-72.932+7.306·10^4S^2t+1.134V-55.004VHB^{-1}
N_e=61.976SVt+6.177·$10^{-4}VS^{-1}t^{-1}$
N_e=10.509+61.029StV+6.083·$10^{-4}VS^{-1}t^{-1}$+8.305·$10^{-5}V^2$
N_e=9.158+60.94StV+6.074·$10^{-4}VS^{-1}t^{-1}$+5.007VHB^{-1}

1. For each experiment we show that the effective force Ne depends on the cutting of structural steels, [W]
2. N_e=16.954+7.332·10^4S^2t+9.501·$10^{-6}V^3$-7.915·$10^{-2}V^{-2}HB^{-1}$
3. N_e=-84.532+7.169·10^4S^2t+1.11^{3}V-1.295·$10^{-4}V^2t^{-1}$
4. N_e=58.053+6.054·10^4S^2t+7.8443·$10^{-6}V^3$-0.298$S^{-1}t^{-1}$
5. N_e=-222.15+8.125·10^4S^2t+1.261V+40.864HB·V^{-1}
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9. N_e=10.509+61.029StV+6.083·$10^{-4}VS^{-1}t^{-1}$+8.305·$10^{-5}V^2$

For processing of steels are used cutting tools mounted on a hard alloy T15K6 plate, geometric elements
γ =8' ,γ =9', φ =45,' λ=0',
Permissible deflection on the cutting surface [hз] = 0.4 During the experiment, the structural steel with a hard alloy cutting tool was recorded using a cutting table.
The obtained results were processed using algorithms to calculate the group of arguments, the result of which was obtained a mathematical model of the effective shear force.

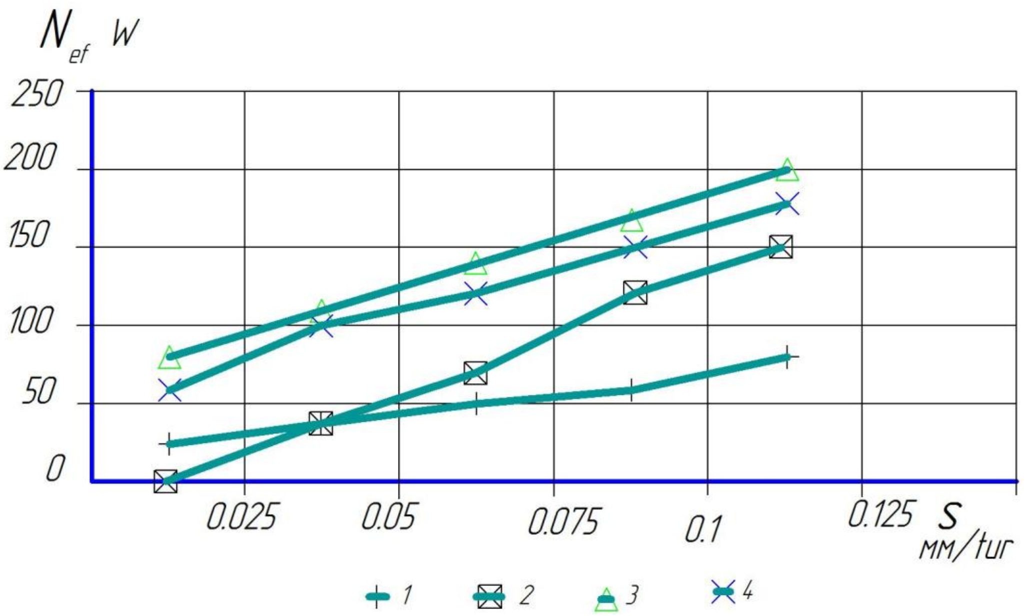

Figure 2. What is the dependence of the effective force on the buoyant thrust t = 0.1; 3.5m / s; HB -156;

A mathematical model of their power was extracted from them.
Ne = 730605 x 1.134 γ -55.004 γ/HB = 72.932 W (11)
For structural steels with HB = 156-265 and cutting
rhythms S-0.025-0.125 mm / tur; t = 0.1-0.3mm.

ISSN: 2350-0328
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It has an accuracy of 5% when V = 1, 7-4, 2 m / s.
The selection coefficients of the mathematical model were obtained on the criterion of displacement.

$$n_0 = \left| \frac{a_0 - b_0^1}{\bar{Y}} \right| \rightarrow \min$$

Figures 1,2,3 show the dependence of the effective force on the cutting rhythms in the direction of structural steels. Power is measured for each specific condition with number 3.

