NON – PARAMETRICAL APPROACH FOR OPTIMISATION OF THE ROUGHNESS OF THE PRODUCTS' SURFACES IN THE MECHANICAL ENGINEERING

Dipl. eng. Leonov D.[1], PhD Ivanov A.[2]
VMZ Co, Sopot, Bulgaria [1]
Saint Petersburg National Research University of Information Technologies, Mechanics and Optics, Russia [2]

Abstract: *At the contemporary mechanical engineering the need of optimisation of the roughness of the surfaces is substantiated. This statement deals with a new methodology, based on the implementation of the so called non - parametrical criteria of the roughness of the surfaces' evaluation, represented by graphic illustration of different functions – functions of distribution and density of distribution of the ordinates of the profile or angles' tangents of the profile's gradient. As functional measurement of the surfaces the adhesion of the polish coat to the surfaces of the details of the steel is treated of.*

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Keywords: ROUGHNESS OF THE SURFACES, NON – PARAMETRIC CRITERIA, ADHESION OF THE POLISH COAT

1. Introduction

It is well known that a great number of different factors have influence on the quality of products in instrument-making and machine manufacture. One of them is roughness of the surfaces. It's established by now, that surface roughness has influence on some 20 different functional properties of surfaces (adhesion, corrosion-resistance, electric conductivity, wear resistance etc.) That is why, if the roughness of the surface has great influence on some particular functional property of the surface it is advisable that influence to be optimized.

Present article considers methods for optimization, evaluation and control of surface roughness, which are new in principle. On the basis of the method given evaluation of the influence of surface roughness on the adhesion of the varnish paint coating of a detail of 45 steel is carried out.

2. Evaluation and control of surface roughness

In the beginning we have to specify - we can speak about optimization of surfaces only theoretically. In practice that must be understood not as optimization in the full sense of word, but rather as a choice of the most suitable value of roughness amongst those possible in practice, which can be achieved in certain production conditions.

Also it is necessary to note that optimization of surface roughness is practically impossible without the fulfillment of the following conditions:

- the optimal roughness of the surface for the particular functional property of hers must be known;

-the known optimal roughness of the surface must be exactly stated the technical documentation;

- the optimal roughness which is known and stated in the drawing, must be technogically ensured during machining of the surface.;

- the surface roughness after machining of the surface should be comparatively quickly, suitably and cheaply compared to the optimal roughness for said surface.

In the frames of the parametric approach for evaluation and control of the surface roughness, the technological insurance of their functional properties is reduced to achieving roughness values stated in the technical documentation, which is designated by one parameter - most often Ra or Rz. But the meaning of these parameters often does not reflect the actual character of surface relief. A great number of different profiles exist for which the standard parameters for roughness are equal. We can prove that with the following simple example: two mirror profiles describing absolutely different microrelief have equal parameters (fig.1).

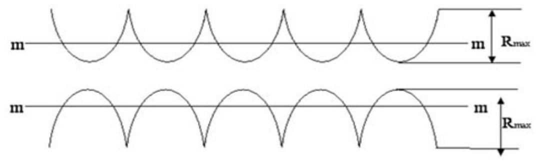


Fig. 1 *Two mirror profiles.*

Specifying a particular value of a roughness parameter in the technical documentation we can, trying to keep it when machining the surface, get one of the many possible microreliefs which will ensure different functional properties [1]. By most methods of machining of surfaces a random profile of roughness is achieved. That is why for modeling of surface roughness the theory of the casual functions can be used the [2], which practically means that a profile of a real surface can be looked on as a realization of a random quantity. It is known from mathematics that for full parametric description of a random quantity from 3 to 25 parameters are needed – and as many parameters for roughness as that have to be specified in the constructors drawing to exactly describe the roughness demanded. Theoretically that is possible, but in practice it is unreal, which shows the inexpedience to norm the roughness of the surfaces by using the standard parameters of roughness

Prof. V.A.Valetov, member of Russian Academy of Science, offers a possible decision in this direction, giving base to an approach new in principle for evaluation and control of surface roughness – a method by using non-parametric criterions and as such the graphics of different functions are taken. As it was said earlier in present article the profile of a real surface from the view point of mathematics can be considered as a realization of a random function. And from mathematics we know also that the greatest quantity of information about the profile as a random quantity is contained in the functions of distribution and the density of distribution of his ordinates and the functions of distribution and the density of distribution of the tangents of the angels of the gradient of the profile which leads to the conclusion for the expedience of using those functions as a criterions for evaluation and control of surface roughness. It is known also, that those function can be presented either analytically (as formulas) or parametrically (as a set of parameters), or graphically (as graphics).

