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ECOLOGY - VEHICLE AND ROAD SAFETY - EFFICIENCY

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CONTENT

INTRODUCTORY LECTURES

SECTION A
Power Train Technology

SECTION B
Vehicle Design and Manufacturing

SECTION C
Driver/Vehicle Interface, Information and Assistance Systems

SECTION D
Vehicle Dynamics and Intelligent Control Systems

SECTION E
Transport Challenges in Emerging Economies

SECTION

B

Vehicle Design and Manufacturing

- Body Structures
- Advanced Materials
- Recycling
- Manufacturing Systems
- Quality Systems in Automotive Industry

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SELECTION OF SHAFT MATERIALS USING A MULTICRITERIA APPROACH

KEYWORDS: multi-criteria decision making, shaft, material, composite

The aspiration of modern mechanisms is to achieve the highest possible speed of work. The same requirements apply to transmission shafts, so a precise dynamic analysis of the stability of these elements is very important. It is known that the frequency of oscillation is directly proportional to the elasticity of the body, and inversely proportional to the mass of the body. The essence of the work is in the selection of the optimal shaft material in order to avoid the occurrence of resonance that can lead to different types of shaft destruction. Aluminum and composite carbon fiber shafts in combination with epoxy resin were analyzed. The paper proposes a multicriteria approach (MCDM) for the selection of the optimal transmission shaft material. It is emphasized how suitable this method is for analyzes of this type because it includes the influence of numerous qualitative and quantitative properties of materials in the selection. Metal drive shafts can have mass limitations, low critical speeds, and potentially destructive vibrations. Composite drive shafts, thanks to the nature of composites, in which the specific modulus of elasticity is higher (modulus to density ratio) than in metal, can be a good replacement. Composite drive shafts offer excellent vibration damping, reduced wear of drive assembly components, are less susceptible to the effects of stress concentration, reduce installation time, inventory costs, maintenance, etc. Replacing conventional metal structures with composite structures has many advantages, due to higher specific stiffness and higher specific strength of composite materials. Material has an important role in the design process. Choosing the right material for a particular product is one of the vital tasks for engineers. In order to meet the final requirements of the product, engineers and designers need to analyze the characteristics of different materials and identify the appropriate material. Due to the presence of a large number of materials with different properties, the process of material selection is a complicated and time-consuming task. There is a need for systematization and an efficient approach to select the best alternative material for a given product. The conflicting nature of the material selection evaluation criteria can be resolved using the Multi-Criteria Decision-Making (MCDM) method.
The aim of this paper is a multicriteria approach (MCDM) for the selection of the optimal material of the transmission shaft. Aluminum and composite carbon fiber shaft in combination with epoxy resin were analysed, taking into account seven evaluation criteria: Elasticity modulus E_1 and E_2, sliding modulus, G_{12}, ratio E_1/ρ, weight m, natural frequency fs, critical speed n_{kr}.

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The analysis considered four different materials (Aluminum, USN 150 carbon/epoxy, HS carbon/epoxy, HM carbon/epoxy) for shaft construction and analyzed the impact of seven characteristic values (performance) which are assigned the role of criteria in the multi-criteria decision-making process. The method of additive weighting methods (SAW Simple Additive Weighting Method) was applied in this paper. An important element in choosing this method is, in addition to its simplicity, the fact that this procedure takes into account the so-called weighting factors.
The weighting coefficients (Wi') of the criteria were determined in two variants using the Saaty procedure. In the first variant, the priority in importance was given to some criteria (sizes), while some were less significant. In the second variant considered, all criteria were equal in importance.
Using the procedure implied by the SAW method, the aggregate characteristics for each of the four considered materials were determined for both variants of weight coefficients. The diagram shown in Figure 1 clearly shows that the fourth considered material (HM carbon / epoxy) in both cases has the highest cumulative characteristic, ie the highest score within the conducted multicriteria analysis.

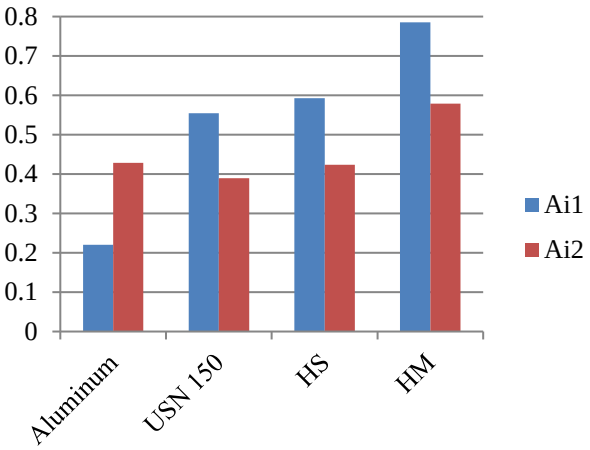

Figure 1. Aggregate characteristics in both considered variants.

Ranking and selecting the best material in the product design process is a very important and complex task. The procedure of analysis of composite materials, which was the topic of this paper, is even more complex. Such materials require a multi-criteria approach in the selection. Such an approach provides an opportunity for the designer to change the design of the product already in the design phase and thus achieve an improved version of the same, and all this leads to a reduction in production costs.
The aim of this paper was to select the optimal material for the transmission shaft, from the aspect of dynamic stability, for which the SAW method was used as one of the methods of multicriteria decision making. Four different materials (aluminum and three composite materials - USN 150, HS and HM carbon/epoxy) were considered. Based on the presented analysis of the mentioned materials and the evaluation of seven selected characteristics, the shaft made of HM carbon/epoxy showed the best results. The analysis was performed for two variants of weight coefficients and in both cases an identical conclusion was reached. The next step in the design process would be the analysis of the economic factor (material prices), which will be the subject of future research in this area.

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