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ASSESSING THE EFFECT OF BIODEGRADABLE CUTTING FLUID ON TOOL WEAR IN MACHINING

OCENA WPŁYWU BIODEGRADOWALNEJ CIECZY CHŁODZĄCO-SMARUJĄCEJ NA ZYŻYCIE NARZĘDZIA W PROCESIE OBRÓBKI SKRAWANIEM

Key words:

tribotechnology, biodegradable cutting fluids, tool wear, friction

Słowa kluczowe:

tribotechnologia, biodegradowalne ciecze obróbkowe, zużycie noża, tarcie

Abstract

This paper is concerned with the wear of a tool in turning under dry and wet conditions. The fluid used in the tests was a biodegradable cutting fluid containing zinc aspartate. The tool surface was analysed using a Talysurf CCI Lite optical profiler and an SX80 stereo zoom microscope. The results indicate that the cutting fluid tested offers all the functions required in turning.

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INTRODUCTION

Machining, which is one of the most common manufacturing processes **[L. 1]**, involves shaping products by removing small chips of material by means of cutting tools **[L. 2, 3]**. The tools, however, wear out with time **[L. 2]** because of the large loads generated during chip formation as well as the relative motion between the tool and the workpiece. Moreover, there is heat produced by friction and material deformation, which can cause the tool, the chip, and partly the workpiece to overheat. The surfaces in contact are generally free from dirt and foreign particles and they are chemically very active, which is why machining involves the occurrence of complex physical and chemical processes. All the basic wear mechanisms can be observed on the tool. The wear of cutting tools is specified in the relevant standards **[L. 4–6]**.

According to the PN-ISO 3685 standard, the wear of the tool is defined as "an undesirable change in the geometry of the cutting edge due to material deformation or loss that occurs during cutting with reference to the original shape, the result of which is a gradual loss or deformation of the material" **[L. 7]**. When there is a change in the original geometry of the tool, the tool becomes less effective and may not perform its basic functions, i.e. remove excess material and achieve good quality surfaces. The lower effectiveness of the cutting process means higher surface roughness and, consequently, a lower quality of the outer layer, with this being a significant factor affecting the tribological properties of the product **[L. 1]**. The wear of the tool is also responsible for a decrease in the strength of the cutting edge, an increase in energy consumption, an increase in the temperature in the cutting zone, and a loss of the dimensional accuracy of the workpiece **[L. 2]**.

When turning is performed under dry conditions, it is essential to minimize the amount of heat transferred to the workpiece, which can be accomplished by reducing the cutting force and properly distributing heat **[L. 8]**. An additional solution is to apply a thin, hard coating to improve the mechanical, tribological, anti-corrosive, and thermal properties of the tool. Cutting tools with coatings are suitable both for dry and wet cutting conditions, because they contribute to the better surface parameters of the workpiece. The most common coatings are those fabricated by chemical vapour deposition (CVD) or physical vapour deposition (PVD) **[L. 9, 10]**.

Under certain circumstances, dry turning is impossible. The best solution is to apply a cutting fluid, which may have various functions. It can act as a coolant or lubricant, it can reduce the friction coefficient, improve the state of the workpiece surface, transport chips away from the cutting zone, offer temporary protection against corrosion, increase the tool life, improve the quality of the finished products, increase the effectiveness of the machining process, reduce the cutting force, and decrease the deformation of the workpiece **[L. 11–14]**.

Cutting fluids are generally toxic substances with a complex composition that poses a threat to human health and the natural environment. In many countries, spent cutting fluids are classified as toxic or hazardous waste **[L. 3, 11]**. Because of these hazards, it is justified to use biodegradable cutting fluids **[L. 15, 16]**.

MATERIALS

The tests were conducted for turning tool bits made of SW18 high-speed steel. This grade of steel is well suited for such tools as turning tool bits, planing tools, milling cutters, drill bits, threading tools, saw blades, and saw segments, capable of machining medium-strength materials. The composition of SW18/HS18-0-1 steel is provided in **Table 1**.

Table 1. Composition of SW18/HS18-0-1 tungsten-molybdenum steel
Tabela 1. Skład chemiczny stali wolframowo-molibdenowej SW18/HS18-0-1

Element	C	Mn	Si	P	S	Cu	Cr	Ni	Mo	V	W	Co
Content, %	0.75-0.85	≥0.4	≥0.5	≥0.03	≥0.03	≥0.03	3.5-4.5	≥0.04	-	1.0-1.4	17-19	≥0.5

The workpieces were in the form of cylinders with a diameter of 40 mm. They were made of 40H/41Cr4 high-chromium steel, which is an average hardenability steel requiring heat treatment. Its composition is given in **Table 2**. The steel is used for heavily loaded shafts, connecting rods, sleeves, axles, gear transmissions, abrasive discs, housings, and long-life moulds.

