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THE EXPERIMENTAL ANALYSIS OF THE BURNISHING PROCESS USING THE METHODS – NPS

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Abstract

The paper presents selected results of experimental research of burnishing process of the steel tube holes. The ballizing process (NPS) is the method of burnishing where consists of pushing the tool through the hole, wherein the ball is greater in size than the opening of the value of the reduction ratio. Used tools to burnishing are hard and smooth surface. Burnishing elements are made of shape: ball, roll and disk. The ballizing process is carry out by a ball. 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, not achieved a satisfactory state surface layer of tube holes. Improve the properties of the surface layer can be obtained after application, as finishing, the slide burnishing. Modelling of the burnishing process using the method, NPS is to determine the impact of a specific curvature a rigid tool with of the workpiece. Ballizing 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. The aim of experimental research was to obtain surface layer state of compressive residual stress and the material ratio curve of convexity shape.

Keywords: *ballizing process, steel tube holes, surface plastic forming, roughness surface*

1. Introduction

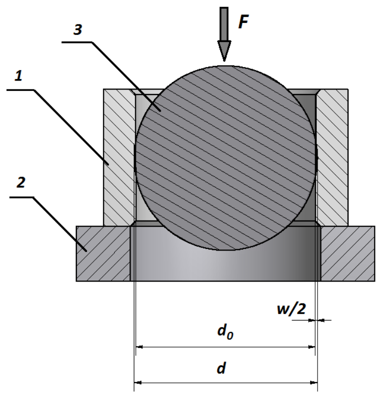
The ballizing process is a finishing machining of tubes, having a number of advantages. This treatment allows increasing the dimensional accuracy of holes, the surface roughness parameters decreases, increasing the hardness of the surface layer with formation of compressive residual stresses. It is also important that the burnishing technology allows machining holes with a lack of straightness of the axis. The advantages of burnishing may also be considered with high performance and relatively easy technological instrumentation. The tools used for processing by the burnishing special broaches plungers in variety of shapes and steel balls such as bearing.

Most burnishing internal diameters are used in serial productions, auto parts, hydraulic equipment for ships and industrial engineering. Burnishing a variety of metals such as steel, bronze, brass, aluminum alloys and cast iron [1, 4, 7, 9, 10, 13]. 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 ballizing the tube holes used in mass production and mass are, shot, push mandrel and multi-element bearings [4, 5, 8, 12]. Because of the influence of elastic object, the size of the maximum element burnishing must be greater than the assumed size of openings of 0.05 mm. These values are selected experimentally [7, 9].

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. The burnishing is extensively 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, 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, 7, 9, 11].

2. Methodology and research results

The experimental research was made by ballizing process steel tube holes, greased with machine 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. The experimental research was conducted for samples C45 steel. The samples had the shape tubes, amongst which you can distinguish a few 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 ballizing process is pushing ball bearing 20CrMo4 steel through the hole. In the Fig. 1 is shown schema of ballizing process by ball.



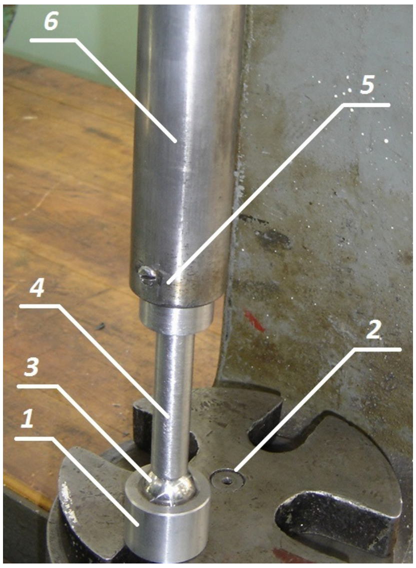


Fig. 1. The schema of ballizing process, d – outer diameter of the ball, d_0 – diameter inner tube before burnishing, w – reduction ratio, 1 – tube hole, 2 – basis of hydraulic press PH-16, 3 – ball, 4 – guide-pin ball, 5 – mounting socket, 6 – punch of hydraulic press PH-16

The formula (1) represents the relative plastic deformation for ballizing process:

$$\varepsilon_{np} = \frac{d - d_0}{d_0} \cdot 100\%. \quad (1)$$

The reduction ratio was calculated based on the following formula:

$$w = d - d_0 , \quad (2)$$

where:
d – outer diameter of the ball,
d_0 – diameter inner tube before ballizing.

