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STUDY OF CUTTERS OPERABILITY WHEN STEEL IS MACHINING BY VARIABLE CUTTING MODES

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Efficiency of machining in automated production can be raised if cutting modes of machining vary depending on performance of cutting process and wear of the cutter. The random character of the tool wear is determined first of all by machining conditions of which are fluctuations of regimes of cutting, feeding of metal cutting lubricant and its kind, geometry of the tool, properties of the work and machining materials, operation parameters of the machine-tool etc. Impact of random factors on cutting tool wear character and intensity in case of machining of steels of 45, 40X, 30 XM and 20X13 grades by varying regimes of cutting has been studied. Interconnection between wear of the back surface and stability parameters. In Fig.1,2,3,4 by $2^{(6-3)}$ scheme curves of $h_3 = f(T)$ *dependency are plotted for all cases. By a program developed for multifactor regression analysis statistical processing of experimental data has been carried out resulting in the following mathematical models of connections - tools stability model* $T = f(V, S, T, HRA, HB, h_3)$, *tools wear intensity model* $Vh_3 = f(V, S, T, HRA, HB)$, *tools wear model* $h_3 = f(V, S, T, HRA, HB,)$, *tools wear statistical characteristics - standard deviation (σh_3) and dispersion (υh_3).*

Key words: cutting edge, wear, operability, stability, cutting mode, wear intensity, cemented carbide alloy.

Introduction

In spite of the fact that the above subject matter is a very important problem in raising the degree of cutting tools' operability, however, the analysis of publications shows that they have not completely clear up the problem under discussion [1].

For this reason a necessity emerged to carry out special experimental studies a part of their results is presented below.

Problem statement

Use of cutting tools in flexible systems of production shows that operation of each unit of tools, as a rule, is implemented by stable modes of machining, regardless of the list of work pieces. This is explained by difficulty of determination of possible duration of cutting tool stability. In an automated production efficiency of machining can be raised if cutting modes of the tool be changed depending on performance and wear of the tool [2].

It has been found that random character of the tool wear is conditioned by a numbers of factors. First of all by machining conditions, of which are variation of cutting modes, supply of cutting lubricant and its kind, geometry of the tool, properties of the cutting tool and the workpiece materials, operational parameters of the machine-tool etc. Revelation of impact of random factors depending on cutting tools wear character and intensity is of intense practical interest [3]. Based on the above mentioned factors the given process was studied and found interrelationship between wear at the back surface of cutters and stability parameters in order to raise effectiveness of machining process and performance of cutting tools.

Wear intensity and nature of cutting tools for steels of 45, 40X, 30XM, and 20X13 grades have been studied.

Dimensions of test part round blanks are D=100mm (diameter), L=1000mm(length).

Experiments have been made by cutting tools equipped with triangular T15K6 cemented carbide alloy tip. The following parameters of cutting modes have been chosen for steels of 45, 40X, and 30XM grades:

$V_{min} = 50$ (m/min); $S_{min} = 0.1$(mm/rev); $t_{min} = 0.5$ (mm),

$V_{max} = 80$ (m/min); $S_{max} = 0.3$(mm/rev); $t_{max} = 1.5$ (mm),

As for steel 20X13 the following mode parameters of cutting were chosen:

$V_{min} = 80$ (m/min); $S_{min} = 0.1$(mm/rev); $t_{min} = 2$ (mm),

$V_{max} = 150$ (m/min); $S_{max} = 0.5$(mm/rev); $t_{max} = 5$ (mm),

Research results

During study the following hardness numbers variations of tools and work pieces have been found

Steel Grade	Brinell hardness number	Rockwell A hardness number
45	HB 198 - 207	HRA 90,9 – 91,6
40X	HB 297 – 371	HRA 90,2 – 91,7
30XM	HB 78 – 341	HRA 90,5 – 91,8
20X13	HB 153 - 185	HRA 90,3 – 91,3

For each machining by cutting mode parameters five repetitions were made. For each batch of experiments the dynamics of the back surface wear of cutting tools were revealed (Tables 1,2,3,4…) and wear (h_s) dependence from its stability time T. Dependence graphs have been plotted for all cases (Fig.1,2,3,4…) by 2(6-3) scheme.

