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CORRELATION OF SURFACE ROUGHNESS, TOOL WEAR, AND CHIP SLENDERNESS RATIO IN THE LATHE PROCESS OF ALUMINUM ALLOY – 6061

Sudjatmiko
Master of Engineering*
E-mail: sudjatmiko@unmer.ac.id
Rudy Soenoko
Professor**
E-mail: rudysoen@ub.ac.id
Agus Suprapto
Professor*
E-mail: agusuprapto@yahoo.com
Moch Agus Choiron
Associate Professor**
E-mail: agus_choiron@ub.ac.id
*Department of Mechanical Engineering
University of Merdeka Malang
Jalan. Terusan Raya Dieng, 62,
Malang, Indonesia, 65146
**Department of Mechanical Engineering
Brawijaya University
Jalan. Mayjend Haryono, 167,
Malang, Indonesia, 65145

Дослідження процесу токарної обробки показало, що радіус вершини різця є одним з факторів, що впливають на шорсткість поверхні як показник якості виробу. Коефіцієнт гнучкості стружки є важливим параметром в токарному процесі, який може застосовуватися теоретично або емпірично. Процес токарної обробки проводився на алюмінієвому сплаві – 6061. Досліджено вплив обраних характеристик, а саме шорсткості поверхні (SR), площі поверхні зносу різця (Vb) і коефіцієнта гнучкості стружки (δ). Вибір радіусу вершини основного різця (ns), швидкості обертання шпинделя (n), швидкості подачі (vf) і глибини різання (a) може вплинути на шорсткість поверхні, за умови постійності, на форму і коефіцієнт гнучкості стружки і площу поверхні зносу різця по задній поверхні. Форма стружки в токарному процесі залежить від шорсткості поверхні виробу, коефіцієнта гнучкості стружки і зносу різця по задній поверхні.

В експериментальному дослідженні і статистичному аналізі використовувався метод експериментального проектування ортогональної матриці L_9 (3^4) по Тагуті. Параметрами, що використовувались в процесі токарного різання алюмінієвого сплаву – 6061, були кут загострення різця, швидкість обертання шпинделя, глибина різання і швидкість подачі, які вплинули на характеристики ((SR), (δ) і Vb).

Внесок кожного фактора в результат визначається дисперсійним аналізом. За допомогою дисперсійного аналізу, отримана модель множинної регресії зі співвідношення факторів (ns, n, vf і a) до характеристик (SR, δ і Vb), що виражається наступним рівнянням: $SR=0,955556+0,074444ns+0,006667n+0,005556vf-0,001111a$, $\delta=7,18889-1,17556ns-0,59222n-0,60222vf-0,09111a$, ***і*** $Vb=0,320370-0,073704ns-0,021481n-0,041481vf-0,032593a$.

Результати кореляції показали, що при (а) радіусі вершини різця 0,4 мм, швидкості подачі 56 мм/хв і глибині різання 0,25 мм, SR=1,11 мкм, при (б) радіусі вершини різця 1,2 мм, швидкості подачі 58 мм/хв і глибині різання 0,25 мм, δ=7,07, при (в) радіусі вершини різця 0,4 мм, швидкості подачі 60 мм/хв і глибині різання 0,50 мм, Vb=0,34 мм^2***. Зроблено висновок про сильний вплив на кореляцію значення*** R^2 ***по відношенню до SR=97,89 %, δ=94,45 % і Vb=67,30 %***

Ключові слова: радіус вершини, коефіцієнт гнучкості стружки, шорсткість поверхні, знос по задній поверхні, метод Тагуті, дисперсійний аналіз

