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# AN INNOVATIVE METHOD OF DEPOSITING LAYERS OF ANTIFRICTION IN MACHINING STEEL PARTS AS ECO-FRIENDLY TECHNOLOGY

**Key words:** energy efficiency, reducing the frictional resistance, closed technological cycle.

**Abstract:** The article presents the results of studies on the impact layer of soft metal on the tribological properties of friction characteristic for machining. Insertion of zinc ions into the cooling-lubricating liquid, applied directly to the contact zone (blade machining tool–construction material) causes a decrease in machining resistance, reduces process of energy consumption, and also lowers the work surface roughness parameter. Preparation of a metallic coating while machining an element on an exposed clean surface of the core does not require a water bath as in the case of the deposition of the galvanic layers. These formed layers are a protection of inter-operative profiled elements, eliminating the need for anti-corrosion agents. A developed and closed technological cycle allows one to recover used substrates and zinc ions and to re-use them.

## Innowacyjna metoda osadzania warstw niskotarciowych w obróbce skrawaniem elementów stalowych jako technologia proekologiczna

**Słowa kluczowe:** energooszczędność, zmniejszenie oporów tarcia, zamknięty cykl technologiczny.

**Streszczenie:** W artykule przedstawiono wyniki badań dotyczących oddziaływania warstwy miękkiego metalu na właściwości tribologiczne węzłów tarcia charakterystycznych dla obróbki skrawaniem. Wprowadzenie jonów cynku do cieczy chłodząco-smarującej zastosowanej bezpośrednio w strefie styku: ostrze narzędzia skrawającego – materiał konstrukcyjny przyczynia się do spadku oporów skrawania, zmniejsza energochłonność procesu, a także obniża parametr chropowatości powierzchni obrabianej. Wytwarzanie powłoki metalicznej z jednoczesnym skrawaniem elementu na odsłoniętej, czystej powierzchni rdzenia, nie wymaga użycia kąpieli wodnych jak w przypadku osadzania powłok galwanicznych. Tak wytworzone powłoki stanowią ochronę międzyoperacyjną profilowanych elementów. Eliminuje to konieczność stosowania środków zabezpieczających antykorozyjnie. Opracowany, zamknięty cykl technologiczny pozwala odzyskiwać użyte substraty oraz jony cynku, co umożliwia ich ponowne zastosowanie.

## Introduction

Steel is one of the most commonly used structural materials for the manufacture of machine parts. Modern construction materials, particularly composites, meeting the highest requirements imposed on them, often replace metal parts, but the popularity of steel does not decrease. It is modified by the introduction of alloying elements, machining and finishing, and various types of coatings, to reduce mechanical wear and corrosion [1, 2].

Machining steel elements requires the use of cutting tools that meet the high requirements for dimensional tolerances of shaped elements and surface quality, ensuring minimum values of roughness.

Such effects may provide tools with appropriate cutting geometry, which is the determinant of shelf life of the cutting tool. Micron changes of the geometry of the blade negatively affect the dimensional tolerance surface of the workpiece, which causes the cutting tool to be replaced. This is a big problem in the machining; therefore, different methods are used to prevent the rapid wear of the tool surface. First of all, more and more modern materials are used while improving tool steel through the introduction of alloying elements. Cutting tools are often made of cemented carbide and coated with hard coatings (PVD, CVD).

Machining steel parts remove surface layers of structural materials and thus uncover the clean surface of the core. Damage to the crystallographic network by breaking atomic bonds and the weakening of the forces of cohesion leads to intense oxidation of the surface of the workpiece and the formation of passivation layers.

To prevent the processes of the formation of oxides on the surface of manufactured components directly after shaping, these surfaces are protected by means of corrosion protection (oils, greases).

These measures must be removed in further processing if the element has to form a metallic film. Then, solutions and chemical cleaning agents for removing lubricants are imposed. It may be necessary to mechanically clean the surface in order to create ideal conditions for the deposition of the coating. As a result of such action, the geometry of elements produced by low-alloy steel are compromised and contribute to failure tolerances.

Developed innovative technology (patent University of Radom) forming part of machinery low-alloy steel, along with the secretion of metallic coatings by electrochemical methods [3], eliminates the cumbersome process of preparing the surface. The blade-cutting tool reveals the pure core material, without oxides and pollution by removing the top layer of the workpiece. They are eliminated in this way the deposition of metallic coatings technology cleaning and etching a fully maintained with the geometry of the shaped elements.