Table 2. Composition of 40H/41Cr4 steel
Tabela 2. Skład chemiczny stali 40H/41Cr4

Element	C	Si	Mn	Cr	Mo	Ni	V	W	S	P
content,%	0.36-0.45	0.17-0.37	0.5-0.9	0.8-1.2	≥0.1	≥0.3	≥0.05	≥ 0.2	≥ 0.035	≥0.035

The cutting process was performed under dry and wet conditions. The biodegradable cutting fluid proved to be suitable to replace a classic coolant, which is usually toxic. The major components of the fluid tested are as follows:

- Demineralised water (DEMI),
- Alkanolamine borate,
- Biodegradable polymer – containing zinc aspartate – 5% vol., and
- A package of corrosion inhibitors and biostabilising additives.

Table 3 presents the main parameters of the demineralised water used in the tests.

Table 3. Parameters of the demineralised water at 25°C
Tabela 3. Wybrane parametry wody demineralizowanej w temperaturze 25°C

pH	conductivity [μS/cm]	maximum resistivity [MΩ · cm]
5.0-7.2	1.42	18.2

METHODS

The experiments were carried out at the Conventional Machine Tools Laboratory of the Kielce University of Technology using an Opti conventional lathe (**Fig. 1**). The lathe had infinitely variable speed control and a digital read-out.

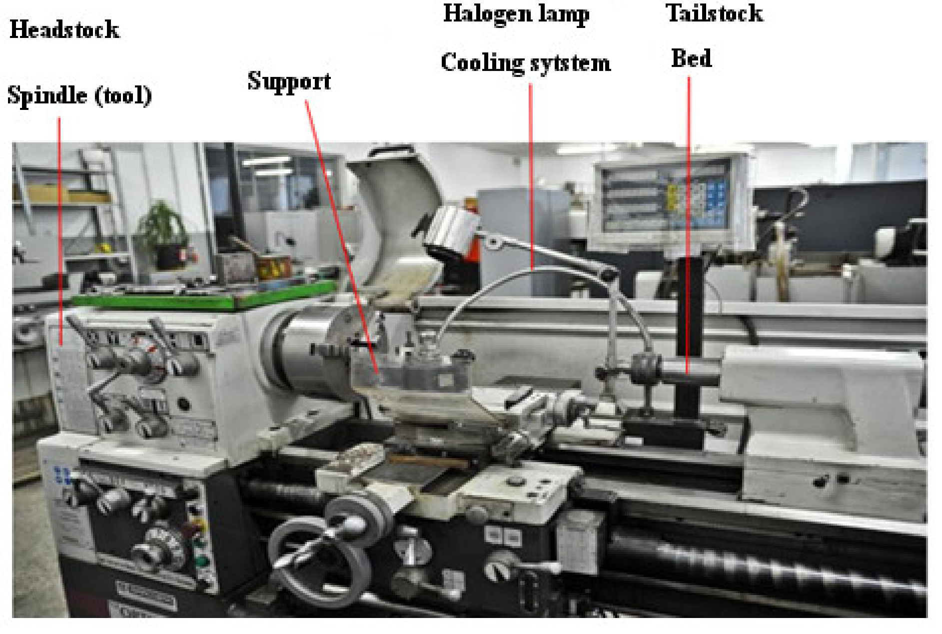


Fig. 1. View of the Opti lathe [L. 17]
Rys. 1. Widok tokarki Opti **[L. 17]**

The cooling and lubrication functions of the biodegradable cutting fluid were assessed by performing face turning on a conventional lathe. The turning process was carried out both under dry and wet conditions. **Table 4** shows the main turning parameters.

Table 4. Turning parameters
Tabela 4. Parametry toczenia

Cutting speed [v_c, m/min]	Feed [f, mm/obr]	Depth of cut [ap, mm]
400	0.098	0.5

The measurements of the surface texture of the turning tool bits and the discs were performed using an SX80 stereo zoom microscope and a Talysurf CCI Lite optical profiler. The analysis with the optical profiler was conducted at the Laboratory for Computer-Based Measurement of Geometrical Quantities at the Kielce University of Technology in Kielce **[L. 18]**.