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1. Introduction

Surface roughness is an important indicator in the lathe process, the main factors affecting surface roughness are cutting speed, depth of cut, and feed rate, machine tool vibration, fluid temperature, tool geometry, etc. This indicates that surface roughness, surface area of tool flank wear and chip slenderness ratio are influenced by the tool nose radius, cutting speed, and depth of cut. The surface area of the tool flank wears. The surface area of the tool flank wears and illustrates the gradual failure of the lathe cutting tool due to the effect of tool friction with hard particles on the surface of the lathe and high cutting temperatures. The increase of cutting speed and nose radius results in a better surface and increased tool edge wear, and affects the lathe cross section on the value of the chip slenderness ratio. Flow chips types that appear in the lathe process in the Aluminum Alloy 6061 material are classified according to the shape of cross section. The continuous and discontinuous form formed in the lathe process has its own unique characteristics, in terms of the material. The chip slenderness ratio (δ) is the result of a comparison of the chip width after being cut divided by the chip thickness after being cut, can be used to identify the characteristics of the chip form. The selection of the main cutting tool nose radius, depth of cut, spindle speed and feeding speed can affect the chip shape and the chip slenderness ratio.

The chip shape of the lathe process has a correlation with the product surface roughness, chip slenderness ratio, and surface area of tool flank wear. For example, most of the material used in the lathe process research is steel with a reference value of specific cutting force $K_{s1.1}$ 1,570 N/mm^2 greater than that of $K_{s1.1}$ 370 N/mm^2 [5], this will affect the specific cutting force so that the results of surface roughness, surface area of tool flank wear and chip slenderness ratio (δ) will have effects.

2. Literature review and problem statement

The Aluminum 6061 lathe process illustrates the relationship between feed motion to surface quality, results in improving surface quality and minimizing machining time, and maximizing productivity [1]. The machining parameter of the depth of cut is the most influential factor to reduce surface roughness. The larger the nose radius will result in a better surface compared to the small tool nose radius, depth of cut and a small feed rate [2, 3]. The hypothesis indicates that with the implementation of the nose radius there is a substantial relationship, or the effect of the interaction between the nose radius and the flank radius is relatively small experiencing flank wear [4]. Tool wear occurs due to changes in cutting mechanical energy into heat energy. Many kinds of failures or chisel defects are resulted, such as flank wear, crater wear, chips build up (BUE) and catastrophic damage. This generally occurs when the tool nose suffers from an impact load as it often occurs in the process of expansion of cutting with feed rate (*f*) or large depth of cut (*a*) [5]. The chip slenderness ratio (δ) of the drilling process is affected by the feed rate and the tool's main angle, while the too small spindle speed is to be ignored. In this study, it can be seen that the surface morphology of the chip shape area has an increase in surface roughness without affecting the dimensions of the drill hole. As with the increasing chip slenderness ratio (δ), the driving force and tool wear decrease. The chip slenderness ratio (δ), optimal is 5:1, is the result of simultaneous research in the process of drilling and lathe parameters which are influenced by depth of cut and feed rate, thus affecting surface roughness [6].

The chip slenderness ratio is the parameter that most influences the surface roughness value influenced by the height and the low value of the chip slenderness ratio. The high chip slenderness ratio value will be obtained, high roughness value and a low chip slenderness ratio value will be obtained, low (smooth) roughness value.

Lathe process creates chip flow which can be classified based on the cross section. Wavy chips occur when the oscillating shear angle extensively causes fluctuations in cutting forces and changes in the chip thickness. [7, 8]. The chip slenderness ratio (δ) which is the result of a comparison of the chip width divided by the thickness of the chip after being cut off can be used to identify the characteristics of the chips form. The sliding angle in the metal cutting process with a high cutting speed can increase the effect of plastic deformation [9]. Tool geometry has a significant effect on chips, heat distribution, tool wear, product finish surface during the lathe process [10]. For each cutting process, the value of depth of cut (*a*) and feed motion (*f*) selected results in a certain value of the chip slenderness ratio (δ) as follows:

$$\delta=\frac{b}{h}=\frac{a}{f\left(\sin Kr\right)^{2}}. \tag{1}$$

The value varies depending on the selection of the value of *a* and *f* and the main cutting angle (*Kr*) used. In general, according to observations in practice, machine tool operators tend to choose the values of δ equal to 5, or at least δ=1 and the largest (δ)=50 (rarely found). The value of the chip slenderness ratio (δ) obtained due to the selection of certain *a* and *f* will affect the shape of the chip, especially in the process of cutting steel or metal which is ductile which generally has a continuous chips form [5]. The tool radius, cutting speed, depth of cut and specific feeding speed selection will influence the chip shape in the metal cutting process which generally has continuous and intermittent form of chips. Based on the explanation in the preceding paragraph, this study is aimed at figuring out the correlation of the effect of cutting parameters on surface roughness (*SR*), chip slenderness ratio (δ), and surface area of tool flank wear (*Vb*). Moreover, it was also aimed at determining the regression equation model of each response, analyzed using ANOVA.

