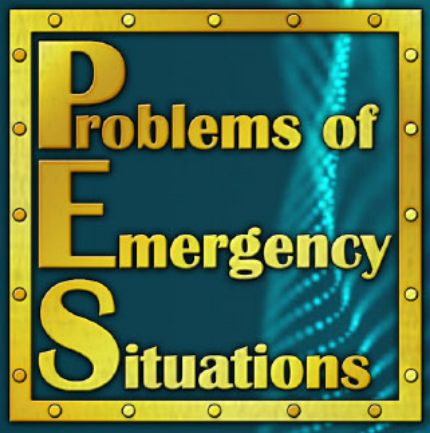

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Technological Process of Manufacturing a Gear Wheel Using the Abaqus Software Product Method

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Keywords: modelling, part, teeth, quality indicators, strength, transcendent system, modulus, oscillation, time point, profile, shear angle, transformation step.

Abstract. In this paper, we consider a detailed technological process for manufacturing parts, namely, a gear wheel. The proposed method with the intervention of modern 3D modelling makes it possible to improve the main indicators of quality and strength of parts. Based on the results obtained, a cycloid transcendental system of circular motion of a gear wheel with the specified basic parameters was modelled. Using multifunctional modules, we studied the vibrations of the gear wheel at different points in time. It was found that due to the fatigue and contact strength, it is possible to ensure uniform flexural strength of the gear teeth. And also, by adjusting the profile of the teeth of the part, we selected the desired strengthening coefficient. The presented dependence of the angles of inclination of the gear teeth on the transformation coefficient allows you to improve the main indicators of quality and strength by at least 2 %.

1 Introduction

Computer and information technologies of our time formulate the scientific and technological progress of mankind and create in general the information foundation for the development of science [1, 2, 3]. It should be noted that obtaining long-lasting indicators of quality [4, 5] and strength [6, 7] with their unique properties is possible with the help of new research technologies [8, 9, 10], which are based on improving accuracy, load capacity, as well as reducing the mass of parts [11, 12]. It should also be noted that the analysis of the main quality indicators of the studied parts will further improve and predict, first of all, these indicators [13, 14], as well as make it possible to improve the efficiency of the mechanism itself, reduce noise and vibration, as well as increase the durability of the part structure as a whole [15]. A special place in modern mechanical engineering technology is occupied by the technological process of manufacturing and processing gears [16] or gears [17], which is associated with high complexity of work and high labour intensity [18]. Because when manufacturing them, it is necessary to take into account a number of quality indicators, namely [19]: high and specific strength, corrosion resistance, a combination of high strength in one source material, as well as their chemical inertia, sound absorption, low thermal conductivity, etc [20, 21]. Thus, to study, analyse and generally justify the main indicators of quality and strength of parts of any type and various purposes with the latest methods of the Abaqus software product is an urgent task of modern mechanical engineering technology.

2 Main Part

The relevance of the use of modern and computer technologies in the study of a wide range of issues related to modelling is reflected in many publications on this topic [22]. It should be noted that these publication studies have worked out both the main issues of theoretical regularities of computer modelling [23, 24], and practical aspects with a more specific description of the technological process of manufacturing parts [25]. The main issues related to the use of 3D modelling [26, 27] in various branches of industrial activity are studied by many scientists, in particular [28, 29]. Research teams [30] have highlighted the main points of research that arise in the manufacture of structural parts [31]. The peculiarity of these works is that the range of computer modelling is limited by certain physical conditions of their existence [32, 33]. And also, the authors claim that the development of information technologies constantly puts forward new requirements for a modern design engineer of any industry [34, 35]. At the same time, indicators of the quality and strength of parts are not taken into account, which in the future allow predicting the durability of parts as a whole [36]. It should be noted that in many cases there are increased requirements both for modelling parts with design elements [37, 38, 39] and for creating design [40] and technological documentation [41], which is the main standard for the technological process of manufacturing parts in production conditions [42, 43]. Therefore, solving such a problem requires a more comprehensive and broader approach, which directly includes the use of new and modern-functional computer technologies. Namely: the main patterns of construction of parts during design, new ideas, methods and basic principles of the step-by-step technological process of manufacturing parts for any purpose, which means conducting fundamental and applied interdisciplinary research using the latest production methods and technologies.

