BEARING TOOLS MACHINING AND NEW EXPERIMENTAL EXPRESSION OF DURABILITY DEPENDENCE FOR SINTERED CARBIDE CUTTING

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Durability of the cutting tools is very complex process that is influenced by more factors. On the base of outputs and results these experiments can be completely described the most important elements acting on the resulting durability of a cutting tool. The technical science defines the basic method for determining durability of the cutting tool according to results and knowledge F. W. Taylor. This paper describes how to create and analytically express new durability dependence for sintered carbide cutting tool on the base of v_c-VB dependence. This dependence consists from v_c - cutting speed and VB - criterion of blunting. The whole procedure and its analytical expression is the subject of this paper.

KEYWORDS

durability, v_c-VB dependence, sintered carbide, analytical expression, turning

1 INTRODUCTION

In engineering can be used for experiments a lot of different technological operations. One of these operations is turning [Kazimir 1989, Panda 2011b].

The turning is the most basic process in machining because it forms 30% from all technologies of machining. In turning there are many types used of cutting tools made of different materials. One of these materials is sintered carbide [Panda 2013a, Panda 2013b, Zelenak 2012, Zajac 1995].

Sintered carbide is one of the most successful composite engineering materials ever produced. Sintered carbide's unique combination of strength, hardness and toughness satisfies the most demanding applications [Holesovsky 2012, Cep 2010, Petru 2014, Wolberg 2006].

Figure 1. Illustration figure of sintered carbide tools

Very important subject for engineering and machining how its subsystem, is the optimization of cutting parameters. For a lot of engineering companies is this process Necessary because the world economic crisis caused decrease of these companies productivity [Holesovsky 2014, Lattner 2014, Michalik 2010]. On the base of cutting parameters optimization will prolongs the life of cutting tool and thus the company can save some funds. This raises the question. How to extend cutting tool life and thus to optimize the cutting parameters? One way is the identification of cutting tool durability on the base of two elementary tests - The short-term durability test and the machining long-term test method. The both methods are for technical practice has long been known, but the both methods have their shortcomings [Cep 2010, Duplak 2013, Isakov 2009].

The Short-term durability test is able in a very short time to describe entire life-time process of cutting wedge and to analyse cutting tool suitability for selected type of machining. But this type has one very important disadvantage. For short-term durability test are implementing intermittent cutting test, whose basis is the stub test or strip test. Significant problem with short-term durability test is the emergence of suppressors. Machining long-term test method is essentially only one. Criterion is value of cutting speed and it makes by turning or milling with describes constant cutting parameters, type of cutting tool with defined geometry and graduated cutting speeds to the optimal tip blunting. This test is considered as basic and by this test takes measure objectivity of machinability for others tests. Disadvantage of this test is consumption of workpieces and time consumption [Duplak 2010, Kazimir 1989].

The comprehensive durability of cutting wedge, that was still described on the base of T-v_c dependence requires significant demands on material, precision, experiment time and in some cases isn´t precision. New method performed on the base of v_c-VB dependence each of these factors is eliminated [Hloch 2012, Panda 2011a, Pandova 2014, Szarkova 2013].

Authors in this paper submit results of research, which is founded on the base of time efficiency of performed experiments compared with known methods. The paper successively analyses procedure how to be v_c-VB dependence created; there are evaluated outputs and results of experiment. Paper shows the entire procedure how to analytically express the experiment and finally are evaluated all the pros and cons of the proposed method.

Figure 2. A schematic view of the turning process

2 EXPERIMENT SPECIFICATION

Very important step before the experiment is definition for used technological system. For experiment was used technological system consisting of machine - tool - workpiece.

2.1 Machine specification

For experiment was selected universal center lathe SU 50 because in the literature is recommended for the both defined methods at to determine durability of cutting tool the conventional center lathe.

Figure 3. Universal center lathe SU 50

2.2 Cutting tool specification

For experiment was selected cutting tool made of sintered carbide (P20 +TiN) because this type of cutting tool is used in significant extent for engineering practice, nowadays.

