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Optimization Of The Brake Chamber Housing Construction Material

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ABSTRACT

In this paper, we consider the options for using computer methods for analyzing the design features of some automobile units, which allowed us to justify the choice of materials and technologies for their manufacture. To increase the parameters of service characteristics that determine the service life of brake chamber housings made of a polymer composite material based on polyamide 6, methods for modifying the matrix are proposed that reduce its characteristic disadvantages – increased moisture absorption and a tendency to aging under the influence of atmospheric factors.

KEYWORDS

The principle of "reasonable sufficiency", flow theory, thermogasodynamic synthesis technology, Pro/MECHANICA, Pro / ENGINEER, composite material, aluminum alloy AK12, polyamide PA6-LTCH-SV30-P, polytetrafluoroethylene.

INTRODUCTION

The design of automobile units determines not only their functional purpose, but also their operational life. In some cases, despite the use for the manufacture of structural elements of materials with high parameters of service characteristics due to the specific conditions of their operation, combined with the features of the stress-strain state due to the need to

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perform certain functions, destruction occurs, leading to a loss of performance of the unit as a whole.

Depending on the purpose of the unit, the optimal variant of its design is determined, which provides the specified parameters of functional characteristics for a certain period of operation. At the same time, they take into account not only the functional purpose of the unit, but also the manufacturability of its production in the conditions of mass production, as well as the technical and economic parameters that determine its competitiveness in the changing market of units. This aspect is of particular importance when assessing the total operational resource of an automotive vehicle, which is not determined by the additive sum of the resource of the constituent units. Moreover, the modern approach to the creation of a large range of automotive, agricultural and special equipment, based on the principle of "reasonable sufficiency", involves the use of unit designs with a certain service life, after which they are replaced without complex maintenance or repair, usually associated with significant material costs that correlate with their original cost.

At the same time, the practical implementation of the principle of "reasonable sufficiency" guarantees the consumer the unconditional fulfillment of the functional parameters of the unit for a certain period of operation at the same time relatively low cost. Achieving such an optimization solution, which includes a combination of contradictory, at first glance, approaches, is possible with the use of modern computer tools, united by the concept of CALS-technology [1].

Based on the above, research on the optimization of materials for the construction of automotive tractor units, due to high-tech composite materials based on polymer matrices, is very relevant.

OBJECTS AND METHODS OF RESEARCH

Using the analysis data given above, as well as a three-dimensional model of the housing (Figure 1), the possibility of using high-tech composite materials based on polymer matrices for its manufacture is analyzed. For the analysis, we used the Pro/MECHANICA application of the Pro/ENGINEER software package.

