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UTILIZATION OF ELASTOMERIC MATERIALS IN THE CONDITIONS OF EXPERIMENTAL PRODUCTION

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INTRODUCTION

Efficient cost reduction in experimental production requires a comprehensive approach and consideration of specific conditions and possibilities of the enterprise. Automation, robotization, the use of universal numerically controlled machines, and the implementation of other advanced technologies in the context of the mentioned production can result in significant initial investments and a substantial increase in product costs in the early stages. However, in the long-term perspective, such an approach undoubtedly leads to a decrease in overall expenses. Despite its advantages, at the early stages of innovative projects, particularly in the field of mechanical engineering, costs associated with increased fixed assets are practically unacceptable due to the lack of financial resources. Experimental production exhibits all the characteristics of a single-unit production. If we open any textbook on mechanical engineering technology, we can read something like this: the main features of single-unit production include a low probability of product repetition, the use of versatile equipment, and highly skilled workers. It is clear that the higher the level of automation, the greater the initial capital investments, but the lower the labor costs due to a reduction in the number of production personnel.

However, there is one significant difference. Single-unit production is aimed at the manufacturing and commercialization of finished products. Experimental production, on the other hand, serves a different purpose - essentially the development and refinement of new designs based on various criteria, such as testing structural parameters, refining assembly processes, and so on. In the end, after obtaining the necessary results, such products are usually discarded regardless of the achieved outcomes.

Therefore, what are the possible directions for enhancing the economic efficiency of experimental production in terms of cost minimization?

1. Analysis and optimization of production processes to reduce overall

labor intensity and decrease expenditures on wages, overhead costs, material expenses, and energy resources.

2. Outsourcing, which involves establishing partnerships with suppliers, industrial enterprises, and other institutions, can help gain access to necessary resources, distribute costs, and reduce overall expenditures on research and development.

3. The utilization of more efficient materials can decrease costs associated with initial raw materials and their processing and machining or reduce production time.

If we focus on the latter direction, the materials used for design experimentation during the development and experimental production stages do not necessarily need to possess the full range of properties found in the materials used for the actual construction elements in the future. For example, in investigating the mechanical properties of a particular component, the substitute material should only meet those specific requirements, while other properties of the substitute material, such as sealing properties or chemical resistance, may not be crucial for such investigations. It is evident that there should be a significant cost difference between the real material and the substitute, taking production expenses into account.

Aim and Objectives

The aim of this study is to explore the potential use of elastomeric materials specifically for addressing the aforementioned production challenges. Elastomers are synthetic materials with predictable and controllable properties. They are a combination of polymer materials, mineral components, various rubbers, plasticizers, solvents, catalysts, antioxidants, stabilizers, lubricants, dyes, and others.

Such a diversity of components results in a wide range of properties of various types, including special ones such as resistance to explosive decompression, water and steam resistance at high temperatures, resistance to benzene at elevated temperatures, hermeticity and impermeability for operation in aggressive environments, wear resistance, high physic and mechanical characteristics at elevated temperatures, thermal stability, vibration isolation, noise absorption, adhesive and anti-friction properties, and so on. Importantly, such materials can combine a specific set of properties suitable for the development of structures in the conditions of experimental production.

Therefore, elastomers can be used as substitutes for real materials, provided they meet the defined economic criteria. Equally important in material selection is its processability. For the development of experimental structures, various manufacturing processes can be employed, such as 3D printing, cold-curing compound casting, including 3D-printed mold production, laser cutting, and mechanical machining.

3D-Printing with Elastomeric Materials

For 3D printing, any thermoreactive elastomers can be used, with polyurethane-based materials being the most widely used [1]. The method offers several advantages: the manufacturing time is almost independent of the complexity of the part, parts of nearly any complexity can be produced, high flexibility, the ability to create anisotropic materials by modeling different mechanical characteristics in different directions through the formation of structural heterogeneity in the material.

However, there are some limitations to this method: it is challenging to achieve material integrity, resulting in reduced strength compared to casting with the same material, the emission of carcinogenic and toxic substances during operation, low productivity, which depends on the weight of the finished product [2].

Cold Cure Compound Casting Using 3D-Printed Molds

This method involves casting cold-curing resins and rubbers into molds, but it has several disadvantages compared to mass production using high-temperature press molds: limited material selection, inability to achieve a fully homogeneous material due to the possibility of bubble formation within the compound, reduced production flexibility compared to the previous method, requirement for specialized equipment, emission of carcinogenic and toxic substances during operation. However, this method offers several advantages over the previous approach: higher productivity when using reusable molds, improved material integrity.

Laser Cutting

The method of laser cutting involves the destruction of materials using a laser. Sufficient absorption of the laser beam leads to heating, melting, and vaporization of the material. The choice of laser cutting parameters, such as power, focal distance, and beam speed, depends on the material being cut, the thickness, and the desired cut quality.

Advantages of this method include high productivity, ability to cut any elastomeric material, high precision in processing and manufacturing of parts.

However, there are several disadvantages to consider: requirement for specialized equipment, emission of a significant amount of carcinogenic and toxic substances during the process, alteration of the surface structure of the cut due to thermal material destruction.

MECHANICAL MACHINING

Mechanical machining is one of the least common methods for obtaining parts from polymer materials due to the following drawbacks: reduction in dimensional accuracy of the finished part due to decreased material hardness and stiffness, difficulty in achieving a defect-free surface layer of the product, distortion of the spatial form of the part after removal from the holding device.

However, there are several specific advantages to consider: possibility of obtaining a highly homogeneous material, ability to use any elastomeric material, utilization of universal machine tools.

As previously mentioned, this method is not widely adopted, leading to research efforts aimed at improving the quality of parts manufactured using this technology.

Based on the research findings, a list of recommendations has been developed to enhance the quality of parts produced through mechanical machining.

1. Recommended to perform mechanical machining at maximum spindle speeds, where there is no softening or melting observed for thermoplastics and no thermal degradation for thermosetting plastics, while ensuring the absence of smoke.
2. Also recommended to use a cutting tool with a large rake angle $\gamma = 45° ... 60°$ [4].
3. The use of cutting fluids is not recommended due to the porous structure found in most polymer materials. The infiltration and retention of fluids in the pores can lead to swelling and alterations in the physical and mechanical properties of the machined part [5].
4. Despite selecting appropriate machining parameters, it is advisable to utilize personal respiratory protective equipment due to the potential emission of carcinogenic and toxic substances.

CONCLUSIONS

Elastomeric materials exhibit a wide range of properties and their combinations, making them suitable substitutes for conventional materials in the development of structures during research and experimental production, provided that such substitution yields clear economic benefits.

All the methods discussed have their own advantages and disadvantages, necessitating consideration not only of material properties but also the available methods of forming parts, considering the technological level of production. Furthermore, it is crucial to consider the variations in material properties during processing and post-processing stages.

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