The purpose of the work: to study, analyse and substantiate the main indicators of the quality and strength of gears using the methods of the modern Abaqus software product.

Materials. Modelling was performed in the Abaqus software package, which has the following main research models: Part, Property, Assembly, Step, Interaction, Load, Mesh, Job, Visualization, Sketch. For a detailed study of the technological process of manufacturing parts, and the gear wheel itself, a multifunctional visualization data module was used. The main indicators of quality and strength were based on a cylindrical coordinate system with a thickness of h and a radius of R. The profile of the teeth of the gear wheel was depicted in the form of a circular shape. That is, the basic Novikov theory, which is characteristic of one or two coupling lines, was fulfilled. It is also a cycloid transcendental system. In addition, this system is designed to transmit the main movement to the gear wheel or receive feces from it. In Fig. 1 shows modelling of a gear wheel using the Abaqus software product and its main parameters.

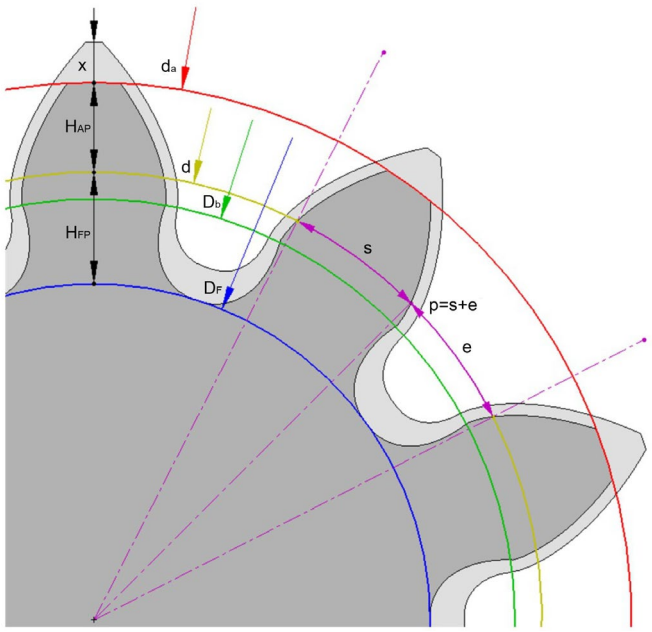

Fig. 1. Gear wheel modelling using a software product Abaqus and its main parameters

It should be noted that the main parameters that are responsible for the quality and strength of this design part are as follows:

x – the tool displacement error that occurs during the manufacture of the gear wheel and is equal to ± 0.2 mm;

H_{AP}, H_{FP} – the height of each (individual) gear tooth;

d_a – diameter of the common circles of the tops of the teeth of the part;

d – the main diameter of the dividing circle of the part;

D_b – diameter of the gear wheel involute (main circle);

D_F – diameter of gear depressions;

s – total number of teeth of the part;

e – distance between teeth;

$p = s+e$ – a function of tooth steps, namely: along the dividing circle.

It should also be noted that these quality and strength parameters are presented in the form of piezoelectric pads of the same thickness δ and radius $r_0 \leq R$. The outer and inner surfaces of this part are bordered by a passive layer, which is covered with infinitely thin continuous electrodes. The gear wheel is affected by an axisymmetric surface pressure, which is evenly distributed along the radius and is equal to: $P = P_0\cos(\omega t)$, which varies within a certain time t with a circular frequency ω, which is close to the natural oscillation frequency. In addition, the main functions of electrical potentials are performed, which are: $\psi (h / 2 + \delta) - \psi (- h / 2 - \delta) = R_e (2 V_a^{iwt})$. This function interacts with the frequency of mechanical loading, where: $V_a = V_a' + i V_a''$, and a small perturbation process occurs. Modeling the behavior of a gear wheel is generally based on the basic Kirchhoff-Lyav statements and hypotheses, and is mainly reduced to solving ordinary and differential equations.

Tests. With help of the additional multifunctional modules: Visualization, Assembly, Step-Interaction of the Abaqus software product, the number of gears was analysed at the moment of the hour, which was changed at the interval t = 450 °C – 850 °C. When modelling these details, they were asked to sing small details, the teeth of the teeth were sniffed at low speeds, the steel of the 40 grade was taken as the basis of the main material, so it was easy to get a sparkle in the middle (oil quenching was used) and the temperature was 550-650 °C at the same NV The door is 200-300, and the HRC becomes 50-60.