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

Tab. 1. The diameter of the ball and inner tube before ballizing process and deformation ratio of the steel tube holes after ballizing process

No. of samples	**d [mm]**	**d_0, [mm]**	**w, [mm]**	**ε_{np}, [%]**
11	33.33	33.23	0.1	0.3
12	33.33	33.13	0.2	0.6
13	33.33	33.03	0.3	0.9
21	21.97	21.87	0.1	0.5
22	21.97	21.77	0.2	0.9
23	21.97	21.67	0.3	1.4
31	15.87	15.77	0.1	0.6
32	15.87	15.67	0.2	1.2
33	15.87	15.57	0.3	2.0

The measurements were performed according to the principles contained in ISO standards. Surface roughness after burnishing ballizing was measured with a profilometer Hommel – Tester T1000 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. A number of parameters of surface roughness after burnishing were determined, among other things, the arithmetic mean deviation (Ra) of the surface roughness profile after burnishing (which should be the lowest) and parameters were defined associated with the material ratio curve. Parameter (Rpk) 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. Parameter (Rk) defines the core roughness depth (which should be the lowest). Reduced depth of roughness profile valley is described by (Rvk) parameter (which should be the highest). It is a measure of the working surfaces ability to keep the lubricant in the valleys created mechanically. Tab. 2 shows parameters of surface roughness for the steel tube holes after burnishing process.

Fig. 2. The samples and ball burnishing used for ballizing process

Figure 3 shows the arithmetical mean deviation of the assessed profile after burnishing ballizing process for relative plastic deformation: ε_{np} = 1.4%. The material ratio curve for relative strain ratio ε_{np} =1.4% after burnishing process is presented in Fig. 3. 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 [2, 3]:

$$K_{Ra} = \frac{R'a}{Ra}, \tag{3}$$

where:

R'a – arithmetical mean deviation of the surface roughness profile before ballizing process, (R'a =4.1 μm),

Ra – arithmetical mean deviation of the surface roughness profile after ballizing process.

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

No of samples	Ra [μm]	Rz [μm]	Rt [μm]	Rp [μm]	RSm [mm]	Rpk [μm]	Rk [μm]	Rvk [μm]	Mr1 [%]	Mr2 [%]	Rmr01 [μm]
11	1.57	8.98	12.39	2.64	0.12	0.34	1.48	5.40	4.9	66.1	1.90
12	1.51	8.85	12.38	2.89	0.09	0.28	1.69	5.03	6.0	67.2	2.23
13	1.39	7.72	9.77	2.27	0.08	0.15	1.58	3.94	2.7	60.3	1.58
21	1.24	7.65	9.16	2.18	0.12	0.27	0.93	4.50	6.1	67.1	1.48
22	0.84	7.91	8.25	1.84	0.11	0.25	0.58	4.13	8.6	77.0	1.50
23	0.35	3.51	5.24	0.75	0.08	0.08	0.40	1.71	6.4	79.9	0.61
31	1.16	6.80	7.97	1.43	0.10	0.15	0.85	4.2	3.2	67.4	0.76
32	0.64	4.86	6.82	1.17	0.08	0.12	0.54	2.4	5.8	69.5	0.84
33	0.32	3.90	6.67	0.84	0.07	0.20	0.33	1.9	10.6	83.8	0.69

For samples No. 23 and No 33 for relative plastic deformation ε_{np} =1.4% and ε_{np} =2.0% after ballizing process defined that the arithmetical mean deviation (refer with: Tab. 2) of the measured profile and the material ratio curve surface roughness parameters take the smallest value.