3. The aim and objectives of the study

The purpose of the work is the relationship between surface roughness, chip slenderness ratio, and tool wear on the cutting parameters of the lathe process AA-6061.

To achieve this aim, the following objectives are accomplished:

– to find out the effect of the relationship of cutting parameters to surface roughness (*SR*), the smallest *SR* value is obtained;

– to find out the effect of the relationship of the cutting parameters to the chip slenderness ratio (δ), the value (δ) is the smallest;

– to find out the effect of the relationship between the cutting parameters to the surface area of tool flank wear (*Vb*), the smallest value (*Vb*) is obtained;

– to determine the regression equation model for *SR*; δ; and *Vb*, intended to determine the value of each result of the smallest equation.

4. Materials and research method

The research method used is an experimental research method to determine the effect of cutting parameters; tool nose radius (*ns*), spindle speed (*n*), feeding speed (*Vf*), depth of cut, which affect surface roughness, chip slenderness ratio (δ), and surface area of tool flank wear (*Vb*).

The lathe process used is dry cutting. The test material used was Aluminum Alloy – 6061 with the following mechanical properties: 350 MPa yield strength, 400 MPa tensile strength. The geometry of the test specimen is a solid cylinder with a diameter of 22 mm and a length of 100 mm (Fig. 1).

The study was carried out using a CNC TU 2 A lathe, with cutting radius parameters for tool nose radius of *ns* 1.2, 0.8, 0.4 mm, spindle speed of *n* 1000.1150, 1,250 rev/minute, feeding speed *vf* 56, 58, 60 mm/minute and depth of cut *a* 0.25, 0.35, 0.50 mm. Table 1 presents four factors with three levels for each factor.

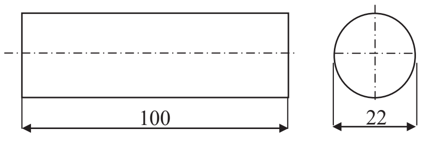


Fig. 1. Geometry of workpiece

Fig. 2. Carbides Insert tool (Catalog Dorian International Tool, 2013)

Table 1

Process and level parameters

Code	Parameter	Unit	Level 1	Level 2	Level 3
A	Nose radius (*ns*)	Mm	0.4	0.8	1.2
B	Spindle speed (*n*)	rev/min	1,000	1,150	1,250
C	Feeding speed (*vf*)	mm/min	56	58	60
D	Depth of cut (*a*)	mm	0.25	0.35	0.50

The experimental design presented in Table 2 is used for experimental analysis using the experimental design of L_9 OA Taguchi carried out with the analysis of variance (ANOVA).

Table 2

The results of the lathe process research using the L_9 Orthogonal Array

Models	Cuting Parameters				Response		
	ns, mm	*n*, rev/min	*vf*, mm/min	*a*, mm	*SR*, µm	*Vb* (mm^2)	(δ)
1	0.4	1,000	56	0.25	1.11	0.12	5.05
2	0.4	1,150	58	0.35	1.07	0.35	6.83
3	0.4	1,250	60	0.50	0.92	0.34	6.60
4	0.8	1,000	58	0.35	1.25	0.43	6.62
5	0.8	1,150	60	0.50	1.12	0.30	10.14
6	0.8	1,250	56	0.25	1.10	0.20	4.88
7	1.2	1,000	60	0.50	0.79	0.54	9.76
8	1.2	1,150	56	0.25	0.65	0.43	4.71
9	1.2	1,250	58	0.35	0.59	0.35	7.07

The experimental design is schematically shown in Fig. 3. The specimens resulted from the lathe process are measured using the MITUTOYO SURFTEST SJ-310 surface roughness tool. Thickness, chip width, and surface area of tool flank wear are measured using the Digital Microscope.

