

## EFFECT OF RELATIVE STRAIN RATIO ON THE REDUCE ROUGHNESS SURFACE LAYER TUBE HOLES AFTER BURNISHING PROCESS

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### Abstract

*Burnishing technology is a technology of surface plastic forming of machine parts. The paper presents experimental research of burnishing process of the steel tube holes. Used tools to burnishing technology are hard and smooth surface. Burnishing elements are of ball, roll and disk. Burnishing be flat surfaces, and cylindrical shape. Burnished surfaces are cylindrical outer and inner. Because of the type of the force can be divided into static and dynamic burnishing. Due to the kinematics can be divided into sliding and roller burnishing. Occurrence of moving parts in direct contact with the material qualifies for the group process of burnishing rolling. The sliding burnishing design element property is part of the work surface burnished permanently attached to the handle. Burnishing is used as a finishing strengthens and smoothness can be realized on the universal machine tools and machining centres, effectively replaces the machining operations, such as grinding, reaming, honing and lapping. The precise tube holes are made mostly methods abrasive machining. Machining these methods can usually maintain a within the tolerances established by the constructor size and shape and surface roughness. However, there is not achieved a satisfactory state surface layer of tube holes. Improve the properties of the surface layer can be obtained after application, as finishing, broaching the slide burnishing. It consists in pushing through the machined hole tool in the shape of a sphere or a special plunger mandrel. After burnishing broaching is increased diameter, reduced roughness surface and improve the physical properties work piece surface layer of the tube holes. Burnishing broaching process can increase the dimensional accuracy of tube holes, reducing the surface roughness, the strengthening of the surface layer, compressive residual stresses constitution. Compressive internal stresses substantially influence the fatigue life of machine parts. A burnishing broaching is carry out by a ball. In the paper presents results measurements roughness and impact of the relative strain ratio on the surface layer after burnishing broaching process.*

**Keywords:** *surface plastic forming, burnishing broaching process, tube holes, roughness surface*

### 1. Introduction

The currently used methods of burnishing divided by the nature of the forces generated during burnishing, the two groups. These are the static and dynamic methods. The static methods are characterized by constant values of forces. They operate statically to the workpiece using burnished element that is in constant contact with the surface of the workpiece. Whereas, dynamic methods are characterized by a periodically variable force. They operate in this way rapidly to the workpiece. The same time burnished element is not in constant contact with the surface of burnished. The value of burnishing force is variable, but does not reach null. The first group includes methods such as rollers, ball bearings and oscillating, roller, pushes sliding and sliding smoothing. The second group includes a ball, hammering, roller dynamic and ball streaming.

In the exercise, burnishing method static contact force can be exerted on a rigid or elastic. During the clamp rigid, they are a source of strength stress interactions burnished tool and workpiece. Clamping force depends on what was fixed allowance for burnishing. For the method of elastic force

exerted by means of elastic elements such as tools or pneumatic springs. This force is independent of the allowance, and the established value of the force. Burnishing inner cylindrical surface is used mainly in the engineering industry for finish machining of the holes. Cylindrical holes are machined through and blind. Size range treated by burnishing is between 3-150 mm. These holes are made sleeves, tube holes, long cylinders, housings, parts of pipelines. Most burnishing internal diameters are used in serial productions, auto parts, hydraulic equipment for ships and industrial engineering. Roller burnishing is used in rigid precise dimensional treatment. Burnishing a variety of metals such as steel, bronze, brass, aluminum alloys and cast iron. The choice of burnishing the holes is dependent mainly on the material element and the number of items treated. There are also important technical and technological conditions. In burnishing, the sleeve openings are usually used multi-roller heads. When dealing with small-scale production, processing is performed on burnishing lathes. Frequently before burnishing, offering an opening with some allowance for burnishing. Then the head is removed and in its place of prominence and placed peening head. Operations are performed on the same so it is fitting hole machining at very high accuracy class. For burnishing broaching the tube holes used in mass production and mass are, shot, push broaches broaching mandrel and multi-element bearings [1–4]. Because of the influence of elastic object, the size of the maximum element burnishing broaches must be greater than the assumed size of openings of 0.05 mm. These values are selected experimentally [5, 6]. There are also broaches made with interchangeable parts burnished ring, and broaches the cutting blades, used for simultaneous machining of holes machining and burnishing without their prior accurate boring. The use of burnishing the holes is a technology useful and very effective. It is recommended to use this type of treatment mainly for the manufacture of hydraulic cylinders and long bearing raceway for the shipbuilding industry. Burnishing technology in all its varieties is widely used in the production of mechanical equipment used in engineering and shipbuilding. The main advantages of surface plastic working are very large to obtain a surface with low roughness, fabricating and low temperature processing, versatile tools and machine tools and high durability. Continuous development of the technology and construction materials research suggests that the burnishing will apply and for many years [6–9].