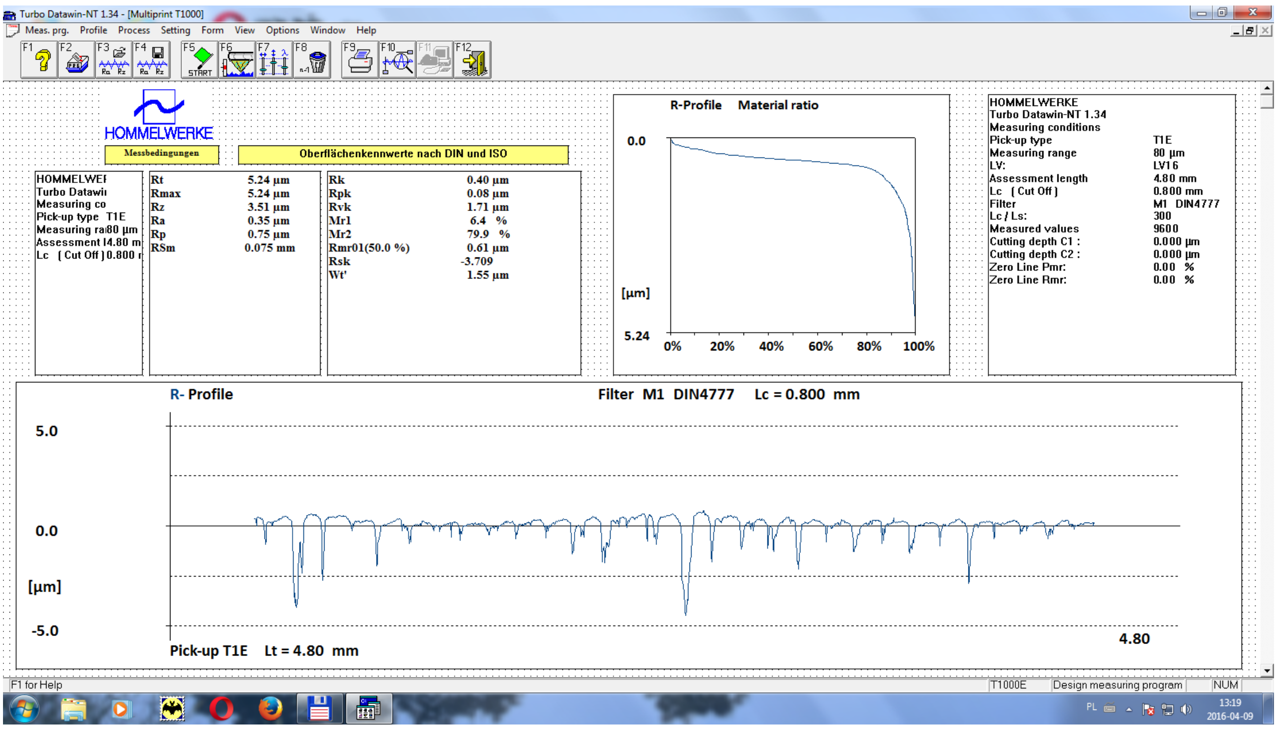


Fig. 3. The material ratio curve and the profile roughness after ballizing process for relative plastic deformation ε_{np} = 1.4% (sample No. 23)

When comparing the parameters related to the parameters material share curve shown in Tab. 2 and Fig. 3 and 4, it can be concluded that the most favourable distribution of the parameters of material share can be observed for relative plastic deformation ε_{np} =1.4%. The depth of the roughness profile core (Rk) and the reduced elevation height (Rpk) take the lowest values possible, while the reduced depth of recesses of the roughness profile (Rvk) takes the greatest value possible for sample No. 23 when tube holes was burnished for relative plastic deformation ε_{np} =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.