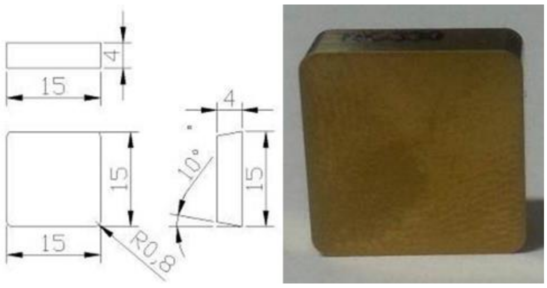

Figure 4. Dimensions and geometry of cutting tool (Sintered carbide – P20 +TiN)

2.3 Workpiece specification

Workpiece for the experiment is made of steel C45 because this type of steel is heavily used in manufacturing companies around the world and also this type of steel indicates the literature that describes methods for determining the durability of cutting tools. Material for workpiece is from specific material list with guaranteed chemical structure and mechanical properties.

Table 1. Chemical structure of material C45 [%]

Chemical structure of C45 [%]			
C	Mn	Si	Cr
0.42-0.50	0.50-0.80	0.17-0.37	max. 0.25
Ni	Cu	P	S
max. 0.30	max. 0.30	max. 0.040	max. 0.040

Table 2. Mechanical properties of material C45

Mechanical properties of C45				
Re [MPa]	Rm [MPa]	A5 [%]	HB	E [GPa]
min. 305	min. 530	16	max. 225	221

The main reasons of this experiment are shortcomings that were found on the base of analysis methods that are used nowadays for determination of cutting tool durability. The major aim was removing shortcomings used methods by means of new experimental dependence v_c-*VB*. This dependence was tested under defined technological conditions and by means of defined technological system. The entire procedure is based on predefined determined machining time that means ▯$_s$ is constant for all cutting speeds. After the expiry of the period is the measured value of *VB* - criterion of blunting. Value of *VB* is recorded to table for the appropriate value v_c. This procedure is repeated for all available range of cutting speeds for defined machine - the universal center lathe SU 50.

3 TECHNOLOGICAL CONDITIONS USED FOR EXPERIMENTS

$$v_c = 5{,}55 - 420 \text{ m.min}^{-1};\ a_p = 0.3 \text{ mm};$$
$$f = 0.1 \text{ mm};\ r_\varepsilon = 0.8\text{mm};\ \kappa_r = 80°;\ \kappa'_r = 10°;\ \tau_s = 5 \text{ min};$$

Table 3. Results of v_c – *VB* dependence for P20+TiN

v_c [m.min^{-1}]	*VB* after 5 min. machining[mm]
5.55	0.05
13.8	0.095
15.4	0.105
22.3	0.104
22.4	0.1
37.5	0.1
50	0.08
67.2	0.03
69	0.05
80	0.04
100	0.03
140.6	0.05
213	0.1
233	0.12
300	0.18
420	0.3

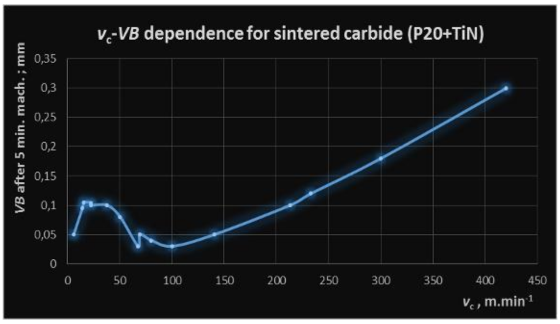

Figure 5. v_c - VB dependence for sintered carbide (P20+TiN)

4 ANALYTICAL EXPRESSION

Least square method represents computational procedure, of which main function is calculation of parameters of equation. Acquired dependence characterizes resulting process of graph. Complicated processing of graph cannot be correctly described according to certain dependencies. Function defined as f*(x) represents created prescription, which describes dependence in graph. Solution inaccuracy is described with parameter I, which represents index of correlation. This parameter value deals with rate of accuracy of described function, which was created by application of least square method. The main subject of analytical expression was creation of template, which contained necessary relations for determination of final relation [Björck 1996, Isakov 2009].

Table 4. Template 1 for least square method

	i	x_i	y_i	x_i^2	x_i^3	x_i^4	x_i^5	x_i^6
Σ								

After the calculation of elementary relations described in previous table, there were calculated values inserted into the next table and with these values there were mathematic operations according to template accomplished.