Fig. 3. Experimental design (Department of Mechanical Engineering CNC, Industrial Metrology and Metallography Laboratory, University of Merdeka Malang)

5. Results

5. 1. Analysis of surface roughness

Table 3 shows the ANOVA results from the average surface roughness (SR) where the results of significance are the nose radius (*ns*), with the results R^2=97.89 % and the test results $P<F(0.002<19.19)$.

Table 3

ANOVA for surface roughness (SR)

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*
ns	2	1.22496	1.22496	0.612478	116.87	0.000
n	2	0.20116	0.20116	0.100578	19.19	0.002
vf	2	0.00202	0.00202	0.001011	0.19	0.829
a	2	0.00162	0.00162	0.000811	0.15	0.860
*ns*a*	4	0.01582	0.01582	0.003956	0.75	0.590
*n*a*	4	0.01029	0.01029	0.002572	0.49	0.744
*vf*a*	4	0.00636	0.00636	0.001589	0.30	0.866
Residual Error	6	–	–	–	–	–
Total	26	1.49367	–	–	–	–
S=0.0724 R–Sq=97.89 % R–$Sq(adj)$=90.88 %						

The coefficient of determination R^2=97.89 % has a very strong influence on the response parameters of the response to the response variable, this is useful for predicting and seeing as much as the contribution of influence given the simultaneous cutting parameters (together) to the response variable (*SR*), with a very small deviation (S=0.0724), so that this equation can be said to be linear regression. The factors that influence the results of surface roughness are feeding speed *(vf)*, from the depth of cut (*a*). The multi regression equation (2) has a relationship with the parameter (*ns*, *n*, *vf* and *a*) as follows:

$$SR = 0.955556 + 0.074444ns + 0.006667n + \\ + 0.005556vf - 0.001111a. \quad (2)$$

Fig. 4 indicates the main effect plot of the final surface of a product in the lathe process. Tool nose radius (*ns*) of 1.2 mm, spindle speed of 1,250 rpm, feeding speed (*vf*) of 60 mm/min, depth of cut (*a*) of 0.35 mm, in response conditions produce product quality with *SR* of 0.59 µm. This is influenced by the feeding speed (*vf*) and depth of cut (*a*), in this case there is the interaction of the tool nose radius (*ns*) with the depth of cut (*a*).

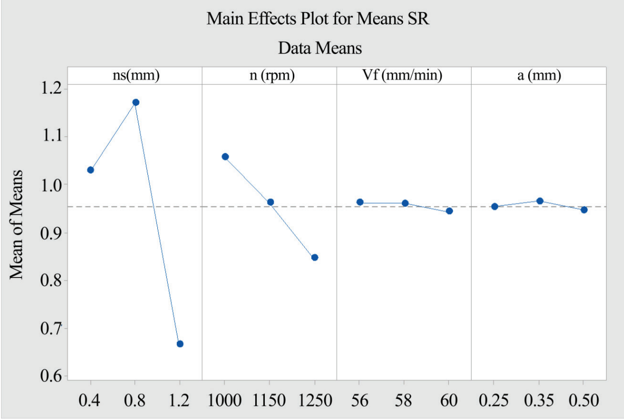


Fig. 4. Main effects of surface roughness of each factor for various levels

5. 2. Chip slenderness ratio (δ)

Table 4 shows the ANOVA results of the average chip slenderness ratio (δ) where the results of the significance are tool nose radius (*ns*), with the results R^2=94.45 % and the results of the $P<F$ test (0.013<9.74).