## 2. Methodology and results research

In this paper is presented experimental research of burnishing broaching process tube holes using ball, lubricated with engine oil, was carried out on a hydraulic press PH-16 in the Laboratory of Plastic Working Department of Marine Materials and Technology, Faculty of Marine Engineering, Gdynia Maritime University.

Experimental research was conducted for C45 (1.0503) steel samples. The samples had the form steel sleeves, among which you can distinguish between four sets of samples.

Internal diameters of samples from each set were made by boring in three dimensions. The largest internal diameter of a set of samples was about 0.1 mm smaller than the diameter of the tool. Two more samples from a given set of internal diameters were smaller than the ball diameter by 0.2 mm and 0.3 mm. The schema of burnishing broaching process by ball is shown in Fig. 1. Burnishing broaching process is pushing ball bearing steel 20CrMo4 (1.3567) through the hole.

The dependence (1) represents the relative strain ratio:

$$\varepsilon_{nc} = \frac{d - d_1}{d_1} \cdot 100\% . \quad (1)$$

Push in was established based on the following formula:

$$w = d - d_1 . \quad (2)$$

Absolute plastic strain is calculated by the formula:

$$\Delta d_0 = d_0 - d_1. \quad (3)$$

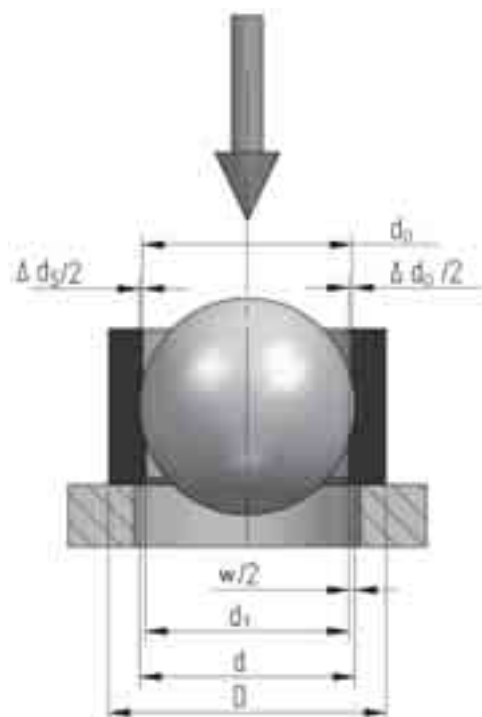


Fig. 1. The schema of burnishing broaching process

Absolute elastic strain is determined by the formula:

$$\Delta d_s = d - d_0, \quad (4)$$

where:

$d$  – outer diameter of the ball, mm,

$d_1$  – diameter inner tube hole before burnishing broaching, mm,

$d_0$  – diameter inner tube hole after burnishing broaching, mm.

Table 1 shows examples of the geometrical parameters for the steel tube holes after burnishing broaching process.