RESULTS AND DISCUSSION

Figures 2 and **3** show photographs and topographies of the turning tool bits after dry turning and turning with a cutting fluid.

a) b)

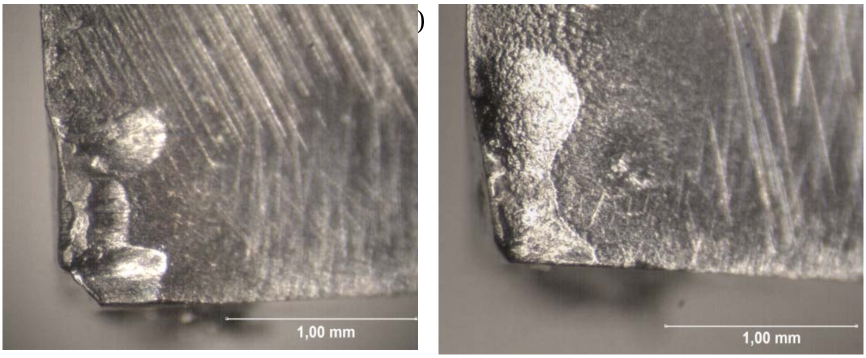


Fig. 2. Photographs of the turning tool bits made of SW18 steel after: a) dry turning, b) turning with the cutting fluid

Rys. 2. Zdjęcia powierzchni noży tokarskich ze stali SW18 po toczeniu: a) „na sucho", b) z cieczą chłodząco-smarującą

a) b)

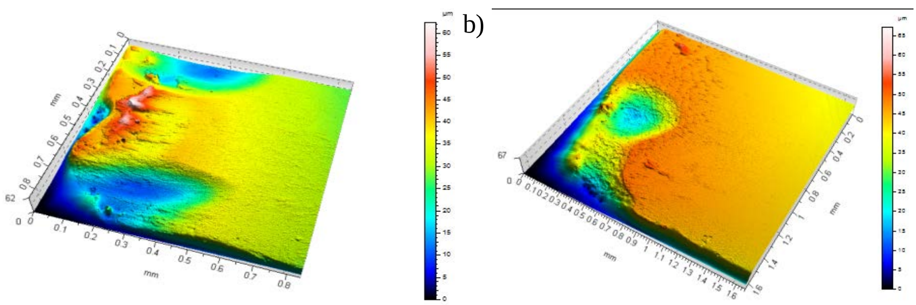


Fig. 3. Surface topographies of the turning tool bits made of SW18 steel after: a) dry turning, b) turning with the cutting fluid

Rys. 3. Topografia powierzchni noży tokarskich ze stali SW18 po toczeniu: a) „na sucho", b) z cieczą chłodząco-smarującą

The stereo zoom microscope and the optical profiler were used to analyse the rake face of the tool after turning. After turning with the biodegradable cutting fluid, the build-up edge was thinner (0.11 mm^2) and the wear marks on the tool were smaller. After dry turning, the tool tip was more worn out.

Moreover, the grooves on the workpiece were deeper and the build-up edge was thicker (0.12 mm^2).

Figures 4 – 6 show photos, topographies, and profiles for the discs after turning.

a) b)

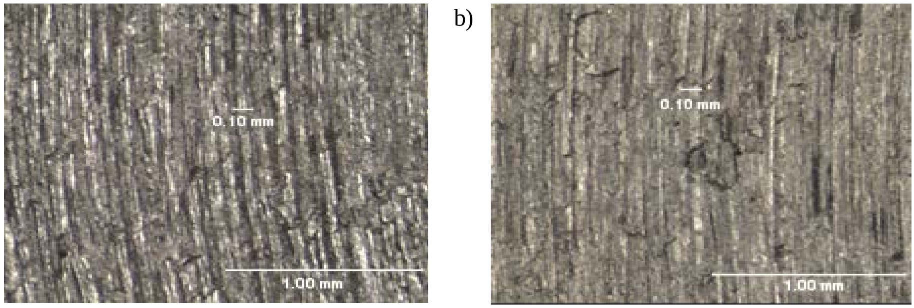


Fig. 4. Photographs of the surface of the disc made of 40H steel after: a) dry turning, b) wet turning

Rys. 4. Zdjęcia powierzchni tarcz ze stali 40H po toczeniu: a) „na sucho", b) z cieczą chłodząco-smarującą

a) b)

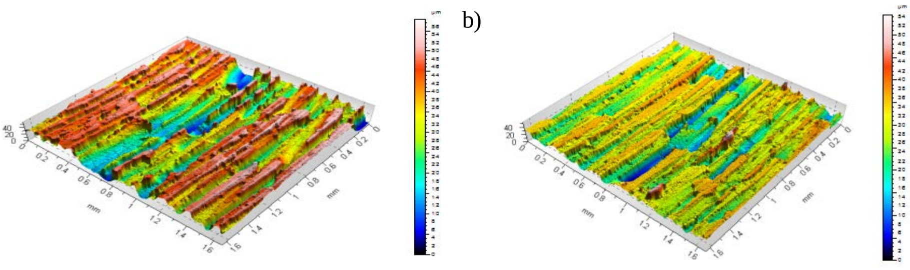


Fig. 5. Surface topographies of the discs made of 40H steel after: a) dry turning, b) wet turning