Figure 2 shows a model of a gear wheel at the moment of the hour t = 450 °C, and figure 3 shows a model of a gear wheel at the moment of the hour t = 500 °C.

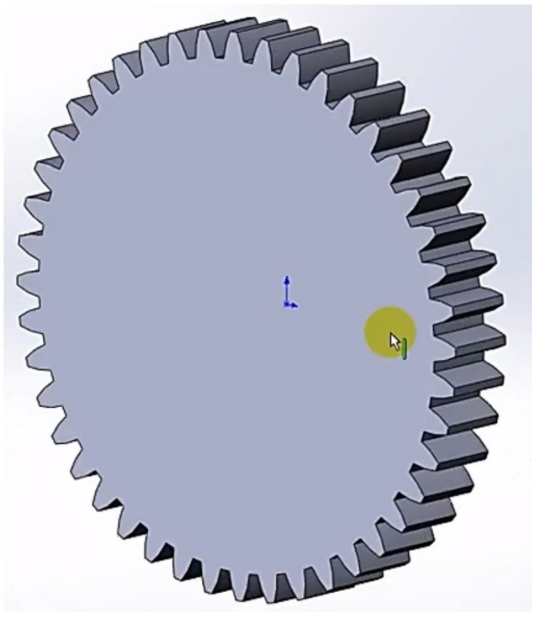

Fig. 2. Gear oscillation at a point in time t = 450 °C

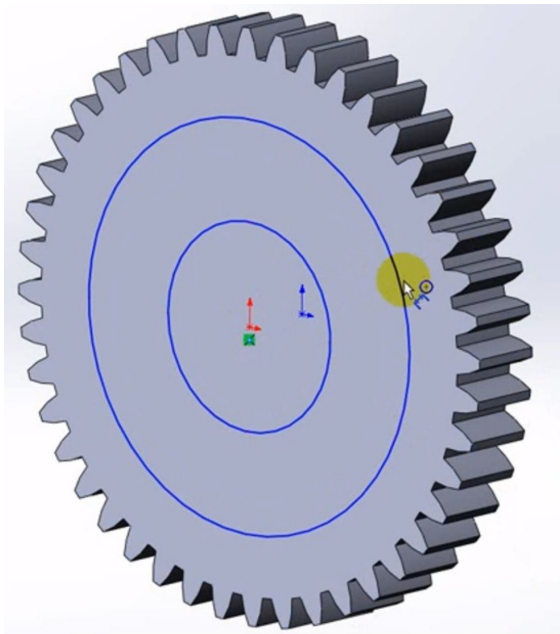

Fig. 3. Gear oscillation at a point in time t = 500 °C

It should be noted that the results obtained show a significant increase in the main quality parameters due to the fatigue and contact strength that occurred during gear modelling and which we were able to observe during modelling based on the Abaqus software product. And it is also important that when adjusting the profile of the teeth of the part itself, it was possible to choose the desired coefficient of strengthening due to the initial contour of the teeth, which provided uniform bending strength of the teeth of the gear wheel, or easily allowed a hole of any size and shape. It should also be noted that the results obtained are fully correlated with the recommendations of GOST 13755-68. Thus, it was decided to increase the oscillation of the gear wheel at time from t = 600 °C to t = 850 °C. From a number of studies, it follows that to a certain extent, the increase in the tooth thickness of this part occurs due to the adjustment of its profile, as well as the displacement of the original generatrix contour with a coefficient $x_i > 0$.

In Fig. 4 shows a simulation of a gear wheel at time t = 600 °C, and figure 5 shows a simulation of a gear wheel with asymmetric through holes at time t = 850 °C.