Table 4

Analysis of Variance for Means of Chip Slenderness Ratio (δ)

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*
ns	2	18.661	18.661	9.3305	9.74	0.013
n	2	12.721	12.721	6.3607	6.64	0.030
vf	2	17.969	17.969	8.9846	9.38	0.014
a	2	1.649	1.649	0.8246	0.86	0.469
*ns*a*	4	10.584	10.584	2.6459	2.76	0.128
*n*a*	4	14.467	14.467	3.6169	3.77	0.072
*vf*a*	4	21.836	21.836	5.4590	5.70	0.031
Residual Error	6	5.750	5.750	0.9583	–	–
Total	26	103.637	–	–	–	–
S=0.9789 $R–Sq$=94.45 % $R–Sq(adj)$=75.96%						

The coefficient of determination R^2=94.45 % has a very strong influence on the response parameters of the response to the response variable, this is useful for predicting and seeing as much as the contribution of influence given the simultaneous cutting parameters (together) to the response variable (*SR*), with a very small deviation (S=0.978), so that this equation can be said to be linear regression.

There are no factors that influence the cutting parameters, there is interaction of the tool nose radius (*ns*) with the depth of cut (*a*), spindle speed (*n*) with respect to the depth of cut (*a*), and feeding speed (*vf*) with respect to the depth of cut (*a*). The multiregression equation (3) has a relationship with parameters (*ns*, *n*, *vf* and *a*) as follows:

$$\delta = 7.18889 - 1.17556ns - 0.59222n - \\ - 0.60222vf + 0.09111a. \quad (3)$$

Fig. 5 shows that the main effect plot resulted by the chip slenderness ratio (δ) is the form of the chips dimension of the lathe process. Nose radius (*ns*) of 1.2 mm, spindle speed of 1,150 rpm, feeding speed (*vf*) of 56 mm/min and depth of cut (*a*) of 0.50 mm on average conditions produce chip slenderness ratio (δ) of 4.71. In this case there was no significant effect on machining parameters. There is the interaction of the tool nose radius (*ns*) with respect to the depth of cut (*a*), spindle speed (*n*) with respect to the depth of cut (*a*), and feeding speed (*vf*) with respect to the depth of cut (*a*).

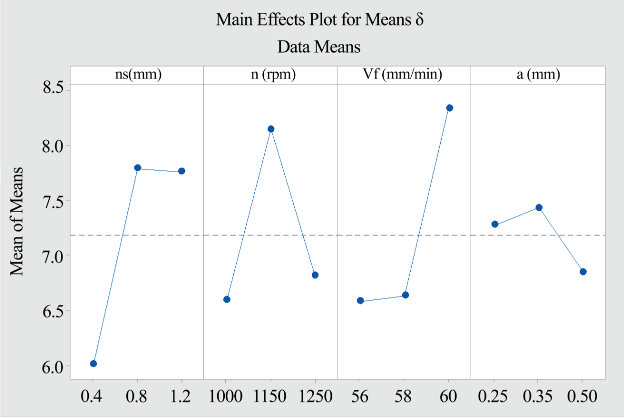


Fig. 5. Main effects of chip slenderness ratio (δ) of each factor for various levels

5. 3. Surface Area of flank wear (*Vb*)

Table 5 shows the ANOVA results of the surface area of tool flank wear (*Vb*) which is significant for surface area of tool flank wear (*Vb*), depth of cut (*a*), results of R^2=67.30 %, the results of the $P<F$ test (0.117<3.13) and (0.577<0.60).

The coefficient of determination R^2=67.30 % has a very strong influence on the response parameters of the response to the response variable, this is useful for predicting and seeing as much as the contribution of influence given the simultaneous cutting parameters (together) to the response variable (*SR*), with a very small deviation (S=0.141), so that this equation can be said to be linear regression.

Other factors influencing cutting parameters are feeding speed (*vf*) and depth of cut (*a*), there is the interaction of the tool nose radius (*ns*) with respect to the depth of cut (*a*), spindle speed (*n*) with respect to the depth of cut (*a*), and feeding speed (*vf*) with respect to the depth of cut (*a*).