Table 5. Template 2 for least square method

	$x_i.y_i$	$x_i^2.y_i$	$x_i^3.y_i$	$\varnothing y_i$
Σ	n			

	y^*	y^*-y_i	$\varnothing y_i$-y_i
	Calculation of index of correlation *I*		
Σ			

	$(y^*-y_i)^2$	$(\varnothing y_i-y_i)^2$
	Calculation of index of correlation *I*	
Σ		

It was able to prescribe determinants D-D3 with obtaining of the elementary values from template. According to count of determinants it is obvious, that there will be cubical dependence.

$$D=\begin{vmatrix} n & \Sigma x_i & \Sigma(x_i)^2 & \Sigma(x_i)^3 \\ \Sigma x_i & \Sigma(x_i)^2 & \Sigma(x_i)^3 & \Sigma(x_i)^4 \\ \Sigma(x_i)^2 & \Sigma(x_i)^3 & \Sigma(x_i)^4 & \Sigma(x_i)^5 \\ \Sigma(x_i)^3 & \Sigma(x_i)^4 & \Sigma(x_i)^5 & \Sigma(x_i)^6 \end{vmatrix} \quad (1)$$

$$D_1=\begin{vmatrix} n & \Sigma x_i & \Sigma(x_i)^2 & \Sigma(x_i)^3 \\ \Sigma x_i & \Sigma(x_i.y_i) & \Sigma(x_i)^3 & \Sigma(x_i)^4 \\ \Sigma(x_i)^2 & \Sigma(x_i^2.y_i) & \Sigma(x_i)^4 & \Sigma(x_i)^5 \\ \Sigma(x_i)^3 & \Sigma(x_i^3.y_i) & \Sigma(x_i)^5 & \Sigma(x_i)^6 \end{vmatrix} \quad (2)$$

$$D_0=\begin{vmatrix} \Sigma y_i & \Sigma x_i & \Sigma(x_i)^2 & \Sigma(x_i)^3 \\ \Sigma(x_i.y_i) & \Sigma(x_i)^2 & \Sigma(x_i)^3 & \Sigma(x_i)^4 \\ \Sigma(x_i^2.y_i) & \Sigma(x_i)^3 & \Sigma(x_i)^4 & \Sigma(x_i)^5 \\ \Sigma(x_i^3.y_i) & \Sigma(x_i)^4 & \Sigma(x_i)^5 & \Sigma(x_i)^6 \end{vmatrix} \quad (3)$$

$$D_2=\begin{vmatrix} n & \Sigma x_i & \Sigma y_i & \Sigma(x_i)^3 \\ \Sigma x_i & \Sigma(x_i)^2 & \Sigma(x_i.y_i) & \Sigma(x_i)^4 \\ \Sigma(x_i)^2 & \Sigma(x_i)^3 & \Sigma(x_i^2.y_i) & \Sigma(x_i)^5 \\ \Sigma(x_i)^3 & \Sigma(x_i)^4 & \Sigma(x_i^3.y_i) & \Sigma(x_i)^6 \end{vmatrix} \quad (4)$$

$$D_3=\begin{vmatrix} n & \Sigma x_i & \Sigma(x_i)^2 & \Sigma y_i \\ \Sigma x_i & \Sigma(x_i)^2 & \Sigma(x_i)^3 & \Sigma(x_i.y_i) \\ \Sigma(x_i)^2 & \Sigma(x_i)^3 & \Sigma(x_i)^4 & \Sigma(x_i^2.y_i) \\ \Sigma(x_i)^3 & \Sigma(x_i)^4 & \Sigma(x_i)^5 & \Sigma(x_i^3.y_i) \end{vmatrix} \quad (5)$$

With the calculation of determinants we were able to determine their values and specify coefficients (a_0, a_1, a_2, a_3) of final formula.

$$a_0 = \frac{value\ of\ determinant\ D_0}{value\ of\ determinant\ D} \quad (6)$$

$$a_1 = \frac{value\ of\ determinant\ D_1}{value\ of\ determinant\ D} \quad (7)$$

$$a_2 = \frac{value\ of\ determinant\ D_2}{value\ of\ determinant\ D} \quad (8)$$

$$a_3 = \frac{value\ of\ determinant\ D_3}{value\ of\ determinant\ D} \quad (9)$$

After the calculation of coefficients (a_0-a_3) it was possible to compile formula for analytical expression.