Table 1

Wear dynamics of the cutting edge when turning steel of 40X grade blank by the following parameters of variable modes

$V_{max} = 200$ **(m/min);** $S_{max} = 1.2$**(mm/rev);** $t_{max} = 2$ **(mm),**

№	**1**	**2**	**3**	**4**	**5**
HRA	90,3	91,3	90,2	90,5	91
HB	330	307	197	341	317
2	0,12	0,06	0,11	0,14	0,08
5	0,28	0,14	0,21	0,24	0,17
10	0,37	0,26	0,33	0,35	0,28
20	0,57	0,46	0,54	0,51	0,48
30		0,78	0,8	0,76	0,72

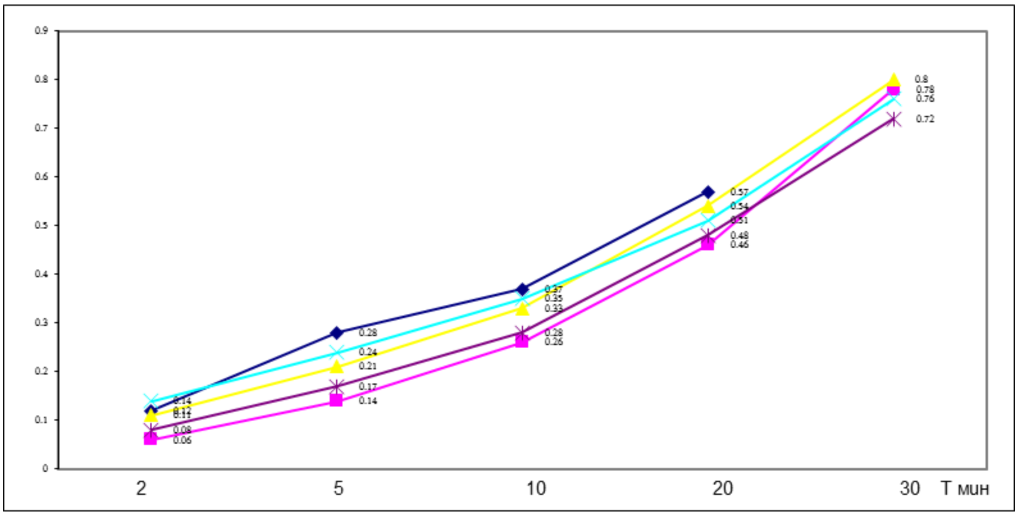

Figure 1. Impact of cutting speed, feed, and feed depth on wear in machining steel of 40X grade when V_{max}=200m/mim, S_{max}=1,2mm/rev., t_{min}=2mm

Table 2

Wear dynamics of the cutting edge when turning steel of 45 grade blank by the following parameters of variable modes when

$V_{min} = 200$ **(m/min);** $S_{min} = 0.5$ **(mm/rev);** $t_{min} = 5$ **(mm),**

No	1	2	3	4	5
HRA	91,6	91	90,8	91,4	91,8
HB	188	208	205	195	205
2	0,03	0,11	0,09	0,08	0,04
5	0,09	0,27	0,16	0,15	0,11
10	0,16	0,39	0,33	0,26	0,19
20	0,33	0,56	0,48	0,44	0,43
30	0,54	0,75	0,7	0,64	0,55
40	0,74	0,98	0,86	0,84	0,75
50	0,94	1,13	1,05	1,02	0,99
60	1,19	1,42	1,32	1,26	1,27

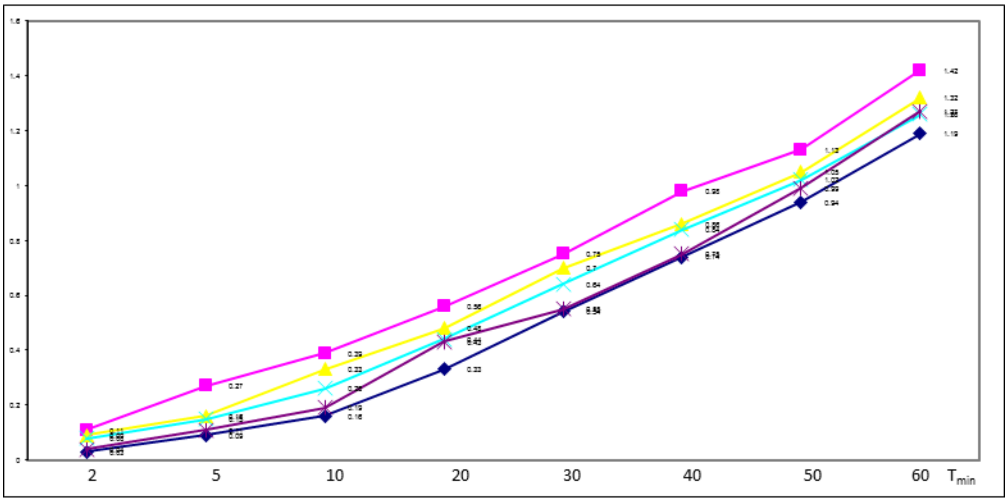

Figure 2. Impact of cutting speed, feed, and feed depth on wear in machining steel of 45 grade when