Tab. 1. Geometrical parameters and strain ratio of the tube holes after burnishing broaching process

| No. of samples | $D$ , mm | $d_0$ , mm | $d$ , mm | $d_1$ , mm | $w$ , mm | $\varepsilon_{nc}$ , % | $\Delta d_0$ , mm | $\Delta d_s$ , mm |
|----------------|----------|------------|----------|------------|----------|------------------------|-------------------|-------------------|
| 02.01          | 35       | 21.97      | 22       | 21.89      | 0.1      | 0.5                    | 0.08              | 0.03              |
| 02.02          | 35       | 21.97      | 22       | 21.80      | 0.2      | 0.9                    | 0.17              | 0.03              |
| 02.03          | 35       | 21.97      | 22       | 21.69      | 0.3      | 1.4                    | 0.28              | 0.03              |

Surface roughness after burnishing broaching was measured with a Hommel – Tester T1000 profilometer in the Faculty of Marine Engineering Gdynia Maritime University. The assumed measurement section length of test sample was 4.8 mm and 0.8 mm for the elementary section. The measurements were performed according to the principles contained in ISO standards. A number of parameters of surface roughness after burnishing were determined; among other things, parameters were defined associated with the material share curve. Parameter ( $R_{pk}$ ) variable of the reduced peak height (which should be the lowest) is characteristic for the upper surface layer that quickly undergoes abrasion after the commencement of, for example, engine running. Reduced depth of roughness profile valley is described by ( $R_{vk}$ ) parameter (which should be the highest). It is a measure

of the working surfaces ability to keep the lubricant in the valleys created mechanically. Parameter ( $R_k$ ) defines the core roughness depth (which should be the lowest).

The measurements were performed according to the principles contained in ISO standards, and then on the basis of parameters of surface roughness after burnishing the surface roughness reduction rate were determined [10, 11]:

$$K_{Ra} = \frac{R'_a}{R_a}, \quad (5)$$

where:

$R'_a$  – arithmetic mean deviation of the surface roughness profile before burnishing broaching, ( $R'_a = 4.17 \mu\text{m}$ ),

$R_a$  – arithmetic mean deviation of the surface roughness profile after burnishing broaching.

On the basis of measurements of the roughness profile determined to improve smoothness. After conducting research burnishing broaching process tube holes of C45 steel it was determined that effectively replaces the machining such as grinding, reaming, honing and lapping – but without the abrasive contaminants in the surface layer characteristic of the grinding.

Table 2 shows parameters of surface roughness for the steel tube holes after burnishing broaching process. Fig. 2 shows the arithmetical mean deviation of the assessed profile after burnishing broaching process for relative strain ratio:  $\varepsilon_{nc} = 0.5\text{--}1.4\%$ . The Abbott-Firestone curve for relative strain ratio  $\varepsilon_{nc} = 1.4\%$  before and after burnishing process is presented in Fig. 3.