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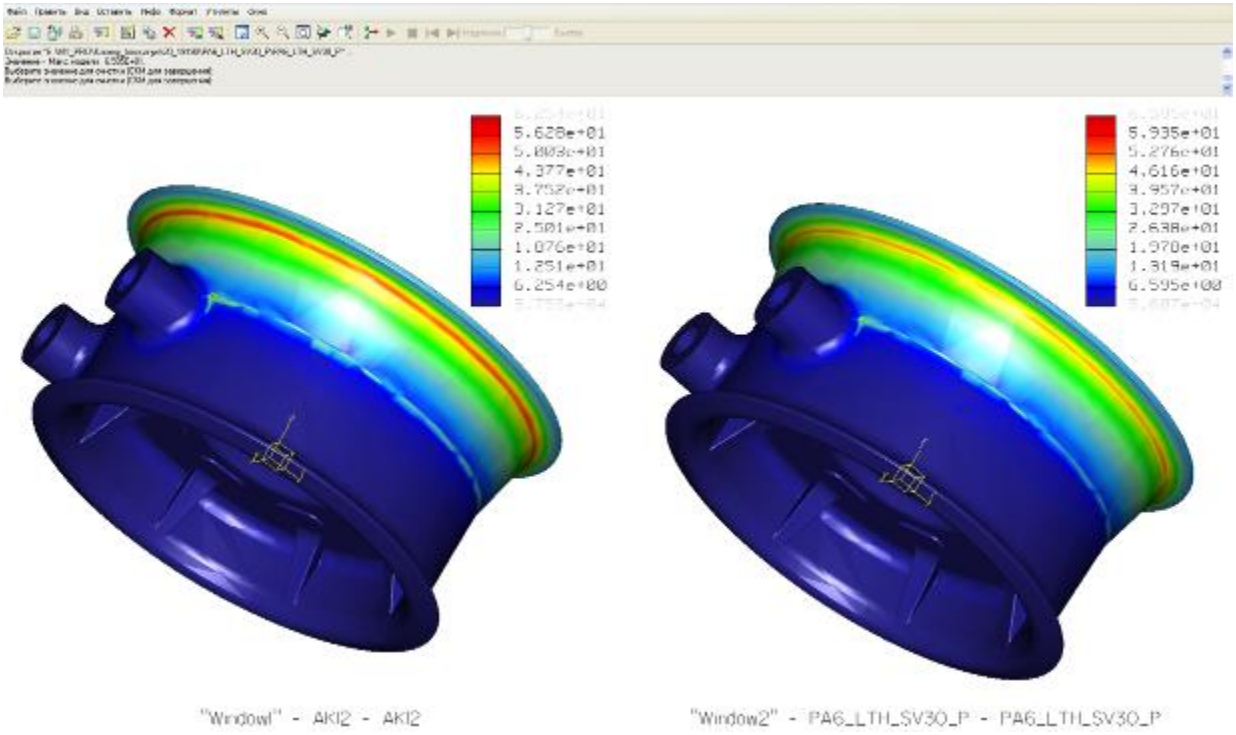

Figure 1. Model of the stress-strain state of the brake chamber under the application of an axial load of 20 kN, made of an alloy AK12 (a) and a polyamide composition PA6-LTCH-SV30-P (b)

Based on the results of comparing the parameters of the deformation and strength characteristics of the material used-the AK12 alloy and the promising polyamide PA6-LTCH-SV30-P, it is concluded that this composition can be used for manufacturing the brake chamber body by injection molding.

The stress-strain state of the brake chambers made of various materials was evaluated at the maximum force generated by the spring of 20 kN at the calculated working pressure of 40 kN. Using a finite element grid, the stress-strain state of brake chamber blanks made of various materials – AK12, PA6-LTCH-SV30-P-is estimated (Figure 1).

The analysis shows the practical identity of the results of modeling the stress-strain state of

brake chambers made of different materials. The calculated maximum stresses arising in the glass-filled polyamide model do not exceed 59 MPa. According to the Mises-Hubert-Genke theory of fluidity (MGG), the critical state of a stressed structure occurs when elementary changes in the limit values determined by the expression

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$$\sigma_{эк} = \frac{1}{\sqrt{2}}\sqrt{\left(\sigma_x - \sigma_y\right)^2 + \left(\sigma_x - \sigma_z\right)^2 + \left(\sigma_y - \sigma_z\right)^2 + \left(\tau_{xy}^2 + \tau_{xz}^2 + \tau_{yz}^2\right)} \leq \left[\sigma\right], \quad (1)$$

где $\sigma_{эк}$ - equivalent voltages according to the MGG theory;

$\sigma_x, \sigma_z, \sigma_z$ - main normal voltages;

$\tau_{xy}^2, \tau_{xz}^2, \tau_{yz}^2$ - main tangential stresses;

$\left[\sigma\right]$ - maximum permissible voltage.

For polyamide products of the PA6-LTCH-SV30-P brand, the value was determined from the expression:

$$\left[\sigma\right] = \frac{\sigma_p}{n}, \quad (2)$$

Where σ_p - ultimate tensile strength;

n - factor of safety margin

$$\left[\sigma\right] = \frac{155}{2} МПа = 77,5 МПа.$$

RESULTS AND DISCUSSION

From the analysis it follows that the polyamide brand PA6-LTCH-SV30-P can be used for the strength characteristics for the manufacture of the brake chamber housing.

The technological parameters of this brand of glass-filled polyamide were evaluated using the Mold flow Plastic Adviser software product.