Table 3

Wear dynamics of the cutting edge when turning steel of 20X13 grade blank by the following parameters of variable modes when

$V_{max} = 150$ **(m/min);** $S_{max} = 0.1$**(mm/rev);** $t_{max} = 2$ **(mm),**

No	1	2	3	4	5
HRA	91,1	90,4	91,2	90,6	92
HB	137	148	172	181	175
5	0,06	0,04	0,07	0,09	0,07
10	0,11	0,09	0,13	0,15	0,14
20	0,18	0,18	0,2	0,22	0,21
30	0,26	0,25	0,3	0,3	0,31
40	0,35	0,36	0,37	0,38	0,4
50	0,44	0,43	0,46	0,49	0,47
60	0,54	0,52	0,55	0,6	0,57

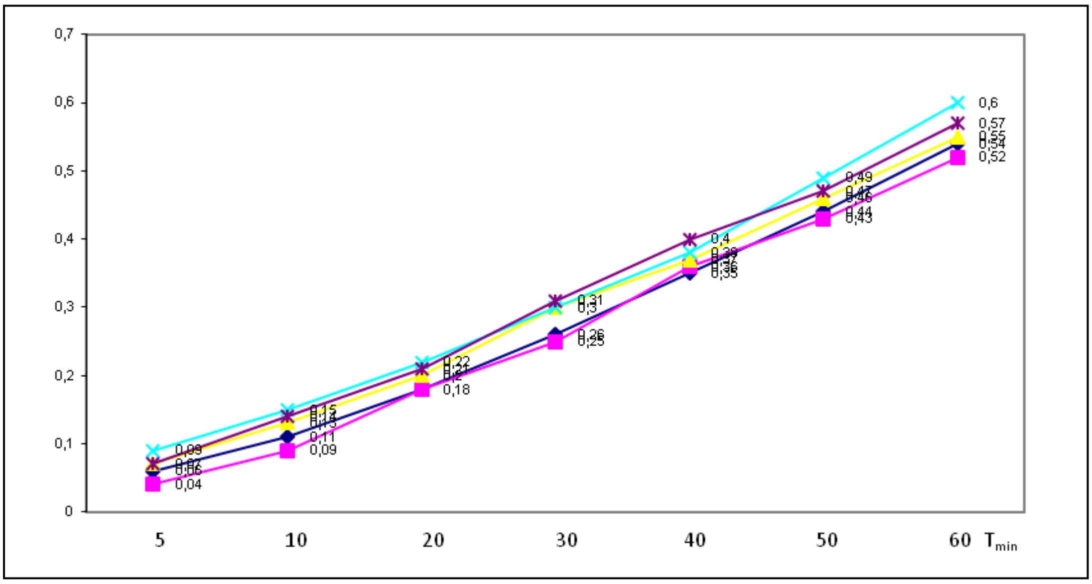

Figure 3. Impact of cutting speed, feed, and feed depth on wear in machining steel of 20X13 grade when V_{max}=150m/mim, S_{max}=0,1mm/rev. t_{min}=2mm

Table 4

Wear dynamics of the cutting edge when turning steel of 30XM grade blank by the following parameters of variable modes when

$V_{max} = 80$ **(m/min);** $S_{max} = 0.3$**(mm/rev);** $t_{max} = 1.5$ **(mm),**

No	1	2	3	4	5
HRA	91,5	91,4	91,1	91,5	91,5
HB	318	304	304	327	327
10	0,18	0,2	0,26	0,25	0,29
20	0,32	0,33	0,4	0,34	0,4
30	0,41	0,45	0,52	0,46	0,51
40	0,55	0,54	0,61	0,6	0,65
50	0,67	0,65	0,72	0,75	0,73
60	0,85	0,83	0,91	0,89	0,9
50	0,67	0,65	0,72	0,75	0,73
60	0,85	0,83	0,91	0,89	0,9