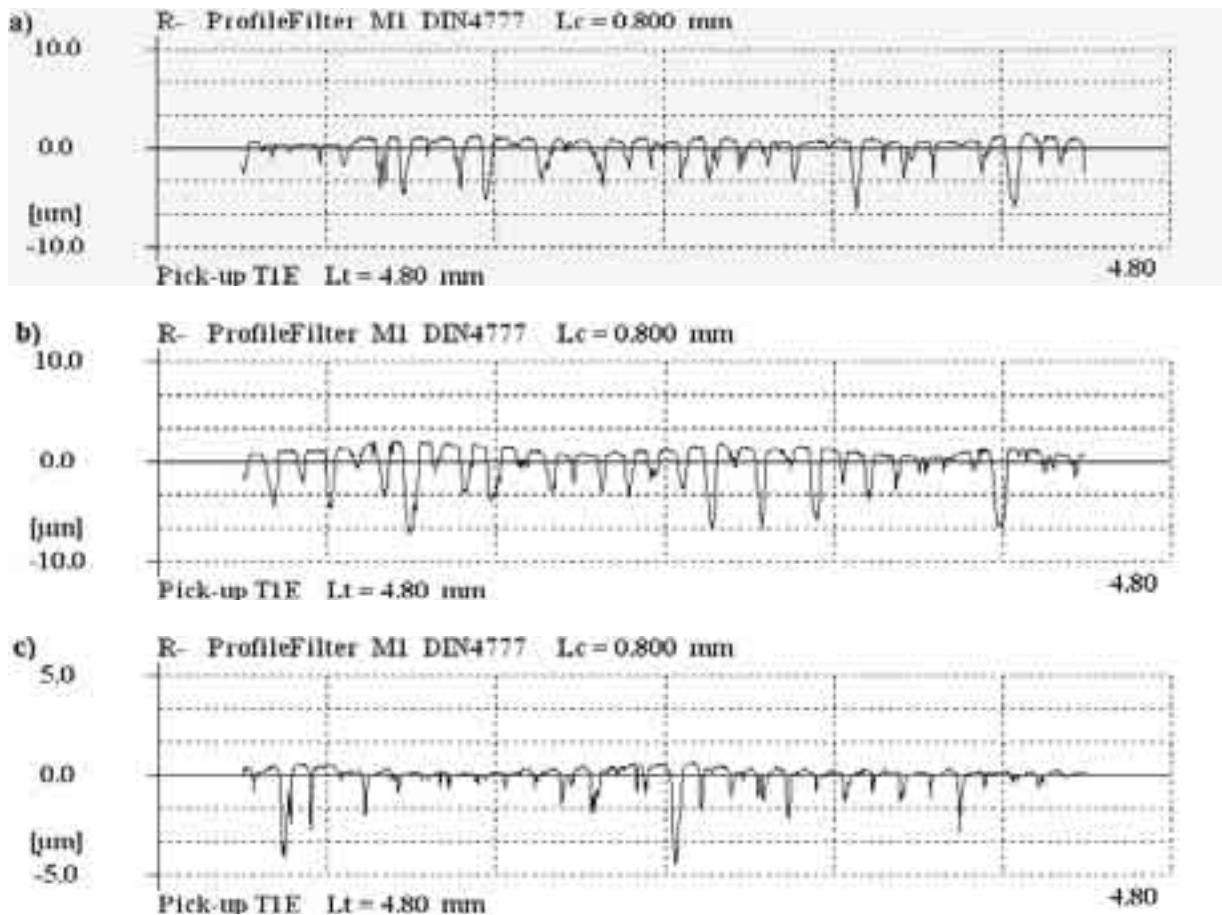


Fig. 2. The profile roughness after burnishing broaching process for relative strain ratio: a)  $\varepsilon_{nc} = 0.5\%$ , b)  $\varepsilon_{nc} = 0.9\%$ , c)  $\varepsilon_{nc} = 1.4\%$

For samples No. 02.03 for relative strain ratio  $\epsilon_{nc} = 1.4\%$  after burnishing broaching process determined that the arithmetical mean deviation of the assessed profile and the Abbott-Firestone curve surface roughness parameters take the smallest value (refer with: Fig. 2).

Tab. 2. The parameters of surface roughness for the steel tube holes after burnishing broaching process

| No. of samples | $R_t$ , $\mu\text{m}$ | $R_{max}$ , $\mu\text{m}$ | $R_z$ , $\mu\text{m}$ | $R_a$ , $\mu\text{m}$ | $R_p$ , $\mu\text{m}$ | $R_{Sm}$ , mm | $R_k$ , $\mu\text{m}$ | $R_{pk}$ , $\mu\text{m}$ | $R_{vk}$ , $\mu\text{m}$ | $M_{r1}$ , % | $M_{r2}$ , % | $R_{mr01}$ , $\mu\text{m}$ |
|----------------|-----------------------|---------------------------|-----------------------|-----------------------|-----------------------|---------------|-----------------------|--------------------------|--------------------------|--------------|--------------|----------------------------|
| 02.01          | 9.83                  | 9.65                      | 6.89                  | 0.91                  | 2.18                  | 0.12          | 0.74                  | 0.32                     | 5.08                     | 6.45         | 68.73        | 2.49                       |
| 02.02          | 8.84                  | 8.79                      | 6.53                  | 0.84                  | 1.46                  | 0.11          | 0.58                  | 0.19                     | 4.73                     | 6.70         | 66.78        | 1.15                       |
| 02.03          | 7.34                  | 7.24                      | 6.33                  | 0.63                  | 1.15                  | 0.10          | 0.41                  | 0.12                     | 3.89                     | 6.40         | 79.90        | 0.61                       |

After burnishing process the results of measurements of roughness parameters, we can conclude that the improved bearing capacity inner surface tube holes (refer with Fig. 3).