To increase the efficiency of the use of composite polymer material, the design of the housing was optimized in such a way as to minimize the number of machining operations. After determining the optimal location of the intake channels using the parameters of the analog (Akulon J-7/3 Nalt composite material), the surface quality was evaluated according to the technological modes that characterize the mold filling time, injection pressure, and cooling rate. At the same time, the probable areas of maximum shrinkage, cold junctions, warping, and places of gas bubble formation were determined. The results of the analysis are partially presented in Figures 2 and 3.

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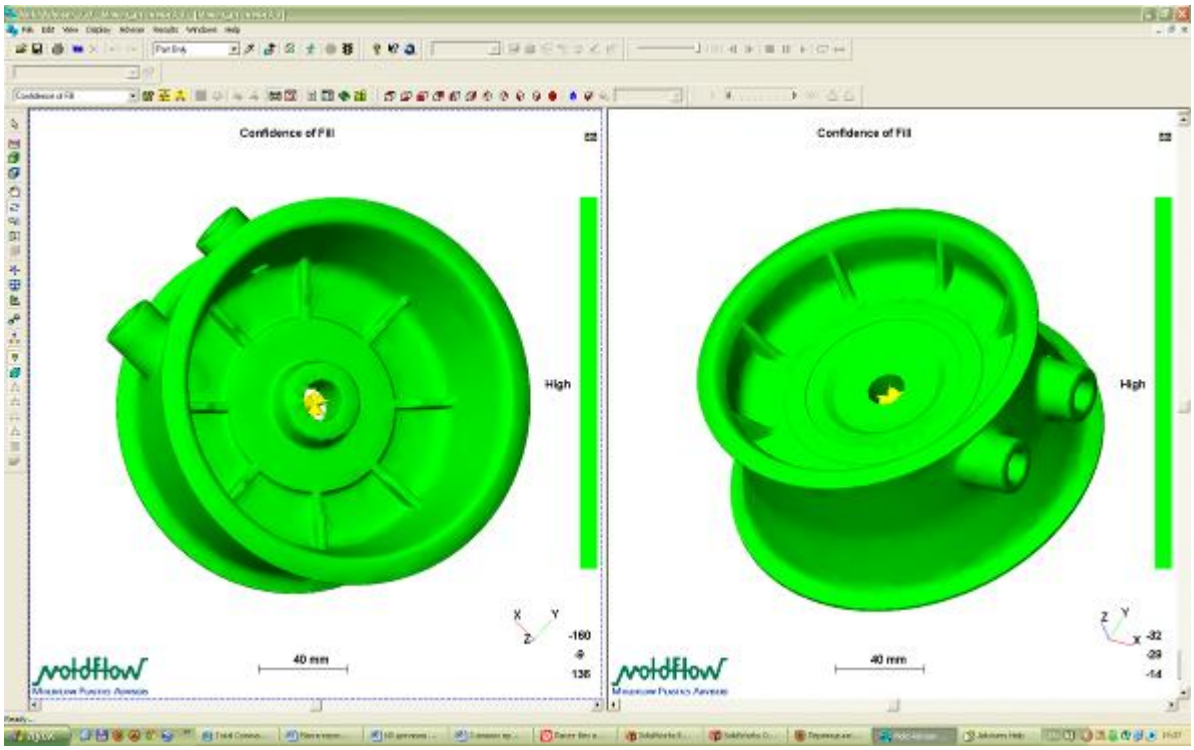

Figure 2. Assessment of the quality of the filling process of the working volume of the injection mold

