METHODOLOGY FOR OPTIMIZING THE INFLUENCE OF SURFACE ROUGHNESS ON THE FUNCTIONAL PROPERTIES OF DETAILS IN MECHANICAL ENGINEERING

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Abstract: *The article deals with a fundamentally new methodology for optimization, assessment, and control of the roughness of surfaces that can be applied in all production facilities. What is meant by optimization is the choice of the most appropriate roughness from among all the practically possible values that can be achieved in certain production conditions. The given methodology is used as a basis for the assessment of the influence of surface roughness on the strength of a joint formed through the process of hot pressing.*

Keywords: *SURFACE ROUGHNESS, NON-PARAMETRIC METHOD, STENGHT OF PRESS JOINTS*

1. Introduction

Improving the quality of output production is the most important task of industry [1]. This task is especially relevant in machine-building and mechanical engineering. It is general knowledge that the correct functioning of every item is determined by its accurate size, the shapes, and the proper positioning of the contact surfaces of its parts, as well as the state of their surface. The least researched areas are problems related to the optimization of the micro geometry of surfaces and providing reliable control.

So far, it has been established that surface roughness has a direct bearing on about 20 functional properties of surfaces (adhesion, corrosion resistance, strength of press joints, etc.). Modern-day machinery requires coping with a number of challenges related to increasing the strength and improving the efficiency of machine parts and constructions, including the fixed joints [2]. This necessitates a thorough analysis to study the effect of a number of factors on the strength of press joints – geometric factors, the macro and micro relief of the contact surfaces of machine parts, the physical and chemical properties of the materials that the parts are made of under the specific conditions of forming the joints.

It is a known fact that the load-bearing capability of press joints is determined by their ability to withstand certain loads (torque or axis force). The quality of the joints is determined to a large extent by the geometry of the contact surfaces of the machine parts. Many of the published studies [3,4] suggest increasing the strength of press joints through applying a regular or partially regular micro relief on one of the machine parts. It is suggested that the process be performed through surface plastic deformation or the creation of micro relief on two levels by means of making curvilinear grooves in the stick. The most significant drawback of the above mentioned methods are the complexity of the relief-making tool, the difficulties arising from providing accurate orientation of the grooves and the projections of the micro relief, and the relatively low productivity of the process.

The article elaborates on a fundamentally new methodology for optimization, assessment, and control of the surface roughness, applicable in all types of production situations [5-8]. What is meant by optimization is the choice of the most appropriate roughness from among all the practically possible values that can be achieved in certain production conditions. The given methodology is used as a basis for the assessment of the influence of surface roughness on the strength of a joint formed through the process of hot pressing.

2. Definition of the task

A joint [7] produced through the process of hot pressing is taken as an example (fig.1).

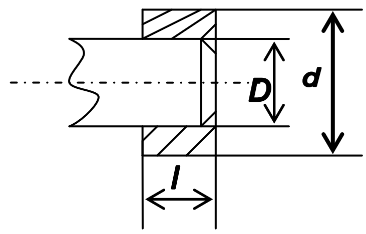


Fig. 1 A hot-pressed joint with a nominal diameter of contact area D = 20 mm, external diameter of the threaded collar d = 30 mm, length of contact area l = 20 mm. Under exploitation the joint is loaded with axis force F = 6,65.10^3 N.

In order to study the effect of surface roughness on the strength of the press joints, we have prepared 9 samples, in three groups of three pieces depending on the obtained surface roughness. The samples in the first group were produced through turning, with the resulting surface roughness of the shaft and threaded collar are respectively: $R_{z\ threaded\ collar}$ = 15,04 μm and $R_{z\ shaft}$ = 17,64 μm. In the second group – through grinding: $R_{z\ shaft}$ = 1 2,69 μm and $R_{z\ threaded\ collar}$ = 10,05 μm, and in the third group – through polishing: $R_{z\ shaft}$ =2,1 μm and $R_{z\ threaded\ collar}$ = 2,65 μm.