Based on the results of measurements parameters of surface roughness after burnishing broaching process it can be concluded that with increasing relative strain ratio decreasing surface roughness (refer with: Fig. 4).

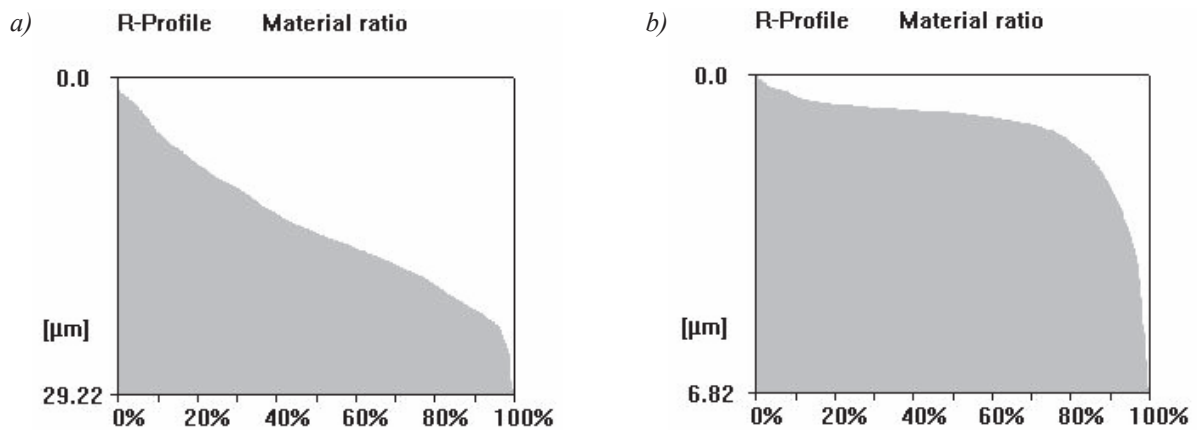


Fig. 3. The Abbott-Firestone curve for relative strain ratio  $\epsilon_{nc} = 1.4\%$ ; a) before and b) after burnishing broaching process

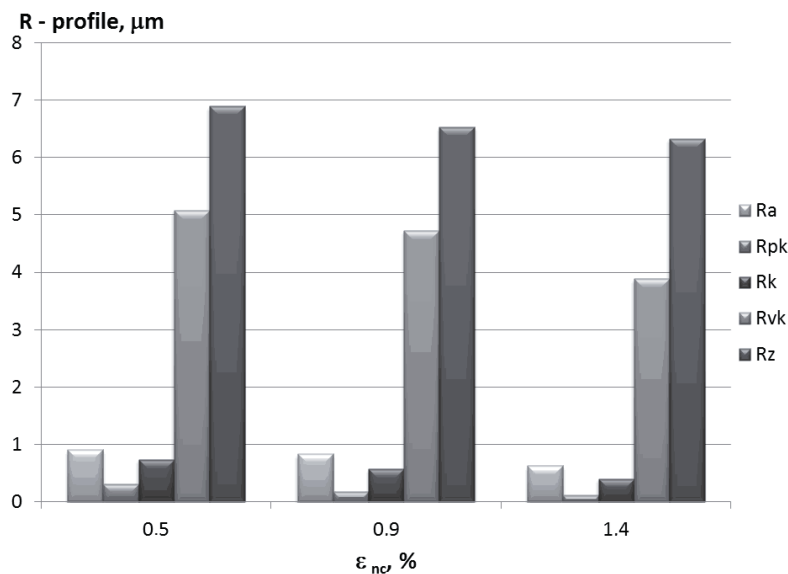


Fig. 4. The profile roughness after burnishing broaching process

When comparing the parameters related to the material share curve shown in Tab. 2 and Fig. 4, it can be concluded that the most favourable distribution of the parameters of material share can be observed for relative strain ratio  $\varepsilon_{nc} = 1.4\%$ .