It is not found out by now and we do not know how to use analytical presentation of those functions in practice as criterions [3]. The parametrical presenting of these functions is also inconvenient due to reason we mentioned before – i. e. for more exact parametric description many parameters are needed. That's why the method of using of graphic presentation of the functions of distribution and density of distribution of the ordinates of the profile and the functions of distribution and density of distribution of the tangents of the angels of his gradient is developed and checked by a number of tests.

3. Roughness of surfaces and adhesion of the varnish paint coating to steel details

To demonstrate the practical value of using the non-parametric method of evaluation and control of the surface roughness let us examine the following example. In the machine manufacturing plant, when machining of the "Corpus" steel detail (fig.2) a task is set: under standard manufacturing conditions such roughness of the surface to be chosen, which can guarantee the necessary adhesion of the varnish paint coating without the necessity of laying a primer coating. The investigation goes trough two stages - evaluation of the influence of the roughness of the surfaces on the adhesion and optimization of the roughness of the surfaces for the particular functional property.

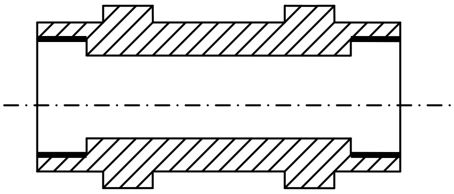


Fig. 2 *Steel detail "Corpus".*

To examine the influence, which the roughness of the surfaces may have on a particular functional property of theirs, it is necessary a simple experiment to be carried on: a quantity of models, acceptable for the statistics, are prepared with the same (equal) surface characteristics, but with different parameters of starting roughness of the examined surface - in this case 15 pcs of models are prepared, divided in three groups of 5 pcs in a group (for each case of a starting microrelief several models which are the same are prepared to ensure the experiment).[4] The technology of manufacture of each model is strictly fixed, so to become clear now each microrelief is technologically obtained - table 1.

Table 1: *Technology of manufacture of each model.*

Numbers of the groups of models	Mechanical processing	Modes of machining	Surface roughness (Rz), μm
1	Turning	*S*=38 mm/rev, *t*=0,75 mm, V=175 m/min	40,33
2	Turning	*S*=19 mm/rev, *t*=0,75 mm, V=150 m/min	15,42
3	Turning	*S*=9 mm/rev, *t*=0,75 mm, V=100 m/min	4,16
S – Feed rate, V - Cutting speed, t - Depth of cut, Rz - Average maximum height of the profile			

By the moment of laying the varnish paint coating (enamel GF-1426 with viscosity 60 s) on the upper surfaces of the models, by use of a profilometer, from the functional surfaces of each model information about the profile is taken out. A data base is created including information about the processes of treatment of the surfaces and their roughness. As a result of processing data about the profiles we get not only Ra and Rz but also graphic images of the functions of distributions and the density of distribution of the tangents of the angels of its gradient (fig.3, where the numbers of the graphics match the numbers of the groups of models) .

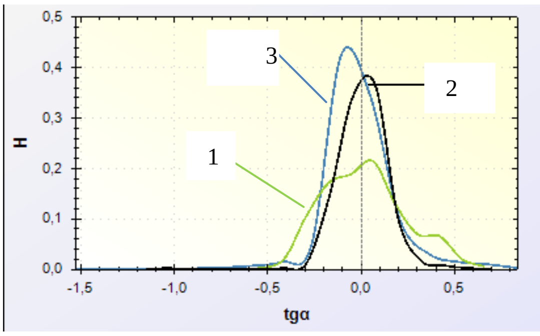


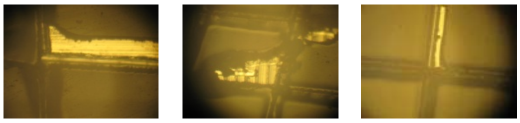
Fig. 3 *The graphics of non-parametric criteria „Density of distribution of the angles' tangents of the profile's gradient" of models. The X axis – value of the angles' tangents of the profile's gradient. The Y axis – frequency of emergence of the angles' tangents of the profile's gradient.*