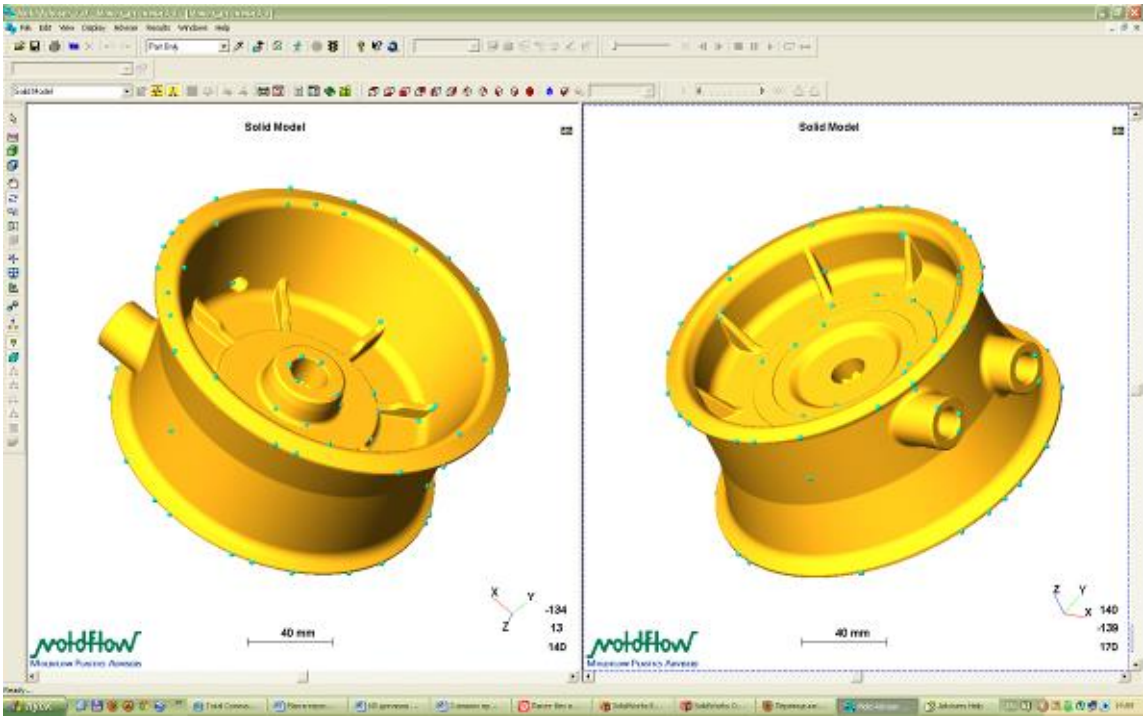

Figure 3 Estimated locations of gas bubbles

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When evaluating the quality of the process of filling the working volume of the mold (Figure 2) using the "Confidence of fill "package and the expected locations of gas bubbles according to the "Air trap locations" package, as well as other parameters that determine the quality of the casting using various software products, it was found that when using modern injection molding machines, there are no fundamental obstacles to replacing the AK12 alloy with a composite polymer material: the working volume of the mold is filled evenly, without significant pressure differences, with uniform cooling, without significant defects in the form of cold junctions and gas bubbles. Deviations of the geometric parameters of the product from the documentation do not have a noticeable effect on the parameters of the service characteristics.

Thus, the analysis made it possible to determine the main reasons for the occurrence of defects in the manufacture of brake chamber housings by injection molding from aluminum alloy AK12 and to offer a full-fledged replacement of the composite, which provides an increase in quality, reduction of defects and cost.

To increase the parameters of service characteristics that determine the service life of brake chamber housings made of a polymer composite material based on polyamide 6, methods for modifying the matrix are proposed that reduce its characteristic disadvantages: increased moisture absorption and a tendency to aging under the influence of atmospheric factors [2, 3]. An increase in the parameter of resistance to atmospheric aging of the composite based on PA6 was achieved by the introduction of highly dispersed copper and polytetrafluoroethylene particles obtained by the technology of thermogasodynamic synthesis (THD).

Due to the adsorption interaction of active copper particles and fluorine-containing groups of macromolecules that are part of the products of ultrafine polytetrafluoroethylene (UPTFE) with the amide group, the probability of interaction of the polyamide macromolecule with air oxygen molecules decreases. Highly dispersed copper particles are formed in the melt of the composite during processing as a result of the thermal decomposition of copper format. According to the results of the studies carried out in [4, 5, 6], the optimal content of Nano dispersed copper in the composite composition was determined, which is 0.05-0.2 wt. %.

The products of the THD synthesis of polytetrafluoroethylene, as follows from the works [9], contain oligomer fractions of different molecular weights, which are capable of homogeneous distribution in the matrix polymer with the formation of hardened regions [7, 8]. As a result of these processes, the composite's resistance to atmospheric aging and moisture absorption increases, which contributes to an increase in the operational life of composite housings to the values characteristic of AK12 aluminum alloy housings (Figure 4)?