$$y = a_3 * x^3 + a_2 * x^2 + a_1 * x + a_0 \quad (10)$$

Relation for calculation index of correlation was deduced from template.

$$I = \sqrt{1 - \frac{\Sigma(y^* - y_i)^2}{\Sigma(\varnothing y - y_i)^2}} \quad (11)$$

Resultant index of correlation was compared with table value defined according to Kažimír and Beňo in publication Theory of machining. [Kazimir 1989]

Table 6. Classification according to value of index of correlation [Kazimir 1989]

0 < |I| < 0,30	very low degree of statistical dependence
0,30 ≤ |I| < 0,50	low degree of dependence, must be taken into account
0,50 ≤ |I| < 0,90	very significant degree of statistical dependence
0,90 ≤ |I| < 1	functional dependence
0 < |I| < 0,30	very low degree of statistical dependence

Parameter x_i was replaced to parameter v_c and parameter y_i was replaced to parameter *VB*. For cutting plates made of sintered carbide (P20+TiN) was prescribed final v_c-*VB* dependence with using of least square method.

$$VB = -8{,}27201.10^{-9} * v_c^3 + 7{,}74802.10^{-6} * v_c^2 - 0{,}001342982 * v_c + 0{,}110682 \quad (12)$$

For defined v_c - *VB* dependence there was calculated index of correlation according to prescribed formula.

I = 0.9567527977 I = 95.6752797 %

Table value index of correlation comprised with calculated value index of correlation according to publication Kažimír and Beňo identifies exactly borders of statistical significance and this value includes to the category of functional dependence.

5 CONCLUSION

Primary factor of each new discovery or piece of knowledge is experiment. Very important part of quality production in engineering companies is quality tool. Tools with listed and described properties are indispensable in the production. The most important part when develop the tools is its material. Material for cutting tools defines theirs machining properties. Testing properties of those materials are very important, because their properties may be different than properties defined in standards ISO. Cutting speed, cutting depth and feed of tool is possible calculate according to defined technological conditions, but durability tool is necessary to evaluate according to realized experiments, or to compare with standard ISO. In this article was described entire procedure how to create v_c-VB dependence for identifying durability of cutting tool. This dependence is a new way how to identify cutting tool durability without shortcomings that are contained in two elementary methods (The short-term durability test, the machining long-term test method). This new method is characterized by mainly time efficiency, but in other factors is retained quality method defined in standard ISO 3685.

Based on the experiments results by means of least square method was prescribed analytical expression of v_c-VB dependence for sintered carbide (P20+TiN) and there was defined value of index of correlation for this dependence. Resultant formula presented in this article that was calculated by means of created template and derived from formulas, describe v_c-VB dependence for one specific experiment indicates imprecision of these resultant formulas. Experiment need to be repeated under other defined technological parameters and result need to be comparing with result obtained from this article and thus verify entire process.

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REFERENCES

[Allo 2013] Allo, S., Krocko, V., Korenko, M., Andrassyova, Z., Foldesiova, D. “Effect of chemical degreasing on corrosion stability of components in automobile industry”. In Advanced Materials Research. ISSN 1022-6680, 2013, vol. 801, special iss., p. 19-23.

[Björck 1996] Björck, A. Numerical methods for least squares problems. USA: SIAM Philadelphia, 1996. ISBN 978-0-898713-60-2

[Brezinova 2014] Brezinova, J., Guzanova, A., Spisak, E. Assessment of properties thermal sprayed coatings realised using cermet blend powder. In: Metalurgija, 2014, vol. 53, No. 4, pp. 661-664, ISSN 0543-5846.

[Cep 2010] Cep, R. et al. Ceramic cutting tool tests with interupted cut simulator. IN-TECH 2010, 2010, Proceedings of International Conference on Inovative Technologies, pp 144-148, ISBN 978–80–904502–2–6

[Cep 2014] Cep, R., Janasek, A, Petru, J., Sadilek, M., Mohyla, P., Valicek, J., Harnicarova, M., Czan, A. ”Surface roughness after machining and influence of feed rate on process”, 2014. In: Key Engineering Materials. Vol. 581 (2014), p. 341-347., ISSN 1013-9826

[Duplak 2010] Duplak, J. Identification of comprehensive T-vc dependence. Diploma Thesis. Presov: TUKE FVT PO, 2010.