Table 5

Analysis of Variance for surface area flank wear (*Vb*)

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*
ns	2	0.13001	0.13001	0.065004	3.13	0.117
n	2	0.01425	0.01425	0.007126	0.34	0.723
vf	2	0.02503	0.02503	0.012515	0.60	0.577
a	2	0.01434	0.01434	0.007170	0.35	0.721
*ns*a*	4	0.01621	0.01621	0.004054	0.20	0.932
*n*a*	4	0.02657	0.02657	0.006643	0.32	0.855
*vf*a*	4	0.02993	0.02993	0.007481	0.36	0.829
Residual Error	6	0.12456	0.12456	0.020759	–	–
Total	26	0.38090	–	–	–	–
$S=0.1441$ $R\text{–}Sq=67.30\ \%$ $R\text{–}Sq(adj)=0.00\ \%$						

The multiregression equation (4) has a relationship with parameters (*ns*, *n*, *vf* and *a*) as follows:

$$Vb = 0.320370 - 0.073704ns - 0.021481n - \\ - 0.041481vf - 0.032593a. \qquad (4)$$

Fig. 6 shows that the main effect plot resulted by the surface area of tool wear (*Vb*). Tool nose radius (*ns*) 1.2 mm, spindle speed 1,150 rpm, feeding speed (*vf*) 60 mm/min, and depth of cut (*a*) 0.50 mm on average conditions produce the surface area of tool wear (*Vb*) 0.35 mm^2. There is interaction of the tool nose radius (*ns*) with respect to the depth of cut (*a*), spindle speed (*n*) with respect to the depth of cut (*a*), and feeding speed (*vf*) with respect to the depth of cut (*a*).

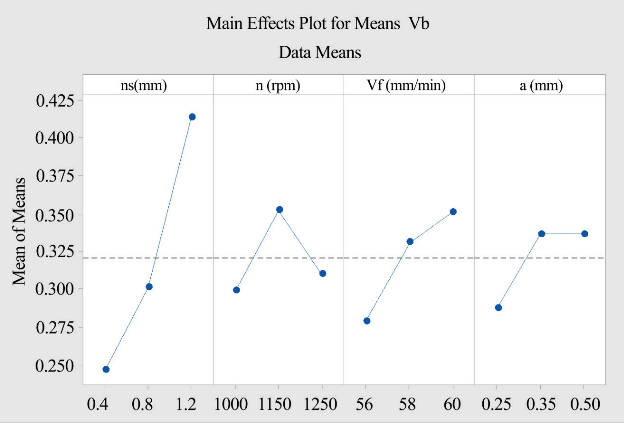
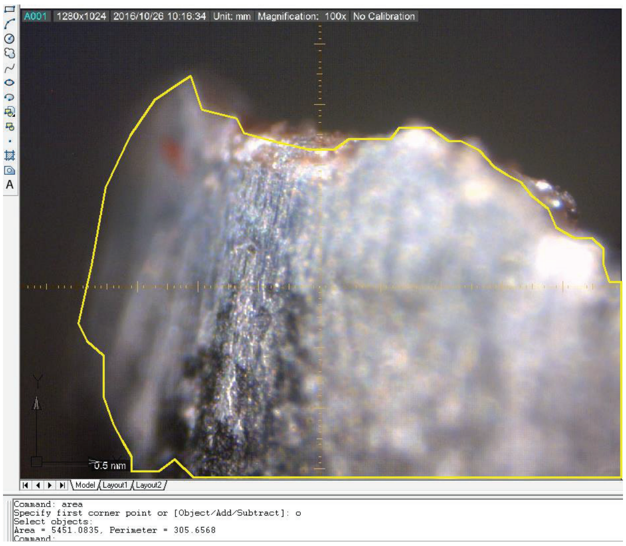


Fig. 6. Main effects of surface area of flank wear (*Vb*) of each factor for various level conditions

6. Discussion of the experimental results

6. 1. Surface measurements of the flank wear area (*Vb*)

Fig. 7 shows the results of measurement of the surface area of verification of the surface area of tool wear model 7, tool nose radius at 1.2 mm, measurement with 1,000 X magnification produces an area of 5451.0835 μm^2 (0.54 mm^2), lathe processing time is 210 seconds with 3 x processes (70 seconds/process). Verification of the surface roughness value of 0.79 μm and the chip slenderness ratio of 9.76, according to [2, 5, 6, 10, 11]. If the nose radius increases, the area of sliding contact increases, resulting in a large surface area of flank wear (*Vb*). If the nose radius increases, the area of sliding contact increases, resulting in a large surface area of flank wear (*Vb*).