In order to test the strength of the produced joints, they were subjected to un-pressing, through fixation of the load. The result of the testing is this: the samples in the third group show un-pressing load of $F = 26.10^3$ *N*, which is 20 % more than the un-pressing load of the samples in the second group with the same force, and 50% more than the samples in the first group under the same conditions.

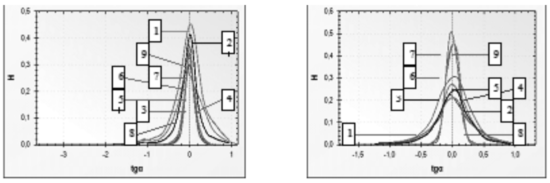
3. Theoretical analysis of the chosen method

The results show the considerable effect of the surface roughness on the force applied to un-press the joints. This proves the expediency of optimizing this effect.

But the task of optimizing the roughness of surfaces cannot be plausibly achieved with the use of the standard parameters for roughness because their alteration does not characterize the factual alteration of the micro relief of the surfaces [5-8]. In order to achieve the preferred parameter for roughness that has been experimentally selected and designed in the draft, either different technologies or different tools can be used to implement a change in the structure of the micro relief and consequently in the properties of the surfaces. Setting a specific parameter for roughness in the technical documentation, we would be able, in aiming to achieve it, to process the surface in a way that will lead to one of the many possible micro reliefs which will provide different functional properties. Most methods of processing surfaces yield a random pattern of roughness. This is why, in modeling the roughness of surfaces, the theory of random functions can be used, which in effect implies that the pattern of roughness of a given surface can be viewed as the realization of a random value. And we all know from mathematics that the full parametric definition of a random value requires 3 to 25 parameters – and this is exactly as many parameters of roughness as need to be specified in the construction draft in order to provide an exact definition of the required roughness. Theoretically this is possible, but in practice this is hardly feasible.

A possible solution for this situation is suggested in one fundamentally new approach for assessment and control of the roughness of surfaces – a method which uses non-parametric criteria such as the diagrams of different functions[1,5,6,7,8]. Taking into account the random element in forming the micro relief of surfaces, and based on the theory of random functions, it has been established that the most comprehensive information about the pattern of roughness as a random value is contained in the functions of distribution and the density of distribution of its ordinates, as well as in the functions of distribution and the density of distribution of the tangents from the angles of inclination of the pattern. This naturally leads to the conclusion that it is expedient to use these functions as criteria for the assessment and control of the roughness of surfaces.

In line with the proposed methodology, below are the diagrams of the non-parametric criteria "Density of distribution of the tangents from the angles of inclination of the pattern" that were made with the samples under analysis.



a) *b)*

Fig. 2 Diagrams of the non-parametric criteria "Density of distribution of the tangents from the angles of inclination of the pattern" : a) for the threaded collars, b) for the shafts.

The numbers in the diagram show the numbers of the studied samples (1 through 3 – first group, 2 through 5 – second group, 6 through 9 – third group).

4. Analysis of the results

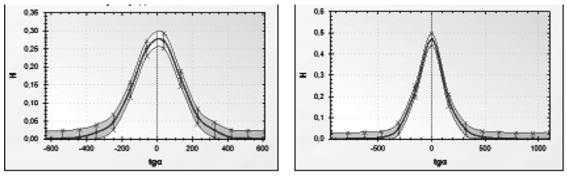
The experiment that was conducted shows that the roughness of surfaces affects the strength of press joints, which proves the expediency of optimizing this effect. The process of optimization is done through trying to find the optimal level of the functional property (optimization parameter) by varying the technological modes of processing (optimization factors) [9]. The force of un-pressing the joints (F) is considered a parameter for optimization, with the optimal level being the highest possible value. The factors of optimization are the modes of processing in polishing the machine parts "shaft" and "threaded collar": $S_{threaded\ collar}$ – use of one rotation in polishing the threaded collar, $V_{threaded\ collar}$ – velocity of cutting in polishing the threaded collar, S_{shaft} – use of one rotation in polishing the shaft, V_{shaft} – velocity of cutting in polishing the shaft. After conducting a statistical regression analysis, on the basis of the theory of planning the experiment, the following data was arrived at:

- a mathematical model relating the optimization parameter with the technological modes of processing and making it possible to forecast the level of force required for un-pressing with variations of the above-mentioned factors

$$F = 17,25 - 3,5S_{threadedcollar} + 2,5V_{threadedcollar} - 1,25S_{shaft} + V_{shaft} + 0,8S_{threadedcollar}V_{threadedcollar}S_{shaft}V_{shaft}$$

- technological modes of processing which produce an optimal surface roughness, guaranteeing the highest level of force required for un-pressing $S_{threaded\ collar} = 0{,}43$ *m/min*, $V_{threaded\ collar} = 37{,}5$ *m/s*, $S_{shaft} = 0{,}467$ *m/min*, $V_{shaft} = 36$ *m/s*

- optimal surface roughness of the following machine parts «Threaded collar» and «Shaft», which can be controlled through the use of non-parametric criteria presented in fig. 3 – these are the reference diagrams and the tolerances.



a) *b)*

Fig. 3 Reference diagrams «Density of distribution of the tangents from the angles of inclination of the pattern» with an indication of the tolerance for: a) the threaded collars, b) the shafts

These curves, assumed as reference curves, are related to the sample surfaces that showed the best results in the course of the experiment. It is possible that there exist other surface roughness values which can require greater load for un-pressing and, therefore, greater strength of the press joints, but the present article's aim is to define the best geometry that can be achieved under specific production conditions.

5.Conclusion

The use of standard parameters to assess and control the surface roughness of machine parts, appliances and machines has only one advantage – the simplicity of its practical use [6]. When we are looking for a complex criterion dependent on several factors, it is simply impossible to apply numerical criteria because they do not allow for the optimal characteristic (the most appropriate of all the possible ones) of the normed functional property of the surface to be accurately defined with a practicable degree of accuracy. The functions of density of distribution and the functions of distribution of ordinates and tangents of the angles of inclination of the pattern unequivocally define the roughness of surfaces and fully satisfy the legitimate requirement of a thorough and comprehensive definition.

6. Literature

1. Мусалимов В.М., Валетов В.А., Динамика фрикционного взаимодействия. СПб: СПбГУ ИТМО, 2006,191 с
2. Буканова И.С., Татаркин Е.Ю., Ятло И.И. Технологическое обеспечение повышенной несущей способности неподвижных соединений типа «корпус – втулка» // Ползуновский вестник. 2009. №1-2. - С.183-187.
3. Шнейдер Ю.Г. Эксплуатационные свойства деталей машин с регулярным микрорельефом. – Л.: Машиностроение, 1982. – 248 с.
4. Бородин А. В., Несущая способность прессового соединения с криволинейны канавками в стыке // Вестник машиностроения. – 2000. - №5
5. Leonov D., Ivanov A., Non parametrical approach for optimisation of the roughness of the products' surfaces in the mechanical engineering, "Machines, Technologies, Materials", Issue 7, -2013, p.32-34
6. Ivanov A.Y., Leonov D.B. Methodology for optimization, evaluation and control of products surface roughness // Journal of the Technical University. – Sofia, Plovdiv branch, Bulgaria «Fundamental Sciences and Applications». – 2012. – V. 17. – P. 19–23.
7. Иванов А.Ю., Леонов Д.Б., Влияние шероховатости поверхности на усилие распрессовки прессовых соединений, Научно-технический вестник информационных технологии, механики и оптики, Выпуск 3(85), 2013, 147-150 с.
8. Иванов А.Ю., Леонов Д.Б., Технологические методы обеспечения качества изделия, Научно-технический вестник СПбГУ ИТМО, 2011, № 5(75), с. 111 – 113
9. РДМУ 109-77. Методика выбора и оптимизации контролируемых параметров технологических процессов. – М.: Изд-во стандартов, 1978. – 48 с.