[Duplak 2013] Duplak, J. et al. Comprehensive expression of durability for the selected cutting tools in comparison with standard ISO 3685. Advanced Science Letters 2013, Vol. 19, No. 2, pp 460-463

[Duranik 2013] Duranik, T., Ruzbarsky, J., Manlig F. Proposal for possibilities of increating production productivity of thermosets compression molding with using process simulation software. In: Applied Mechanics and Materials, Trans Tech Publications, Zurich, Switzerland, vol. 308, 2013, pp. 192-194.

[Fabian 2013] Fabian, S., Salokyova, S. The technological head vibrations with different abrasive mass flow rates. In:Applied Mechanics and Materials, TTP, Zurich, Switzerland, vol.308, 2013, p.1-6.

[Gombar 2013] Gombar, M., Vagaska, A., Kmec, J., Michal, P. Microhardness of the Coatings Created by Anodic Oxidation of Aluminium. In: Applied Mechanics and Materials, Trans Tech Publications, Zurich, Switzerland, vol. 308, 2013, p. 95-100.

[Hloch 2012] Hloch, S. et al. Classification of technical materials according to classes machinability for hydroabrasive cutting. Metalurgija, January 2012, Vol. 51, No. 1, pp 125-128.

[Holesovsky 2012] Holesovsky, F. et al. GICS for Grinding Process Optimization. Manufacturing Technology, 2014, Vol. 12, No. 12, pp 22-26, ISSN 1213-2489

[Holesovsky 2014] Holesovsky, F. et al. Effect of machining the load capacity notched components. Key Engineering Materials, 2014

[Isakov 2009] Isakov, E. Cutting Data for turning of steel. USA: Industrial Press,Inc., 2009. ISBN 978 – 0 – 8311- 3314-6

[Janekova 2014] Janekova, J., Kovac, J., Onofrejova, D. Modelling of Production Lines for Mass Production of Sanitary Products. Elsevier, Netherlands, 2014. In: Procedia Engineering, Elsevier, Vol. 2014, no. 96(2014), p. 330-337, 2013

[Jurko 2016] Jurko, J., Panda, A., Valicek, J., Harnicarova, M., Pandova, I. Study on cone roller bearing surface roughness improvement and the effect of surface roughness on tapered roller bearing service life. In: The International Journal of Advanced Manufacturing Technology. Springer London Ltd, pp. 1099-1106, Volume 82, Issue 5-8, 2016, ISSN 0268-3768

[Kazimir 1989] Kazimir, I. and Beno, J. Theory of machining. Slovakia: Alfa, 1989. ISBN 063-720-89

[Krehel 2013] Krehel, R., Straka, L, Krenicky, T. Diagnostics of Production Systems Operation Based on Thermal Processes Evaluation. In: Applied Mechanics and Materials, Trans Tech Publications, Zurich, Switzerland, Vol. 308, 2013, pp. 121-126.

[Krolczyk 2015] Krolczyk, G. et al. Investigation of selected surface integrity features of duplex stainless steel (DSS) after turning. Metalurgija, January 2015, Vol. 54, No. 1, pp 91-94. ISSN 0543-5846

[Lattner 2014] Lattner, M. and Holesovsky, F. Effect of machining the load capacity notched components. Manufacturing Technology, 2014, Vol. 14, pp. 47-50

[Lesso 2010] Lesso, I., Flegner, P., Sujansky, M., Spak, E., Research of the possibility of application of vector quantisation method for effective process control of rocks sisintegration by rotary drilling . In: Metalurgija. Vol. 49, no. 1, p. 61-65. (CMS). ISSN 0543-5846, (2010)

[Michalik 2010] Michalik, P. and Zajac, J. Intelligently programming of holes machining. Manufacturing Engineering, 2010, Vol. IX, No. 4, pp 63-65, ISSN 1335-7972

[Monkova 2013] Monkova, K., Monka, P., Jakubeczyova, D. The research of the high speed steels produced by powder and casting metallurgy from the view of tool cutting life. In:Applied Mechanics and Materials,TTP,Switzerland,vol. 302, no. 302, 2013, p. 269-274.

