TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
MECHANICS | MECHANIKA
3-M/2016

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WEAR OF WORKING PART OF SURGICAL DRILLS

ZUŻYCIE CZĘŚCI ROBOCZEJ WIERTEŁ CHIRURGICZNYCH

A b s t r a c t

The paper presents the results ofstudies onthe topography of surgical borers flank after their operation. The studies were carried out on borers made of X39Cr13 martensitic steel, which was subject to heat and surface (plasma nitriding) treatment. Test drilling was performed in beef bones, which were fixed in a vice to ensure appropriate stability, a borer 6 mm in diameter and 160 mm long was used. The studies on the topography of flank comprised studies on roughness, which were carried out by means of a profilographometer designed for 2D and 3D studies on the surface by means of a contact method. The studies were carried out for borers of flank formed by successive drilling cycles.

Keywords: surgical drills, martensitic steel, surface treatment

S t r e s z c z e n i e

W artykule przedstawiono wyniki badań topografii powierzchni przyłożenia wierteł chirurgicznych po eksploatacji. Badania przeprowadzono na wiertłach ze stali martenzytycznej X39Cr13, które poddano obróbce cieplnej oraz powierzchniowej (azotowanie jarzeniowe). Testowe wiercenia wykonywano w kościach wołowych, które mocowano w imadle, w celu zachowania odpowiedniej stabilności, użyto wierteł o średnicy 6 mm i długości 160 mm. W ramach badań topografii powierzchni przyłożenia przeprowadzono badania chropowatości, które realizowano z zastosowaniem profilografometru przeznaczonego do badań 2D i 3D powierzchni metodą stykową. Badania przeprowadzono dla wierteł o powierzchni przyłożenia ukształtowanej poprzez kolejne cykle wiercenia.

Słowa kluczowe: wiertła chirurgiczne, stal martenzytyczna, obróbka powierzchniowa

DOI: 10.4467/2353737XCT.16.127.5738

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1. Introduction

Intensive development of technology causes continuously increasing requirements for surface engineering [1–9] and biomaterials engineering [1, 6–8, 10–15], both in the field of operational life and biocompatibility. Material wear occurs mainly on the surface, therefore the development of surface treatments creates broad possibilities to manufacture products of required properties based on the existing materials. Numerous attempts are made to shape the usable properties of biomaterials by means of surface engineering techniques [1, 6–8], which enable forming the microstructure, phase and chemical composition or the internal stresses state in the layers. Surgical instruments comprise a very wide, functionally and geometrically diversified group of products [13, 14]. The usable features of such instruments depend on the proper selection of materials used for individual components. The expected characteristics distinguishing surgical instruments in terms of design and operation include: high reliability, safety of use for the operator and the patient, ease of operation, specified set of mechanical properties as well as geometry useful to perform a specific procedure, design enabling full sterilisation of the instrument or device [13, 14]. The borers used in bone surgery should be stable, i.e. should not move on the bone bark during drilling. Such borers feature primarily appropriate geometry of the drill point and appropriate rotational speed during drilling.

The paper presents the results of studies on the topography of surgical borers flank after their operation. Both heat treated and plasma nitrided borers were used.

2. Material and experimental methods

The object of studies consisted of surgical borers made of martensitic steel which belongs to a group of X39Cr13 stainless steels. Test drillings were carried out using borers: (a) quenched + low-temperature tempered, 300°C (Q + LT), (b) quenched + low-temperature tempered + nitrided (Q + LT + N), (c) quenched + high-temperature tempered, 620°C + + nitrided (Q + HT + N).

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The heat treatment consisted of compressed nitrogen quenching from the austenitising temperature of 1050°C. The time of holding at this temperature was 20 minutes. After quenching the borer was subject to two-hour tempering at 300°C with compressed nitrogen cooling. Instead, prior to nitriding the steel was tempered at 300°C and 620°C. A precise description of the nitriding process execution was presented in paper [7].

Operational tests were carried out on borers, 6 mm in diameter and 160 mm long, used in the bone tissue surgery (Fig. 1).

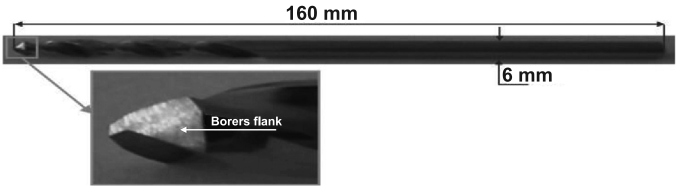

Fig. 1. Surgical borer

A special stand was arranged for borers' operational tests, consisting of:

- a drill mounted on a stable stand. Borer's pressure was ensured by the load of 3.5 kg mounted on a 30 cm long arm. This resulted in the feed force of around 200 N, i.e. an average manual feed force – of a drill's operator;
- a meter (time-measurer), which automatically stopped measurements after the preset drilling time (60 s);
- an external stabilised power source, to which the drill and the meter were connected.

Test drilling was performed in beef bones, which were fixed in a vice to ensure appropriate stability. The drilling was performed in four cycles. During each cycle the drilling time which lasted 60 seconds, and the depth of individual holes were registered. After 60 seconds of drilling the sterilisation procedure was applied and the next drillings were carried out.

The sterilisation by steam was carried out in an ASVE type autoclave at $T = 134°C$ and pressure $p = 0.21$ MPa during 30 min.

Stereometric examinations of the borers flank were carried out by means of a FormTaly Series 2 profilographometer made by Taylor Hobson, applying the contact method. All operations and computations on the measurement files were performed by means of the TalyMap Universal software. The obtained file represented the original surface subject to further analysis and a stereometric description. The stereometricdescription of each measured specimen consisted of: visualisation (2D) using a photographic simulation; Abbott's curve (load capacity curve) together with a graphical interpretation of its basic parameters; isometric image (3D) of surface fragments.