This method eliminates the need for corrosion protection (interoperation), because a separate metal layer protects the surfaces perfectly shaped elements. Conducted studies have documented [4–7] the deposition of soft metal directly during machining causes a decrease in cutting forces and therefore a reduction in the energy consumption of a machining process.

The synergism of these two processes, machining with simultaneous separation of low friction coatings, have a positive effect on the extension of the shelf life of cutting tools.

With electrolytes (coolants) used in this technology, metal ions released can be recovered and re-introduced into the electrolyte in order to complete their concentration [8]. Such a possibility makes electroplating processes an important issue in relation to generated wastes by reducing pollution in the natural human environment [9]. Electroplating consumes massive amounts of water in the electrolytic baths. In the present method, a closed technological cycle has been developed to limit water consumption and to re-use it in the process of the deposition of metal during the rolling of steel.

## 1. Research methods

Zinc, while plasticizing the metal at a temperature of 150°C, comes to iron in the reduction reaction. In order to isolate it, when machining steel parts (Figure 1), it is necessary to use additional controlled electrical circuit, which will force the course of phase transitions on the surface of the workpiece 1 and on the edge of the turning tool 2. These changes are controlled by the parameters of the desired voltage u or current A of electric charges, which are defined outside of a real system using voltammetric linear, DC. The voltage value occurring is interfacial: workpiece – electrically conductive environment.

In the case of turning, the electric circuit is closed through the mechanisms of the machine 3 and an electrolyte (cutting fluid) containing a zinc ion from the soluble electrode 5. The release of zinc mating surfaces occurs during the reduction of the distance l and during turning of the turning tool or the contact element workpiece. The polarized area is limited to the infinitesimal small pieces of surface on which single crystallization centres of metal coating are created due to reduction. The drilling process prevents the course of the deposition of the metal layer due to the close contact of associated components. In this case, the zinc coating is applied directly to the drilling process, the clean exposed surface of the cutting edge, and the surface of the chip discharge of the twist drill.

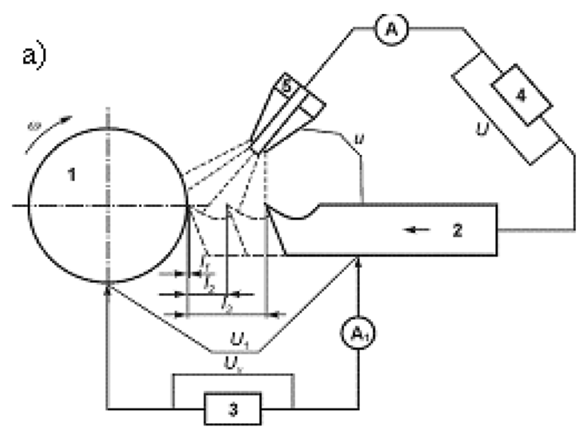


**Fig. 1. Scheme of cooperation systems: mechanical and electrical debited when turning: 1 – workpiece; 2 – turning tool; 3 – working mechanisms of machine tools; 4 – DC power source; 5 – electrode; U – a DC voltage source; u – as measured by the difference voltage electrical; u 1; u x – variable voltages in a circuit uncontrolled, A – bias current in the circuit controlled; A1 – bias current in the circuit uncontrolled; l1, l2, l3 – the distance between the mating parts [7]**

In a study conducted during the turning of the shaft with a diameter of 20 mm made of C45 steel with a hardness of 42 ± 1 HRC, using a turning tool of high-speed SW18 tool steel with a hardness of 62 ± 1 HRC (machining parameters: cutting speed: 68 m / min ; feed 0.2 mm / rev, cutting depth 0.5 mm at a spindle speed of 600 rev / min and a turning length 130 mm), measurements of the energy consumption of this process with the use of the electrochemical deposition of coatings during rolling were made.

Parameters of the deposition of zinc was determined using the Atlas Potentiostat 99 by setting the bias voltage in the range of continuous coating from -1.3 V to -1.5 V.

Investigations of the effects of the antifriction layer, the zinc of the torque acting during drilling steel 11SMnPb37 samples (samples with a diameter of 30 mm and a height of 30 mm), and flute drill bits HSS 10 mm diameter drill ZDW11 were performed on a dynamometer using a load cell. Drilling was at a speed of 760 rev / min and a feed rate of 0.16 mm / rev without cutting fluid.

A layer of zinc deposited on the surface of the workpiece, which is protected intermediate prepared element, can be removed under acidic or basic solutions, such as 10% sodium hydroxide solution to form aqueous solutions of zinc regenerative.