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

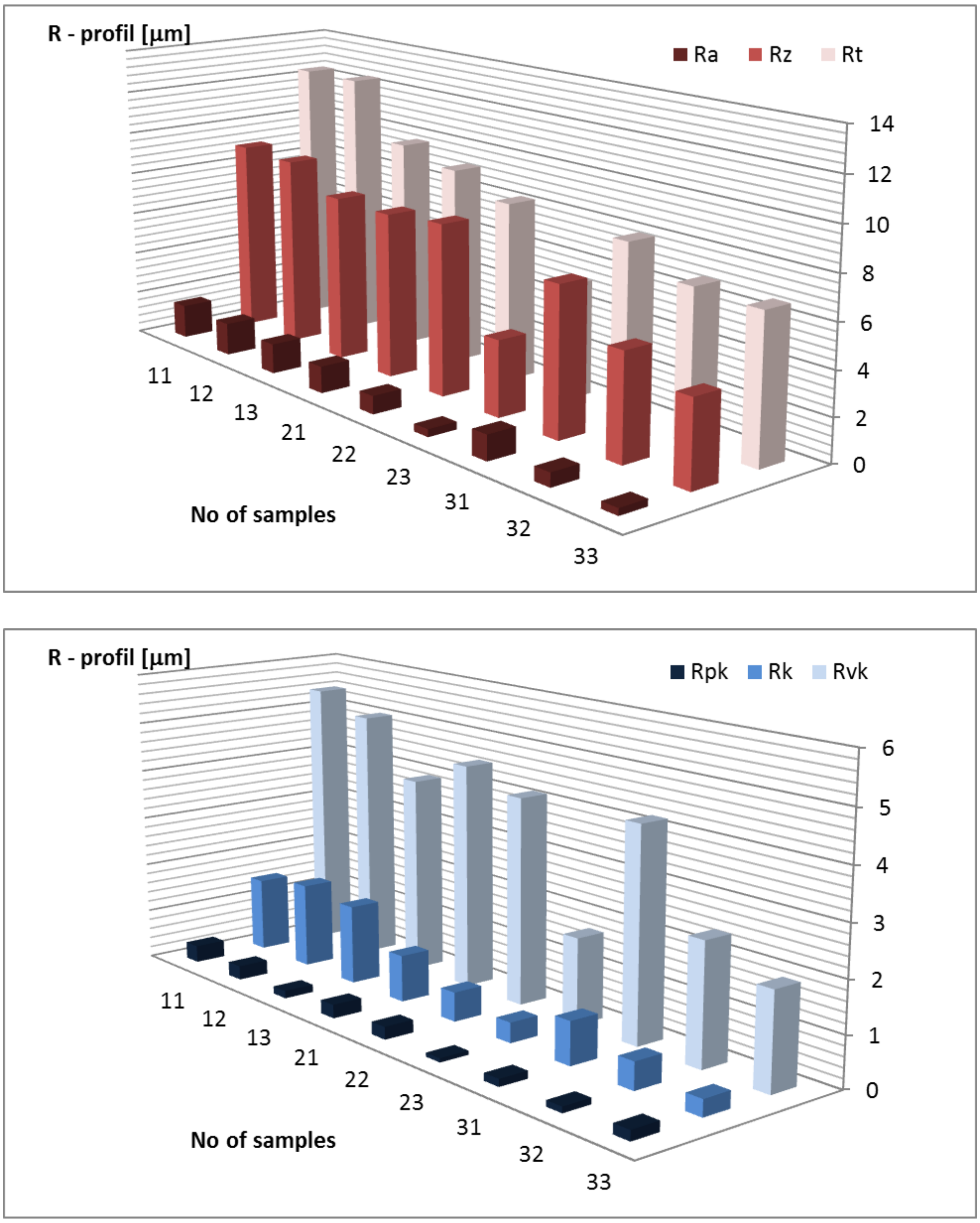


Fig.4. The parameters of the surface roughness and parameters of the material ratio curve after ballizing process for samples refer with Tab. 1

The data presented in Fig. 5 shows that with an increase in the relative plastic deformation, the value of the surface roughness reduction rate increases.