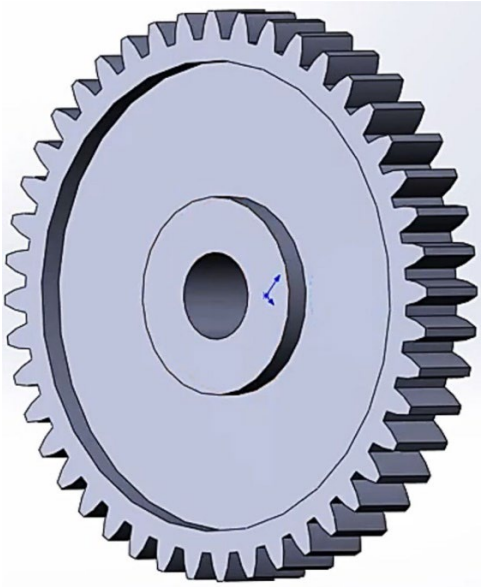

Fig. 4. Gear oscillation at a point in time t = 600 °C

Fig. 5. Gear oscillation at a point in time t = 850 °C

The conducted studies show that the angle of inclination of the gear teeth plays an important role in increasing the oscillation at a certain point in time. Also, each of the transformed cylindrical and spur wheels can be made in the form of a specific block, which consists of two identical wheels and with a given shear angle along the transformation step. Therefore, it can be argued that the gears must be modelled helical with a certain given angle of teeth, which allows you to provide the necessary end and axial overlap coefficient. The results obtained allow us to improve the main indicators of quality and strength by at least 2 %. Figure 6 shows the dependence of the angles of inclination of the gear teeth on the transformation coefficient.

The obtained dependence shows that the specified angles of inclination of the gear teeth increase due to an increase in the transformation coefficient of a certain tooth pitch. This additionally allows you to improve the main indicators of quality and strength, as well as predict additional parameters, namely: modulus, gear tooth height coefficient, part tooth profile angle, transformation coefficient, as well as permissible radial clearance coefficients.

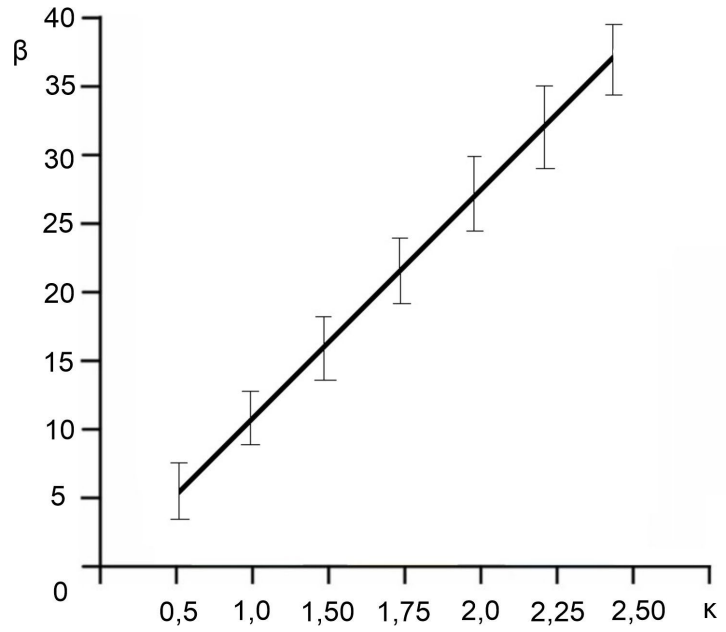

Fig. 6. Dependence of the angles of inclination of the gear teeth on the transformation coefficient, where: β – is the angle of inclination of the gear tooth, k – is the transformation coefficient of a certain pitch of the teeth of this part

3 Conclusion

From a number of studies conducted, it follows that:

1) the transformation of a certain pitch of the teeth of parts, namely the gear wheel, occurs with constant and basic parameters of quality and strength, namely: modulus, the height coefficient of the gear tooth, the angle of the profile of the teeth of the part, the transformation coefficient, as well as permissible radial clearance coefficients. The results obtained make it possible to model a gear wheel that has acceptable diametric dimensions and the same geometry of the tooth surfaces as untransformed gears. The main point in this case is modelling a certain tooth thickness, which allows you to significantly increase the bending strength of the gear teeth, or easily make a hole of any size and shape;

2) the problem of overlapping the teeth of the gear wheel is solved on the basis of the fact that the transformed gears must be modelled with helical teeth and with a certain angle of inclination of the teeth of the part, which directly depends on the transformation coefficient and increases due to its increase indicators;

3) the teeth of the gear wheel transformed in a certain step can also be modelled by copying, which directly allows you to improve the main indicators of quality and strength of parts by at least 2 %.

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