[Mrkvica 2012] Mrkvica, I., Janos, M., Sysel, P. Cutting efficiency by drilling with tools from different materials. Advanced Materials Research, Materials Processing Technology II. 2012, Vols. 538-541, pp. 1327-1331.

[Panda 2011a] Panda, A. et al. Analytical expression of T-vc dependence in standard ISO 3685 for cutting ceramic. Key

Engineering Materials 2011, Vol. 480-481, pp 317-322, ISSN 1013-9826

[Panda 2011b] Panda, A., Jurko, J., Dzupon, M., Pandova, I. „Optimalization of heat treatment bearings rings with goal to eliminate deformation of material". In: Chemicke listy, 2011, vol. 105, issue 16, ISSN 0009-2770, p. 459-461.

[Panda 2013a] Panda, A. et al. Turning bearing rings and determination of selected cutting materials durability. Advanced Science Letters 2011, Vol. 19, No. 8, pp 2486-2489.

[Panda 2013b] Panda, A., Duplak, J., Jurko, J. „Theory and Practice in the process of T-vc dependence creation for selected cutting material". In: Advanced Materials Research, Trans Tech Publications, Zurich, Switzerland, 2013, vol. 716, ISSN 1022-6680, p. 261-265.

[Panda 2016] Panda, A., Jurko, J., Pandova, I. Monitoring and Evaluation of Production Processes. An Analysis of the Automotive Industry. Monograph, Springer International Publishing, Switzerland, 2016, (8.4.2016), 117 pages, ISBN 978-3-319-29441-4

[Pandova 2012] Pandova, I., Gondova, T., Dubayova, K. Natural and modified clinoptilolite testing for reduction of harmful substance in manufacturing exploitation. In: Advanced Materials Research, vol.518-523, Switzerland, 1757-1760 p. 2012, ISSN 1022-6680.

[Pandova 2014] Pandova, I. Nitrogen oxides reduction by zeolite sorbents in manufacturing use. Advanced Materials Research 2014, Vol. 937, pp 487-490, ISSN 1022-6680

[Peterka 2014] Peterka, J., Pokorny, P. Influence of the Lead Angle from the Vertical Axis Milling on Effective Radiu sof the Cutter. In: Key Engineering Materials, Trans Tech Publications Inc. Switzerland, vol. 581 (2014), No. 581, p. 44-49. ISSN 1013-9826.

[Petru 2014] Petru, J. et al. The Effect of Thermal Shocks on Wear of Exchangeable Sintered Carbide Inserts during the Cutting Process. Manufacturing Technology, 2014, Vol. 14, No. 4, pp 590-596, ISSN 1213-2489

[Prislupcak 2016] Prislupcak, M., Panda, A. Comparsion and Analysis of the Flow Rate. In: Key Engineering Materials, Trans Tech Publications, Zurich, Switzerland, 2016, vols. 663-696 (2016), pp. 197-204, ISSN 1013-9826.

[Ragan 2012] Ragan, E., Dobransky, J., Baron, P., Kocisko, M., Svetlík, J. Dynamic of taking out molding parts at injection molding. Metallurgy No.4/2012,vol.51, Zagreb, Croatia, Croatian Metallurgical Society, 567-570 p.

[Rimar 2014] Rimar, M., Fedak, M., Mihalcova, J., Kuna, S. Adaptive rejection filter for the drives stabilization of pressure die-casting machines. In: Advances in Mechanical Engineering. 2014), pp. 1-10, ISSN 1687-8132.

[Szarkova 2013] Szarkova, V. et al. Influence of longitudinal cold rolling on the surface topography of low carbon structural steel. Tehnicki Vjestnik, 201, Vol. 20, No. 4, pp 705-709. ISSN 1330-3651

[Wolberg 2006] Wolberg, J. R. Data analysis using the method of least squares: extracting the most information from experiments. Germany: Springer, 2006. ISBN 978-3-540-25674-8

[Zajac 1995] Zajac, J. et al. Cutting facilities of new type of came cutting material. Proceedings of the conference PPTO, pp 138-139

[Zelenak 2012] Zelenak, M. et al. Comparison of mechanical properties of surface layers with use of nanoindentation and microindentation tests. Metalurgija, 2012, Vol 51, pp 309-312, ISSN 0543-5846

[Zaborowski 2007] Zaborowski, T. Ekowytwarzanie. Gorzow, p.100 (2007)

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