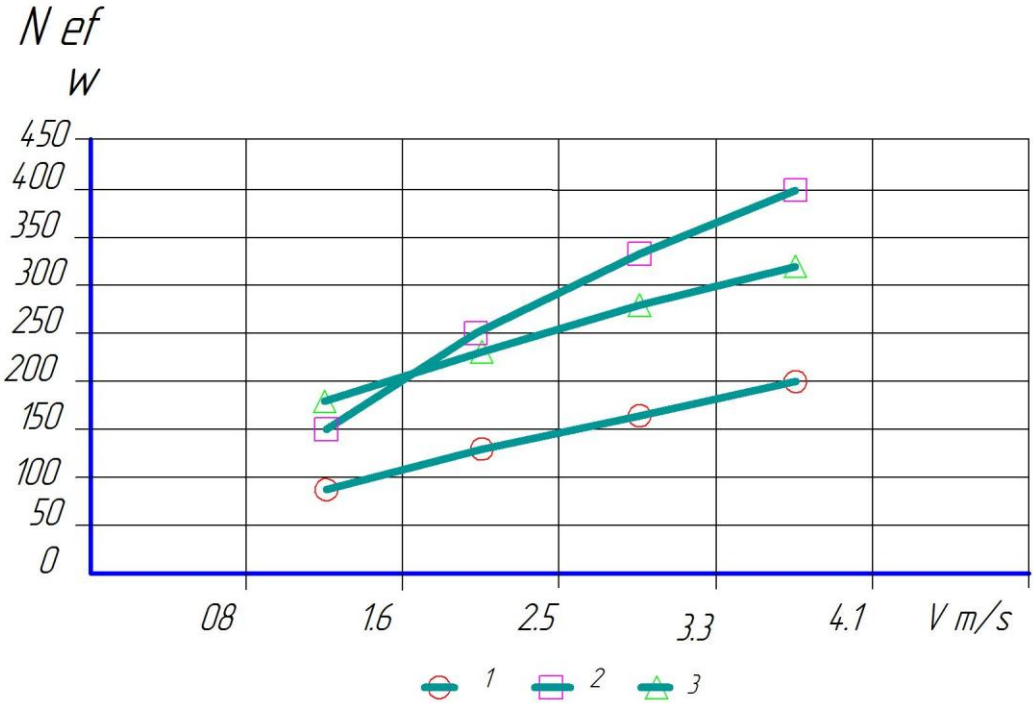

Figure 3 Ne depends on the cutting speed of the effective cutting power.

The graphs are almost exactly aligned with the 2 experimental points of the 3 curves seen in the experimental study results, (11) depicting the change in the effective power of the correlation cutting process almost completely.
The analysis of the dependencies shows that the effective power also increases with a certain increase in the value of the cutting norms. It should be noted that the effective force size is most affected by the cutting speed and the thrust and cutting depth.

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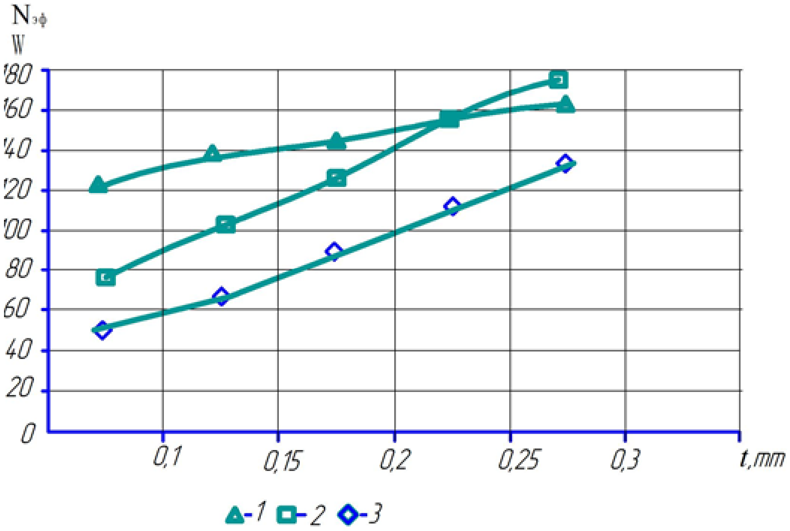

Figure 4. The dependence of the effective shear strength on the shear depth.

In Figure 4, we consider the effect of the elements of the cutting norms on the specific energy consumption of the cutting process, which depends on the effective cutting force N to the cutting depth.
The analysis of the dependencies shows that the effective force also increases with a certain value of the cutting rhythms. It should be noted that the magnitude of the effective force is affected by the maximum shear rate and the thrust and shear depth in the range.

To do this, at what values of cutting rhythms $\frac{\partial e}{\partial V} = 0$, we determine that the condition is satisfied.