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Area = 5451.0835, Perimeter = 305.6568
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Fig. 7. Surface area of tool wear model 7

6. 2. Chip slenderness ratio (δ) result graph of each model

Fig. 8 of the results of the chip slenderness ratio (δ) on the cutting parameters (*n*, *ns*) shows that the value (δ) 10.4, machining conditions *ns* 0.8, *n* 1150, and *a* 0.50, with product quality (*SR*) 1.12 μm obtain the surface area of tool wear (*Vb*) 0.30 mm^2, according to [5] in the range of values of the chip slenderness ratio (δ)=2–20. According to the results of research on the form of growl in the form of more desirable debris, it is approached with a specific cutting force formula as follows [5]:

$$K_s = K_{s.1.1} h^{-z} \left(\text{N/mm}^2\right), \qquad (5)$$

where *h* – chips thickness (mm); *B* – width of cut (mm); *Z* – chip thickness rank.

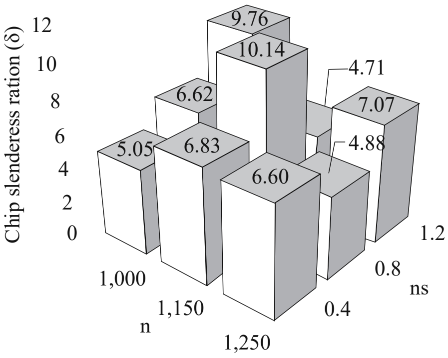

Fig. 8. Graph of chip slenderness ratio (δ) on each model

The calculation on formula (5) was based on two variables of depth of cut (*a*), feeding speed (*vf*), and tool oblique angle (λ*s*) or two variables of chip dimension before being cut; b and h are used, and the tool nose radius was ignored.

The principal cutting edge angle and the rake angle. Influences, among others, on the cross section, cutting force, and tool life, the difference in depth of cut (*a*) which will cause different chip width divided (*b*) which causes a difference in cutting force (*Fc*) [5].

This research has limitations. They are:

a) the value of the specific reference force of the specific aluminum alloy metal does not yet exist;

b) the position change of tool geometry is not optimum, only carbide inserts are used;

c) the picture taking the wide metal microscope and chip thickness after being cut was less accurate.

6. 3. Surface roughness

Fig. 9 shows that if the nose radius (*ns*) is greater, the depth of cut (*a*) is large and feeding speed (*vf*) is constant, the amount of sliding contact area increases and produces a low surface roughness [12, 13], also affects the surface area of tool wear (δ) which is quite large and the surface area of the tool wear is enlarged [5]. Surface fineness is affected by: (*a*) stiffness conditions of the cutting system on the lathe (*b*), tool nose radius and (*c*) the ability of the workpiece machine.

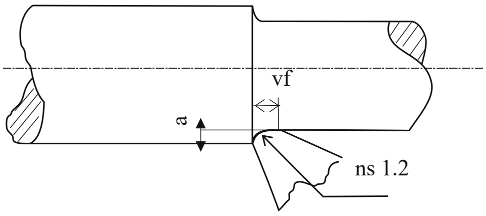

Fig. 9. Sketch of the influence of the nose radius on surface roughness, surface area of tool wear and chip slenderness ratio (δ)

From the visualization of chip type in Fig. 10, it proves that all models produce a continuous chip type because they are in a range of values of (δ). From this research, it can be developed to the chip slenderness ratio (δ) with non-ferrous material and the change in tool geometry will be obtained by the amount of lathe force, tool life.

Research on the development of advanced lathe processes is recommended:

1. In this study, predictions of the surface area of tool flank wear and chip slenderness ratio (δ) to the frequency range of the lathe process using aloe vera lubrication.
2. Effects of the chip slenderness ratio (δ) on cutting force and cutting power in the lathe process, and surface roughness.
3. The temperature of the dry lathe has an effect on the cutting force, cutting power to the surface area of tool flank wear.