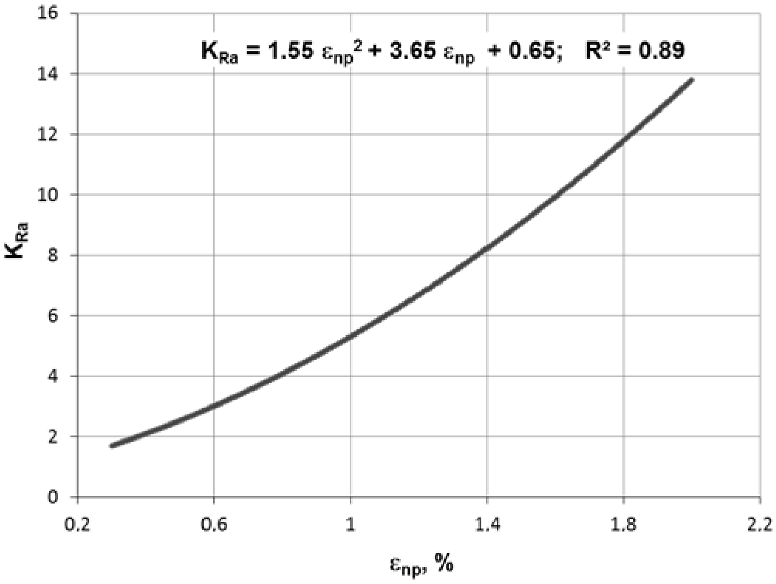


Fig. 5. The influence of the relative plastic deformation (ε_{np}) on the surface roughness reduction rate (K_{Ra})

After experimental studies, ballizing process determined the dependence between relative plastic deformation (ε_{np}) and surface roughness reduction rate (K_{Ra}). The increase in value surface roughness reduction rate is dependent on the applied degree of relative strain ratio. For a given range ε_{np}= 0.3-2.0% can to determine the change of roughness with the known values of arithmetic mean deviation of the surface roughness profile before and after ballizing process. After ballizing process and made measurements of surface roughness can be concluded that there was a significant reduction in roughness. The maximum value of the surface roughness reduction rate was equal to K_{Ra} = 13.8 for the relative plastic deformation ε_{np} = 2.0%. After executed experimental research we can determined that the greater the degree of deformation of the inner surface tube holes the more decrease the values of roughness profile.

Conclusions

1. After ballizing process steel tube holes it was determined that successfully replaces the machining such as grinding, reaming, honing, but not the abrasive contaminants in the surface layer characteristic of the grinding.
2. An increase in the value of relative plastic deformation (ε_{np}), the value of the rate increases of surface roughness reduction.
3. After ballizing process, an improvement in roughness and condition of the surface and specifically more advantageous share of the material ratio curve.
4. The arithmetical mean deviation profile roughness after burnishing process has adopted very low values.
5. For relative plastic deformation ε_{np} =1.4% (sample No 23) and ε_{np} = 2.0% (sample No 33) after ballizing process determined that the arithmetical mean deviation of the assessed profile and the material ratio curve surface roughness parameters take the smallest value.
6. After the studies carried out, it was determined that the relative plastic deformation has significantly influenced on the alteration roughness of the inner tube holes after burnishing.
7. In the paper presented the relationship between relative plastic deformation (ε_{np}) and the surface roughness reduction rate (K_{Ra}). Therefore, knowing the initial roughness and the degree of deformation ballizing process you can specify the expected roughness recommended by the producer of a steel tube holes.

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