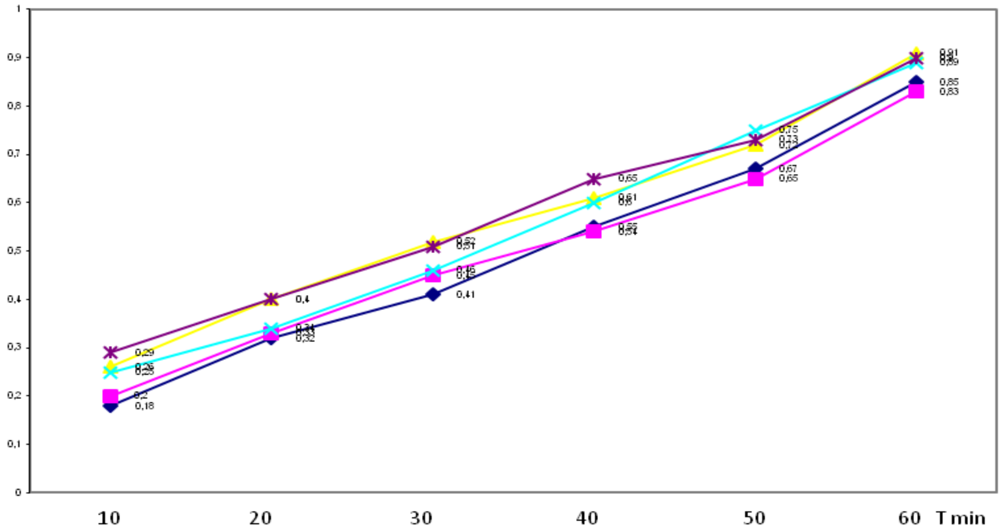

Figure 4. Impact of cutting speed, feed, and feed depth on wear in machining steel of 30XM grade when V_{max}=80m/mim, S_{max}=0,3mm/rev. t_{min}=1,5mm

For steels under study root-mean-square deviation of the cutting tool cutting edge increased during machining process and dispersion – decreased. At that the curve of the root-mean-square deviation had a character of the tool wear, that is in 8-10 time period we have intensive wear (run-in) zone, at a later time – (normal working) and catastrophic wear zones. In the first zone the wear curve had underwent essential oscillations and had no definite direction. For this reason cutting tool wearing process modeling has been done for the second zone. The root-mean-square deviation of the wear in case of optimal comparison of hardness of the tool and work piece materials depending on the time was 0,0205-0,0305, and in case of not optimal comparison (HB-max, HRA-min) it was 0,0259-0,384. In case of optimal comparison root-mean-square deviation decreased by 21 percent.

It has become clear that in case of smooth machining all steels under study depending on parameters of cutting modes of turning in 2-6o minutes time interval cutting speed decreased in the main slowly and negligibly. Therefore, it can be assumed invariable. However, in 8-10 minutes time interval (running-in zone of the tool) tool-wear rate is 1,5-2 times higher than in the normal wear zone. In case of rough work of steels of all grades normal wear from 5-10 to 50-70 minutes interval tool-wear rate can be considered constant, however 1,5-2 times lower than in smooth machining.

On the bases of obtained experimental data processing mathematical models of connections have been developed having the following form:

Tools stability model – T=f(V,S,T,HRA,HB,h3).

Tools wear intensity model – Vh3=f(V,S,T,HRA,HB),

Tools wear model – h3= f(V,S,T,HRA,HB),

Tools wear statistical characteristics - root-mean-square deviation $(\sigma h3)$ and $(Vh3)$

For steel 45

T-dependence is negligible,

$$h_3 = -9.567 + 095S + 0.6t + 0.006HRA + 0.019HB + 0.006T \,, \tag{1}$$

$$\sigma h_3 = 0.195 - 0.01V - 0.06S - 0.1t - 0.07HRA - 0.12HB - 0.78T \,, \tag{2}$$

$$vh_3 = -26.742 - 0.8V + 0.201S + 0.074t + 0.254HRA + 0.14.HB - 0.77T \,, \tag{3}$$

$$Vh_3 = -21.056 + 0.914S + 0.094t + 0.017HRA + 0.025HB \;: \tag{4}$$

For steel 40X

T-dependence is negligible,

$$h_3 = 71.615 + 1.16S - 0.07t - 0.08HRA + 0.024HB + 0.009T, \quad (5)$$

$$\sigma h_3 = 2.131 - 0.27V + 1.38S - 0.24t - 1.3HRA + 0.754HB - 0.41T, \quad (6)$$