Fig. 10. Continuous chip visualization on model 7 with a 1.2 mm nose radius

7. Conclusions

1. Tool nose radius (*ns*) 1.2 mm, spindle rotation 1,250 rpm, feeding speed rate (*vf*) 60 mm/min, depth of cut (*a*) 0.50 mm in response conditions produce good product quality *SR* 0.59 μm.
2. Tool nose radius (*ns*) 1.2 mm, spindle speed 1,150 rpm, feeding speed (*vf*) 56 mm/min, and depth of cut (*a*) 0.50 mm on average conditions produce a chip slenderness ratio (δ) 4.71.
3. Tool nose radius (*ns*) 1.2 mm, spindle speed 1,150 rpm, feeding speed (*vf*) 60 mm/min, and depth of cut (*a*) 0.50 mm on average conditions produce the surface area of tool wear (*Vb*) 0.35 mm^2.
4. The model equation for each response:

$$SR=0.955556+0.074444ns+0.006667n+$$
$$+0.005556vf-0.001111a,$$

$$\delta=7.18889-1.17556ns-0.59222n-$$
$$-0.60222vf-0.09111a,$$

$$Vb=0.320370-0.073704ns-0.021481n-$$
$$-0.041481vf-0.032593a.$$

This has an effect on the correlation of the R^2 value is very strong against surface roughness 97.89 %, the chip slenderness ratio is 94.45 %, and the surface area of tool flank wear is 67.30 %.

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EFFICIENCY ANALYSIS OF THE TECHNOLOGY OF ROLLER FORMATION OF FINELY-GRAINED CONCRETE PRODUCTS

O. Lazarieva
Doctor of Economic Sciences,
Associate Professor*
S. Belinska
PhD, Assosiate Professor**
E-mail: melek2405@bigmir.net
P. Lavrinev
PhD, Assosiate Professor*
N. Rudenko
PhD**
*Department of Land Management***
**Department of Accounting and Audit
***Petro Mohyla Black Sea National University
68 Desantnykiv str., 10,
Mykolaiv, Ukraine, 54003

Викладена ефективність використання технології роликового формування примусового повороту робочого органу (ролика чи сектора). Представлені результати розробки удосконаленої технології роликового формування. Особливостями цієї технології є відсутність прослизання і заклинювання робочого органу відносно поверхні бетонної суміші, що формується. Воно виникає за рахунок зростання інерційних сил роликів, що вільно обертаються.

Вказані переваги даної технології перед вібраційною, а саме:

– можливість суміщення в одному агрегаті процесів розкладання, ущільнення та загладжування бетонної суміші, що створює, в першу чергу, можливість організації високомеханізованих та автоматизованих технологічних ліній, і, тим самим, підвищити їх продуктивність:

– можливість ефективного ущільнення особливо жорстких дрібнозернистих бетонних сумішей, що, в свою чергу, створює передумови для отримання довговічних виробів, скорочення циклів термообробки, а також зменшення металомісткості виробництва;

– можливість використання дрібнозернистих сумішей з нестачею цементного тіста, що не перевищують норми для бетону на крупному заповнювачі;

– можливість ефективного покращення санітарно-гігієнічних умов для обслуговуючого персоналу за рахунок відсутності вібрації і суттєвого зниження шуму;

– відмова від дороговартісного і у ряді випадків дефіцитного крупного заповнювача, що дозволяє отримати значну економію.

Зазначені залежності характеризують і показують збільшення пресуючого тиску робочого органу на поверхню виробу, що формується. В результаті цього коефіцієнт ущільнення суміші збільшується з 0,983 (при вільному оберті ролику) до 0,998 (при примусовому його оберті)

Ключові слова: дрібнозерниста суміш стабілізуюча балка, фібробетон, сталефібробетон, стальні волокна, орієнтація фібри, примусовий оберт сектора

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1. Introduction

The need to increase efficiency of capital construction is inextricably linked with improvement of the reinforced concrete technology. Development of new and improvement of existing concrete forming methods substantially determine product quality and cost which is of great importance. Prospective and relevant forming methods include the non-