## 2. Results

Technology deposition producing low friction during the machining of steel protects the cutting edge in an innovative way. The introduction of soft metal in the zone of friction causes it to be consumed, thus preventing the destructive changes in blade geometry. A coating of metal ions was introduced into the working fluid used during machining of the deposited both on the cutting edge and the workpiece surface. As exposed, clean surface with torn atomic joints creates ideal conditions for the crystallization of the metal coating.

Measurements of the cutting power have shown that, when cutting with the simultaneous creation of a zinc coating, the power consumption of the lathe (550 W) decreased by approximately 50 W (340 W to 290 W), which is about 14.5%. Taking into account the power consumption of an additional controlled electric circuit, the order of 4–7, depending on the resistance of the circuit by means of the closing machine, which is within 2% of power consumed by the lathe, the process energy consumption decreased by about 12.5% compared to dry treatment. It should be noted that the power of the lathe does not affect the power consumed by the additional circuitry that is affected by the resistance components of the machine, through which it is closed [7].

An electrolyte was used in the electrochemical deposition of the layers of zinc ions, in addition to low friction made of hexagonal boron nitride particles of hBN, to form a composite coating [10].

The study used twist drills HSS with the following characteristics:

– I – without coating (after removing the shell trade),
– II – with metallic coating deposited over 3 minutes, and
– III – the composite coating deposited over 3 minutes.

Cutting resistance drills coated with zinc (II) stood at about 2 Nm less than the drill without shells (I) (Fig. 2). The introduction of microbeads of hBN into the matrix and the produced zinc composite coating resulted in a rapid decrease in the torque (2 to 8 Nm) in the first phase of the drilling of steel samples 11SMnPb37 (in the drill in a workpiece). During drilling and "wear" of dispersive microbeads, the hBN moment is increased to 8 Nm in the final moment of drilling (drill exit from the workpiece), and the value for a drill with a zinc coating was approximately 10 Nm.

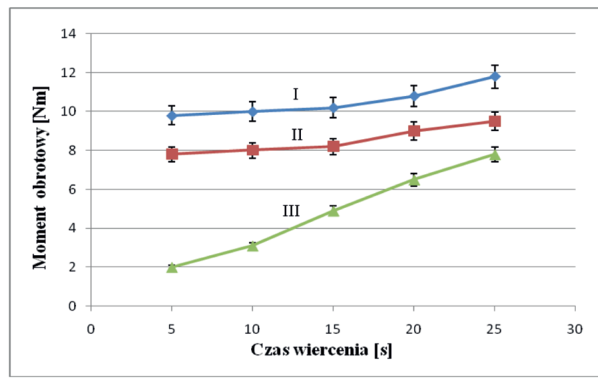


**Fig. 2. Graphic illustration of changes in torque during drilling 11SMnPb37 steel drill bits HSS, I – drill without coating; II – with metallic coating deposited over 3 minutes; III – with a composite coating deposited from hBN within 3 minutes [10]**

The micro-roughness Ra of the drilled surface, tested using a profilometer Surftest SJ-301, decreased from 5.4 µm for the drill without coating to the value of 4.0 µm for the drill with a zinc coating.

In the proposed method, the deposition of antifriction coatings in the machining of steel, a closed cycle characterized by a technological possible recovery of the technology used in the substrates is provided. In the electrolyte or coolants used in the process of rolling with simultaneous deposition of metal coatings, metal ions are recovered in the coating, which are used to reintroduce the electrolyte. (As applied to particles, e.g., micrograin hBN, which are subject to sedimentation and are also recovered).

## Conclusions

The innovative and pro-environmental discussed methods may indicate the possibility of an electrolytic system for the regeneration of damaged coatings, for example, chips and scratches, without the need for disassembly and removal of the coating from the entire surface [11].

The presented technology reduces cutting forces and reduces the energy consumption of the process making is more economical. The solutions used in the presented technology can produce a recycling during electrolytic deposition of metallic machining process, after the addition of the metal ion concentration of the coating (zinc). Removal of metal coating applied by this method does not affect the micro-roughness of the substrate, which is the core element. On the exposed surface of the deposited coating, an antiwear surface may be engineered without additional surface preparation, i.e. without the use of stripping and cleaning. The water used for preparing the electrolyte may be reused in technology.

This method requires technical solutions that allow the collection and recycling of used electrolytes. However, in an era when environmentally friendly technologies are preferred, such solutions should be widely used.

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