$$vh_3 = 24.0439 - 0.33V + 0.18S - 0.13t - 0.39HRA + 0.24HB - 0.88T, \quad (7)$$

$$Vh_3 = 69.076 + 1.17S - 0.07t - 0.07HRA + 0.23HB: \quad (8)$$

For steel 30XM

$$\mathrm{T = -1842.393 - 0.44V - 61S - 1.6t + 1.35HRA + 0.109HB + 61.6h3}, \quad (9)$$

$$\mathrm{h_3 = 21.958 + 0.07V + 0.985S + 0.025t - 0.02HRA + 0.015T}, \quad (10)$$

$$\sigma \mathrm{h_3 = 0.348 + 0.103V + 0.504S + 0.163t - 0.09HRA - 0.03HB - 0.63T}, \quad (11)$$

$$vh_3 = \mathrm{-1.343 - 0.27V - 0.08S + 0.015t + 0.039HRA - 0.03HB - 0.83T}, \quad (12)$$

$$Vh_3 = \mathrm{41.292 + 0.004V + 1.2S + 0.02t - 0.04HRA}: \quad (13)$$

For steel 20X13

$$\mathrm{T = 12160.959 - 0.49V - 35S - t - 7.6HRA - 0.34HB + 43.8h3}, \quad (14)$$

$$\mathrm{h_3 = 185.782 + 0.011V + 0.799S + 0.024t + 0.179HRA + 0.008HB + 0.013}, \quad (15)$$

$$\sigma \mathrm{h_3 = 1.298 - 0.2V + 0.4S + 0.116t - 0.18HRA + 0.19HB + 0.048T}, \quad (16)$$

$$vh_3 = \mathrm{-1.417 - 0.33V - 0.09S - 0.05t + 0.014HRA + 0.031HB - 0.84T}, \quad (17)$$

$$Vh_3 = \mathrm{-216.021 + 0.009V + 0.779S + 0.02t + 0.209HRA + 0.008HB}: \quad (18)$$

Models 1 -20 are equivalent which is shown in Table 5, this can be evaluated as satisfactory.

Table 5

Quality of 1-20 models equivalency

Model №	Determination factor R^2	Degree of determination factor impact P	Fisher's coefficient :F
1.	-	-	-
2.	0,999	0,000000	181949,8
3.	0,561	0,000000	11,4398
4.	0,631	0,000000	14,43370
5.	0,999	0,000000	449129,9
6.	-	-	-
7.	0,999	0,000000	319230,7
8.	0,358	0,000362	5,369942
9.	0,819	0,000000	36,63906
10.	0,999	0,000000	1390265
11.	0,935	0,000000	115,7391
12.	0,999	0,000000	502231,5
13.	0,5579	0,000000	10,88894
14.	0,7286	0,000000	22,03894
15.	0,999	0,000000	271990,1
16.	0,633	0,000000	16,56992
17.	0,999	0,000000	80275,36
18.	0,142	0,037394	2,463527
19.	0,754	0,000000	28,14314
20.	0,999	0,000000	77338,66

Regression analysis of the developed models has shown that impact of cutting speed, feed, and feed debt on cutting tool wear and root-mean-square deviation and variation coefficient is different. The cutting speed impact on the cutter wear and its root-mean-square deviation is higher than cutting feed and feed debt. On the contrary, feed and feed debt impact on variation coefficient is higher than cutting speed. Wear of the tool by increase of cutting speed, feed, and feed debt increases, but in that case its root-mean-square deviation that is also increases, that is wear values dispersion. The dependence of the variation coefficient from cutting speed and feed has an extremal character which means that by the feed increase variation coefficient also increases and its minimum value is shifted towards the cutting speed.

Conclusion

The developed connection models take into consideration not only impact of cutting speed, feed, and feed debt onto cutting tools wear and their statistical characteristics but also their interference, and physical-mechanical properties of work piece and tool materials as well [5]. Statistical optimization of the cutting process enables to create conditions under which minimum intensity of cutting tools wear and minimum dispersion of the wear value are obtained.

On the basis of the developed connection models we can determine optimal stability of an edge-tool and its statistical characteristics while machining steels by variable cutting modes [6]. Raising guarantied stability of edge-tools up to optimal stability will increase endurance of cutting tools and ensure high economy.