All models prepared in this way are submitted to one and the same functional influence, in order to determine the influence of the roughness of the surfaces on a particular property of theirs. The check is made according to EN ISO 2409 "Paints and varnishes – Cross-cut test" [5], specifying the method for evaluation the resistance of the varnish paint coatings. According to the standard the results of the test are distributed in 6 qualification degrees (form 0 to 5). In our case the following results are obtained:

for the models of the first group (fig. 4-a) - the coating partly separates by the length of the edges of the cuttings and the touched area is 25 % - 3 degree;

for the models of the second group (fig. 4-b) - the coating partly separates by the length of the edges of the cuttings and the touched area is 36 % - 4 degree;

for the models of the third group (fig. 4-c) - the coating partly separates by the length of the edges of the cuttings and the touched area is 14 % – 2 degree.



a) b) c)

Fig. 4 *Photos of gratings under the microscope.*

4. Results and discussion

The experiment shows that surfaces roughness has influence on the adhesion of the GF 1426 enamel to the surface of the 45 steel detail which proves the expedience that influence to be optimized. The process of optimization is carried out by searching for the optimal level of the functional property (parameter of optimization) by varying the technological regimes of treatment (factors of optimization). In the quality of a parameter of optimization the result of the adhesion testing is considered, and the optimal level is the lowest qualification degree according to EN ISO 2409. The factors of optimization are the regimes of machining in turning the "Corpus" detail: S – feed rate, V - cutting speed, t - depth of cut. After carrying out the statistic regression analysis, on the basis of the theory of planning the experiment [6], the following are obtained:

- the mathematical model, connecting the parameter of optimization with the technological regimes of machining and allowing to prognosticate the level of adhesion when varying the mentioned factors :

(1) $A = 3,375 + 0,75S - 0,75V + 0,375t$,

where S – feed rate, V - cutting speed, t - depth of cut;

-the technological regimes at which the optimal surface roughness is obtained of the, which guarantees the best level of adhesion of the varnish paint coating : S=0,09 mm/rev, V=150 m/min, t=0,55 mm ;

-the optimal roughness of the surface of “Corpus“ detail, the control of which we suggest to be carried out by using the non-parametric criterions, shown on fig. 5.

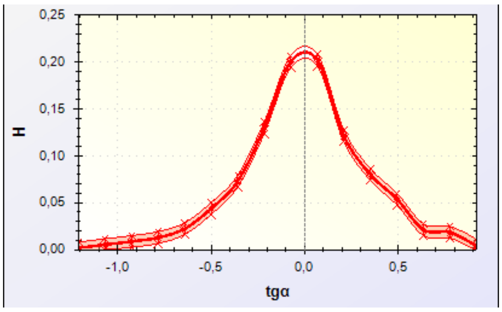


Fig. 5 *The optimal graphics “Density of distribution of the angles’ tangents of the profile’s gradient” and the deviation tolerances. The X axis – value of the angles’ tangents of the profile’s gradient. The Y axis – frequency of emergence of the angles’ tangents of the profile’s gradient.*

5.Conclusion

Using the suggested non-parametric method for evaluation and control of the surface roughness, we can experimentally determine the optimal surface roughness for a particular functional property of theirs, we can exactly and fully describe the necessary microrelief, we can provide technologically for its obtaining and we can control if fast and with of high quality. These conditions are sufficient to raise the quality of manufactured products through optimization of the microgeometry of their surfaces.

6. Literature

1. Мусалимов В., В. Валетов, Динамика фрикционного взаимодействия / Монография. - СПб: СПб ГУ ИТМО, 2006. - 191 с.

2. Valetov V., J. Grabov, Neue Verfahren auf dem Gebiet der Analyse und Kontrolle der Oberflachenmikrogeometrie. 41. Internationales wissenschaftliches Kolloquium, 1996, Band2.

3. Ivanov A., D. Leonov, Methodology for optimization, evaluation and control of products surface roughness, Journal of the Technical University - Sofia, Plovdiv branch, Bulgaria “Fundamental Sciences and Applications”, Volume 17, 2012, 19 – 23 p.

4. Леонов Д., А. Иванов, Оценка на влиянието на грапавостта на повърхнините върху корозионната устойчивост на металите и сплваите. - В: Сборник доклади от „Юбилейна научна конференция по повод 10 години от създаването на НВУ „Васил Левски” том 7, 14 – 15 юни 2012 г., 113 – 120 с.

5. EN ISO 2409 ”Paints and varnishes – Cross-cut test“, 2007

6. Орлов А.И., Прикладная статистика, Учебник. - М.: Издательство "Экзамен", 2004.