We use the following element model.

$$\frac{\partial e}{\partial v} = -4383,6\frac{S}{V^2} + 4,376\frac{1}{StV^2} = 0$$

De=-4383.6 + 4.376
V≠0 because

$$S^2 t \cong 0.001$$

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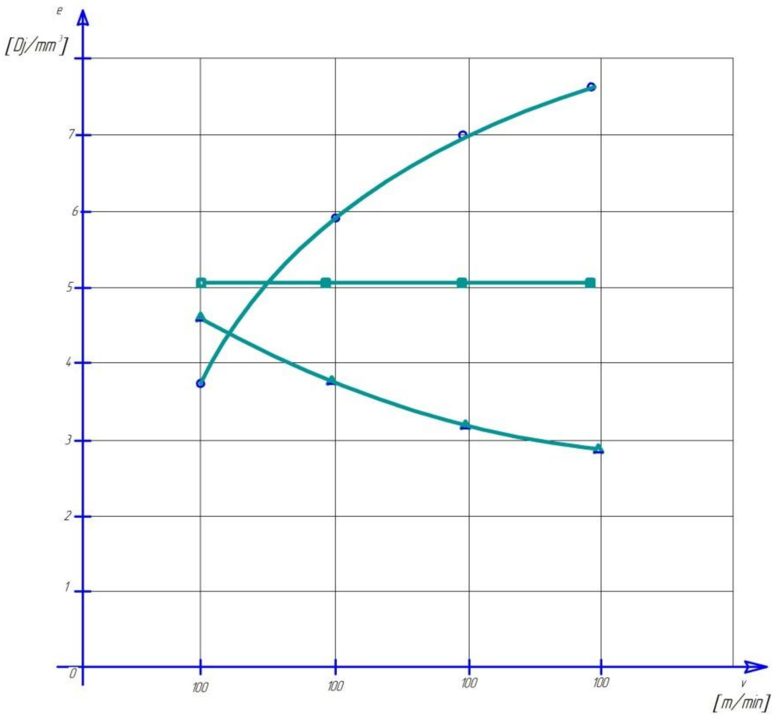

Figure 5. For the following 3 cases, curves were constructed in which the specific energy consumption depends on the cutting speed.

-1-t=0,1mm, S=0,05 , HB=200
-2- t=0,3mm, S=0,1, HB=200
-3- t=0,1mm, S=0,1, HB=200

1- for the case $S^2t < 0.001$

2- for the case $S^2t > 0.001$

3- for the case $S^2t = 0.001$

Analyzing the curves, we found that the dependence of the specific energy consumption on the pure direction of structural steels on the cutting speed goes in the following order.

$S^2t = 0.001$ the specific energy propagation under the conditions does not depend on the cutting speed /e = const/;

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International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 12 , December 2020

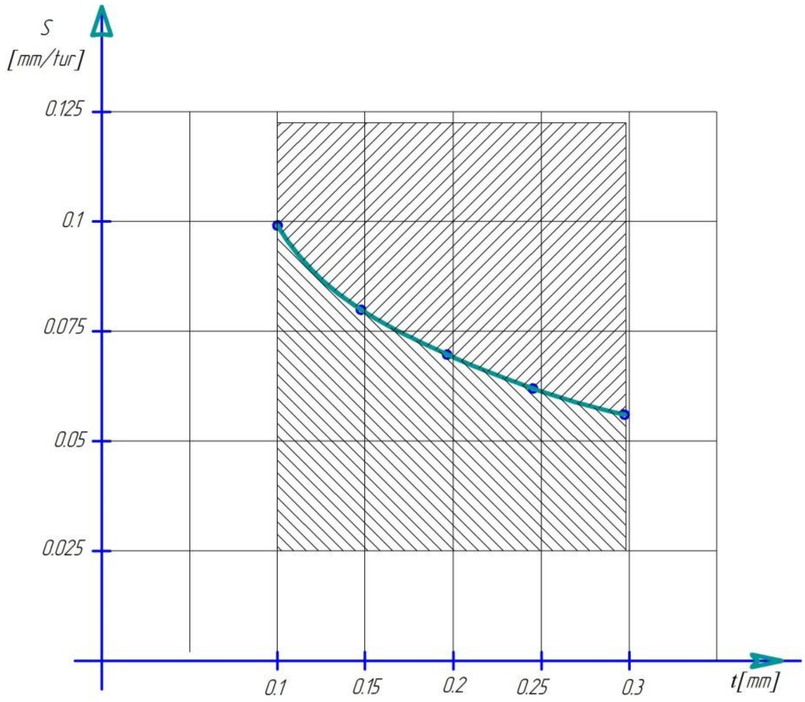

Fig. 5. Reduction and increase of the corresponding areas of the specific energy erosion push and cutting depth with increasing cutting speed when cutting structural steels and (11).

V.CONCLUSION

Analyzing the dependence of effective power and specific energy consumption on the cutting rhythms in the cutting process, we are convinced that the information signals received on the power can be used in control systems of machining parts of machine parts. If the loss of power in the engine and in the transmission system were constantly the same, the task of automatically controlling the cutting rhythms on the cutting power would be solved.

In this case it is possible to add the loss in the engine and bench kinematics to the loss in free walking. But the power of free walking varies for many reasons. For example, the change in frictional force on a machine as a result of heating can sometimes make it possible to connect these quantities.Yukorida kursatilganlar ishlatilayotganda kesish kuchi buyi bo'yicha boshkarish tizimini tuzish mumkinligini rad qilmadi.

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