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ՊՈՂՊԱՏԻ ՓՈՓՈԽԱԿԱՆ ԿՏՐՄԱՆ ՌԵԺԻՄՆԵՐՈՎ ՄՇԱԿՄԱՆ ԴԵՊՔՈՒՄ ԿՏՐԻՉՆԵՐԻ ԱՇԽԱՏՈՒՆԱԿՈՒԹՅԱՆ ՀԵՏԱԶՈՏՈՒՄԸ

Պ. Յու. Գասպարյան
Շուշիի տեխնոլոգիական համալսարան

Ավտոմատացված արտադրությունում մշակաման արդյունավետությունը կարելի է բարձրացնել, եթե փոփոխենք մշակման կտրման ռեժիմները՝ կախված կտրման պրոցեսի արտադրողականությունից և գործիքի մաշից:Գործիքի մաշվածության պատահական բնույթը որոշվում է նախ և առաջ մշակման պայմաններով, որոնցից են կտրման ռեժիմների տատանումները, քսուկահովացնող հեղուկների մատուցումը և տիպը, գործիքի երկրաչափությունը, մշակող և մշակվող նյութերի հատկությունները, հաստոցի շահագործական պարամետրերը և այլն: Ուսումնասիրվել է պատահական գործոնների ազդեցությունը կտրող գործիքի մաշման բնույթի և ինտենսիվության վրա պողպատ 45-ի, 40X-ի, 30XM-ի և 20X13-ի փոփոխական կտրման ռեժիմներով մշակման դեպքում: Բացահայտվել է կտրիչների հետին մակերևույթով մաշման և կայունության պարամետրերի միջև փոխադարձ կապը: $2^{(6-3)}$ սխեմայով, բոլոր դեպքերի համար կառուցվել է $h_3 = f(T)$ կախվածության գրաֆիկները (նկ.1, 2, 3, 4…): Բազմագործոն ռեգրեսիոն վերլուծության ծրագրով կատարվել է փորձնական տվյալների վիճակագրական մշակում, որի արդյունքում ստացվել են կապերի մաթեմատիկական մոդելներ հետևյալ տեսքով. գործիքների կայունության մոդել – $T = f(V, S, T, HRA, HB, h_3)$, գործիքների մաշման ինտենսիվության մոդել – $Vh_3 = f(V, S, T, HRA, HB)$, գործիքների մաշի մոդել – $h_3 = f(V, S, T, HRA, HB,)$, գործիքների մաշի վիճակագրական բնութագրերը՝ միջին քառակուսային շեղումը (σh_3) և դիսպերսիան (υh_3):

Բանալի բառեր. կտրող եզր, մաշվածություն, աշխատունակություն, կայունություն, կտրման ռեժիմներ, մաշման ինտենսիվություն, մետաղակերամիկական կարծր համաձուլվածք:

ИСЛЕДОВАНИЕ РАБОТАСПОСОБНОСТИ РЕЗЦОВ ПРИ ОБРАБОТКИ СТАЛИ С РАЗНЫМИ РЕЖИМАМИ РЕЗАНИЯ

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В автоматизированном производстве производительность обработки можно повышать, при изменении режимов резания обработки, в зависимости от производительности процесса резания и износа инструмента. Случайный характер износа инструмента определяется прежде всего условиями обработки, которыми являются колебания режимов резания, подача и тип смазочно-охлаждаюших жидкостей, геометрия инструмента, свойства обрабатывающих и обрабатываемых материалов, эксплуатационные параметры станка итд.

Исследован процесс точения сталей марок сталь 45; 40Х; 30ХМ; 20Х13 в широком диапазоне изменения режимов резания при действии возмущающих факторов нестабильности режущих свойств инструмента и обрабатываемости заготовки на характер и интенсивность износа инструмента. Установлена взаимосвязь износа задней поверхности и параметрами стойкости резцов. По схеме 26-3 получены кривые реализации функции $h_3 = f(T)$ (рис.1, 2, 3, 4, …). По программе многофакторного регресионного анализа проведена статистическая обработка эксперементальных данных, в результате которой получены математические модели связей в следующей форме; модель стойкости инструмента: $T = f(V, S, T, HRA, HB, h_3)$; модель интенсивности изнашивания: $\mathrm{Vh}_3 = \mathrm{f(V, S, T, HRA, HB)}$; модель износа инструмента: $\mathrm{h}_3 = \mathrm{f(V, S, T, HRA, HB,)}$ и их статистических характеристик: средне квадратическое отклонение *(σh₃)* и дисперсия *(υh₃)*:

Ключевые слова. Режушая грань, изношенность, работоспособность, стойкость, режимы резания, интенсивность изнашивания, металокерамические твердые сплавы.