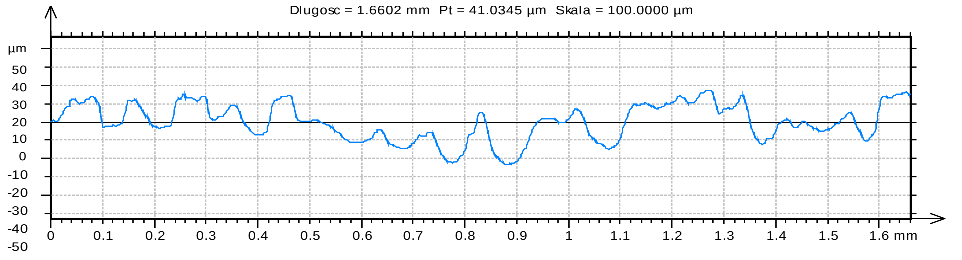
Rys. 5. Topografia powierzchni tarcz ze stali 40H po toczeniu: a) „na sucho", b) z cieczą chłodząco-smarującą

The surface produced in turning under wet conditions had lower peaks and more shallow valleys, which made it smoother than that obtained in turning without a coolant. In dry turning, the grooves on the discs became more visible with each pass of the tool, as can be seen in the images, topographies, and surfaces profiles. **Table 5** shows the surface texture parameters for the discs turned under dry and wet conditions.

Comparing the surface texture parameters obtained for the discs made of 40H steel machined under dry conditions with the surface texture parameters reported for turning under wet conditions, we can see that the values of the parameters are as follows:

- Sa, Sq, Sv, Sz – increased; and,
- Sp, Ssk, Sku – decreased.

a)



b)

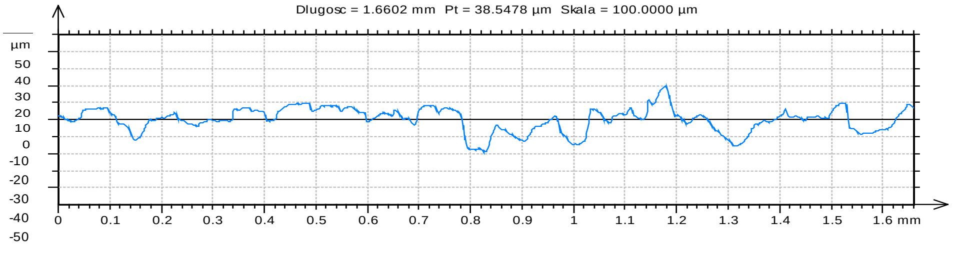


Fig. 6. Surface profiles of the discs made of 40H steel after turning under: a) dry conditions, b) wet conditions

Rys. 6. Profil powierzchni tarcz ze stali 40H po toczeniu: a) „na sucho", b) z cieczą obróbkową

Table 5. Surface texture parameters obtained for the discs after turning

Tabela 5. Parametry chropowatości powierzchni tarcz po toczeniu

Surface texture parameters			**Dry conditions**	**Wet conditions**
Sa	µm	arithmetic mean height	9.5	5.32
Sq	µm	root mean square height	11.35	6.74
Sp	µm	maximum peak height	22.36	26.05
Sv	µm	maximum valley depth	35.5	28.33
Sz	µm	maximum height	57.85	54.39
Ssk	-	skewness	-0.47	-0.81
Sku	-	kurtosis	2.35	3.75

From the test results it can be concluded that surfaces produced by wet turning with a biodegradable cutting fluid are smoother than are those obtained through dry turning.

CONCLUSIONS

The investigations described in this paper have contributed to the development of tribological materials. The study focused on the use of a biodegradable cutting fluid in turning.

When turning was performed using a new generation biodegradable cutting fluid, the wear of the tool was smaller and the quality of the workpiece surface was better. Thus, the use of a cutting fluid is fully justified.

The cutting fluid under analysis performed all its functions: It provided lubrication, reduced the resistance resulting from friction, and it reduced the tool wear.

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Streszczenie

W artykule przedstawiono zużycie narzędzia przed i po operacji toczenia bez oraz z biodegradowalną cieczą chłodząco-smarującą zawierającą asparginian cynku jako dodatek uszlachetniający. Obserwacje powierzchni noża wykonano profilometrem optycznym Talysurf CCI Lite oraz stereoskopowym mikroskopem inspekcyjnym SX80. Badania wykazały, że użyta do badań ciecz chłodząco-smarująca spełnia swoje funkcje.