The topography of studied borers was determined on the flank. For the specimens examined, 0.85 mm × 0.85 mm surface was the measurement area. The sampling interval in X and Y axis was 1 μm, the measuring speed was 0.5 mm/s.

3. Results of examinations

The obtained results of studies have shown that after 60 seconds of drilling (the first drilling cycle) the total depth of drilled holes amounted to 35.46 mm for Q + LT borers, 25.34 mm for Q + LT + N, and 28.74 mm for Q + HT + N borers. Instead, significant differences in the depth of drilled holes are visible after the fourth drilling cycle. After this drilling time the depth amounted to 32.63 mm for Q + LT borers, 9.66 mm for Q + LT + N and 17.76 mm for Q + HT + N borers.

Stereometric measurements carried out on borers' flanks have shown substantial differences in the studied parameters (Fig. 2–4).

Quenching + low-temperature tempering (Q + LT)

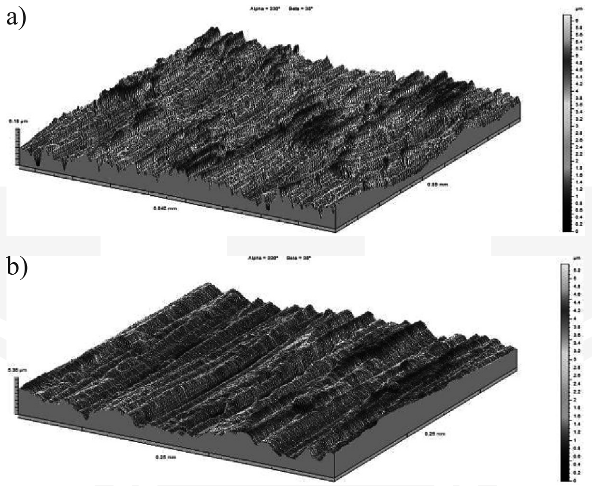

Fig. 2. The topography of borers flank after the fourth drilling cycle: isometric image (3D) of the studied surface (a) and enlargement of its selected fragments (b)

Quenching + low-temperature tempering + nitriding (Q+LT+N)

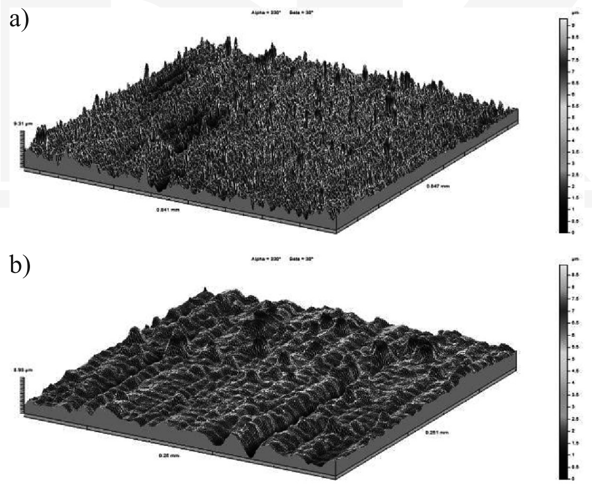

Fig. 3. The topography of borers flank after the fourth drilling cycle: isometric image (3D) of the studied surface (a) and enlargement of its selected fragments (b)

After the fourth drilling cycle the greatest wear of the studied surface was observed for Q + LT + N borers. The obtained 3D images show substantial differences in the topography of this layer. Local chippings of the nitrided layer are visible. These defects caused considerable blunting of borer's working part, which is proven by a smaller depth of the drilled holes. The application of plasma nitriding treatment to surgical borers is unfavorable, because on the one hand the borer edges blunt quickly, while on the other hand the chipped layer may get to the body and thereby cause adverse outcomes.

Quenching + high-temperature tempering +nitriding (Q + HT + N)

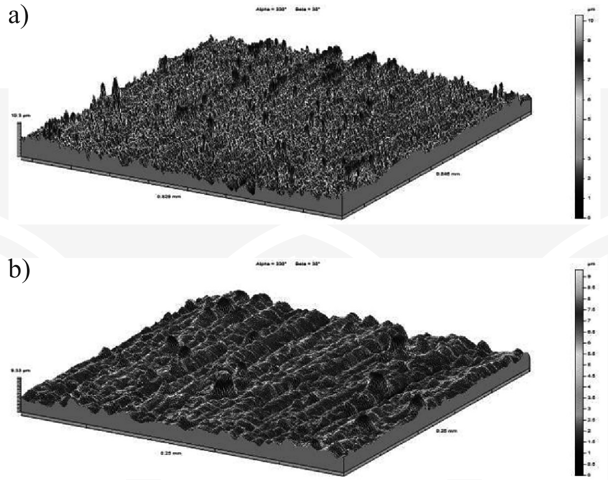

Fig. 4. The topography of borers flank after the fourth drilling cycle: isometric image (3D) of the studied surface (a) and enlargement of its selected fragments (b)

4. Summary of results

Heat and surface treated (plasma nitrided) borers used in bone surgery were analysed. The studies on the topography of borers flank after operation were carried out by means of a profilographometer, which allowed for a precise determination of the degree of borers wear. The studies have shown that the borers subject only to heat treatment were worn to a substantially lower degree than the borers with a nitrided layer. The obtained results have shown greater local chipping of the nitrided layer with previous low-temperature tempering ($T = 300°C$) as compared to high-temperature tempering (620°C). The application of plasma nitriding as a surface treatment for surgical borers is unfavourable due to the possibility of leaving nitrided layer chips in the body. Instead, such surface treatment may increase the operational life of instruments used in soft tissue surgery.

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