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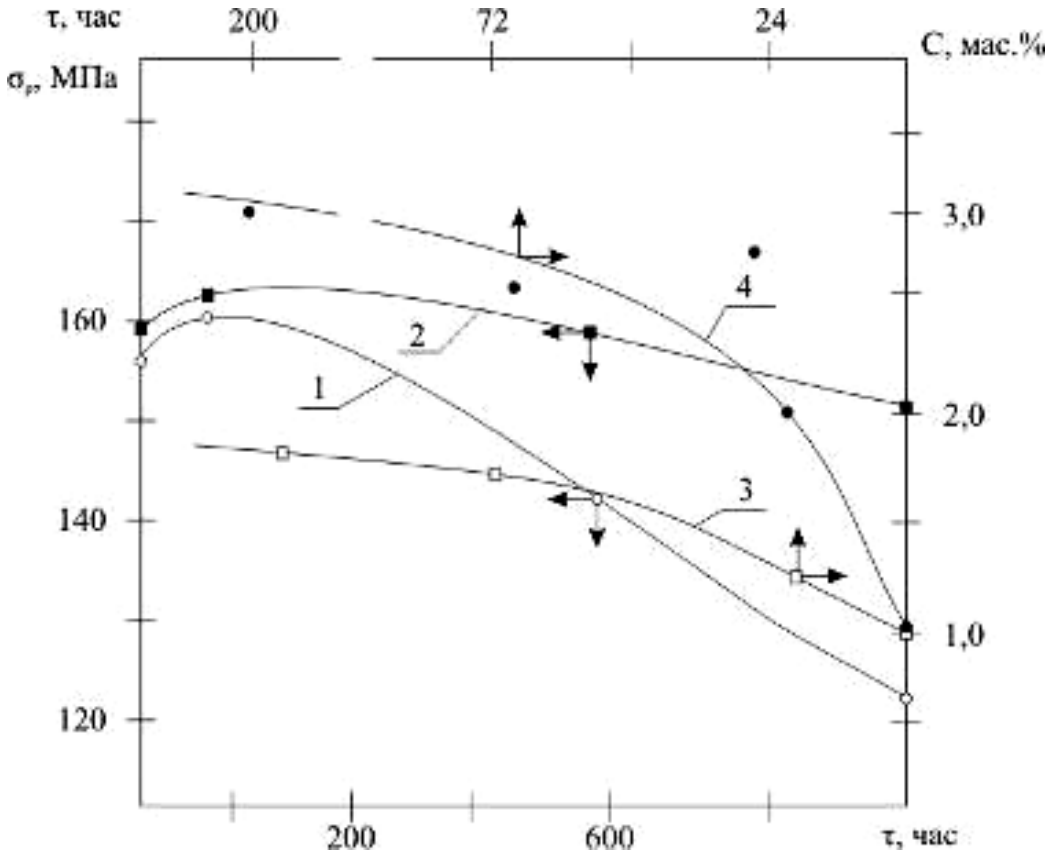

Figure 4 Dependence of the breaking stress at tension σp on the time of thermal oxidation at 250C (1, 2) and moisture absorption on the time of exposure in water (3, 4) of the polyamide PA6-LTCH-SV30-P of the original (1, 4) and modified 0.1 wt. % Cu and 1.0 wt. % UPTFE (2, 3)

CONCLUSION

The composition of the composite material of the body structure of the brake chamber of cars is optimized using computer modeling methods. A computer analysis of the design was carried out according to the criteria of equal strength, manufacturability of the casting process and product defects. Based on the principle of multilevel modification, the composition of a composite material based on polyamide 6 modified with glass fiber and a mixture of nanocomponents – copper particles and ultrafine polytetrafluoroethylene-is proposed. The developed composite material is superior to the basic composite in terms of resistance to aging and moisture absorption and is a full-fledged alternative to aluminum alloy.

The developed optimization design, technological and material science solutions allowed us to recommend a composite material based on glass-filled polyamide 6 as an alternative to the imported analog-aluminum alloy AK12.

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