The depth of the roughness profile core ( $R_k$ ) and the reduced elevation height ( $R_{pk}$ ) take the lowest values possible, while the reduced depth of recesses of the roughness profile ( $R_{vk}$ ) takes the greatest value possible for sample No. 02.03 when tube holes was burnished for relative strain ratio  $\varepsilon_{nc} = 1.4\%$ .

We can conclude that the greater the degree of deformation of the inner surface tube holes the more decrease the values of roughness profile.

After burnishing broaching process experimental studies determined the dependence between relative strain ratio ( $\varepsilon_{nc}$ ) and surface roughness reduction rate ( $K_{Ra}$ ).

The data presented in Fig. 5 shows that with an increase in the relative strain ratio, the value of the surface roughness reduction rate increases. The increase in value surface roughness reduction rate is dependent on the applied degree of relative strain ratio. For a given range  $\varepsilon_{nc} = 0.5\text{--}1.4\%$  can to determine the change of roughness with the known values of arithmetic mean deviation of the surface roughness profile before and after burnishing broaching process (refer with: Fig. 5).

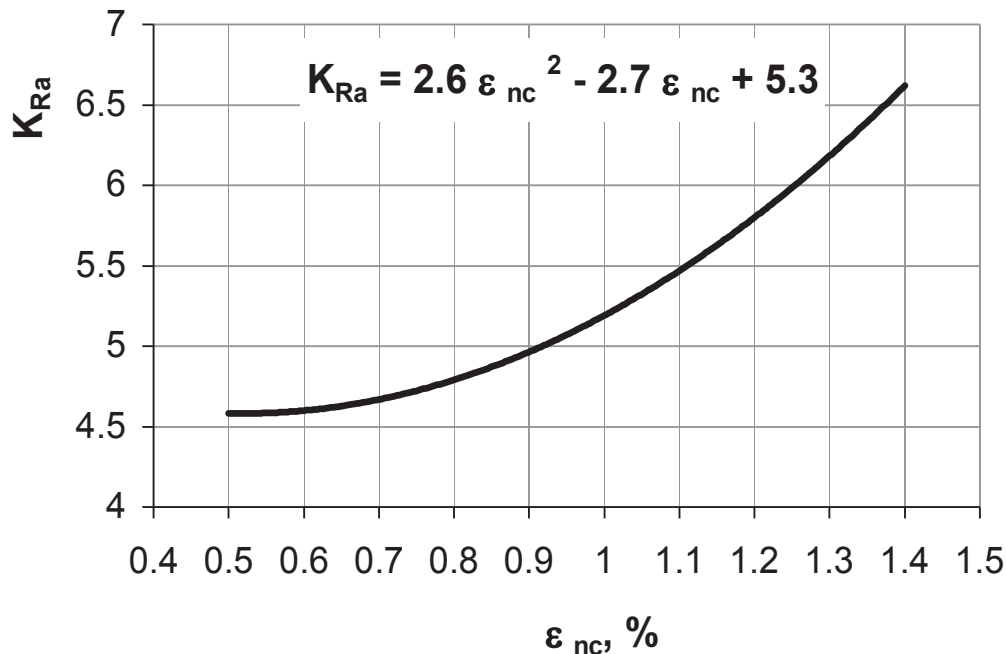


Fig. 5. The influence of the relative strain ratio ( $\varepsilon_{nc}$ ) on surface roughness reduction rate ( $K_{Ra}$ )

## Conclusions

After the studies carried out, it was determined that the relative strain ratio has significantly influenced on the alteration roughness of the inner tube holes after burnishing broaching process.

An increase in the value of relative strain ratio, the value of the surface roughness reduction rate increases.

After conducting research burnishing broaching tube holes of C45 steel it was determined that effectively replaces the machining such as grinding, reaming, honing and lapping – but without the abrasive contaminants in the surface layer characteristic of the grinding.

After burnishing broaching, process an improvement in roughness and general condition of the surface and specifically more advantageous share of the material bearing.

The arithmetical mean deviation profile roughness after burnishing broaching process has adopted very low values.

The paper determined the relationship between relative strain ratio and the rate of reduction in surface roughness.

On this basis, knowing the initial roughness and the degree of deformation burnishing broaching process you can specify the expected roughness recommended by the producer of a steel tube holes.

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