

Theoretical research of transmissions and gearboxes

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Abstract. Significant aspects of the consequences of global warming and some measures that can be undertaken in order to reduce energy consumption and harmful emissions have been presented. The most important actions in this field are related to the renewal of the design of automobile vehicles and their components. A theoretical survey has been carried out in two main areas: investigating possibilities of improving the operational characteristics and the design parameters of transmissions and gearboxes, aiming to identify the areas of future dissertation research. A systematization of the reviewed scientific publications has been carried out. Main areas in which additional research can be carried out, related to the specific features of the Bulgarian industry and the state of the available cars in usage, have been identified.

1 Introduction

In order to reduce the consequences of global warming and to strengthen the empathy of countries to climate change, the Paris Agreement [1], [2] formulated important actions and measures aiming to reduce harmful emissions and to control the increase of environmental temperature.

As it is known, the largest concentration of carbon monoxide, nitrogen oxides, ozone and other chemical compounds is observed in the central part of the cities. In [3] and [4], the authors create an extremely significant mathematical models of four analysed case studies, through which they offer recommendations for reducing pollution in an urban environment.

The authors teams of [5], [6], [7] and [8] investigate and justify several particularly important and applicable measures that can be undertaken to reduce energy consumption and emissions, the most important of which is related to the design renewal of automobile vehicles and their components.

Based upon the professional and academic experience of the author's team, it was decided to carry out a theoretical research in two main areas: investigating the possibilities of improving the operational characteristics and design parameters of transmissions and gearboxes.

The objective of the paper presented is to identify areas for future dissertation research concerning these extremely significant components of the automotive engineering design.

Besides, it is necessary to take into account the challenges related to the age and the technical characteristics of the cars owned by Bulgarian citizens and the unfavorable consequences of the circumstance that the automobile industry in our country is not particularly very well developed.

2 Investigating the possibilities for improving the operational characteristics of transmissions and gearboxes

The possibilities for theoretical and experimental research of transmissions and gearboxes are presented in a considerable number of publications. The most widely used experimental methods, described in [9] and [10], are based on the experimental determination of vibrations.

The modal analysis presented by the authors is a method related to vibration theory. Its main goal is to obtain the inherent characteristics of the structural system, such as natural frequencies and natural modes.

Due to the increasing requirements for comfort in the vehicle and the optimization of noise and vibration in the powertrain imposed by these conditions, the noise from the gearbox no longer has only a secondary role and it becomes a significant component of the car's interior noise. This circumstance is of particular importance for tonal noise frequencies in the teeth meshing, as indicated in [11] and in [12].

Very often the load mode analysis is performed using ANSYS, as presented in [13] and [14]. Research implemented by other scientists [15, 16], applies modal analysis of gearbox housings, taking into account some specific aspects of this approach.

The authors of [17] mainly focus on gear modal frequencies. The vibration modes of compound planetary gears as transmission components have been investigated by the authors' teams of [18] and [19].

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3 Investigating the possibilities for improving the design parameters of transmissions and gearboxes

In order to define and select appropriate methods for determining the optimal design and kinematic parameters of transmissions and to study methods of monitoring and possibly system control towards better efficiency, it is necessary to apply appropriate analytical and computational tools to the problem.

In order to reduce fuel consumption and to increase autonomy, various types of engines and power transmission components have been investigated. Modern car manufacturers are focusing on new or optimized drive systems that can achieve minimum fuel consumption. These types of car design layouts are being developed not only for cars with internal combustion engines, but also for hybrid/electric vehicles [20].

The authors of [21] analyze the possibilities of a multi-stage gearbox to increase the torque, to reduce the acceleration time and to increase the achievable road gradient. A multi-speed transmission adapted to an electric drive has advantages in terms of energy consumption compared to its single-speed equivalent [21].

The approach suggested is characterized by the following main advantage: the probability of the drive system to operate in a higher efficiency range is greater according to [22, 23].

The development of other parameters of the drive design is reflected in the publications of university scientists and representatives of the automotive industry. An interesting analysis is proposed in [24]. The relationship between clutch load, speed and torque during the shifting process is examined. Two adaptive control strategies are proposed, which according to the authors, can effectively compensate clutch coupling in a suitable time range.

The implementation of design improvements of transmissions and gearboxes is carried out with suitable modern CAD systems (Catia, ProEngineer, Unigraphics) in established manufacturing companies in the field of vehicle drive systems and combustion engines, [25].

Based upon CAE company products and authors' software from the field of MBS and FEM, extremely precise calculations can be applied. The objective of research in these areas is to minimize vibrations and to optimize the geometry parameters of the gearbox housing concerning transmission-specific excitations, [26, 27].

An important additional result considering contemporary design is the precise determination of shaft deformation, which can indicate misalignment. The highest level of precise calculation is achieved through the integration of flexible components in the MBS (multi-body simulation) model.

The vibration behaviour of the elements is described in details in [28, 29] and it becomes possible to perform resonance and strength calculations, local stress values and safety boundaries.

4 Conclusions and future work

The theoretical analysis made can be summarized in the following way. The authors' team considers that the future research of the PhD student will continue the scientific work described in details in previous works of scientists at the University of Ruse. These publications are mainly based on current STEM research achievements, [30-33].

Besides, the circumstance is to be taken into account that the automotive industry in Bulgaria is not particularly well developed and due to this reason the equipment facilities for experimental research is limited in university and scientific research laboratories.

Due to these circumstances and thanks to the extremely active international activity of the University of Ruse, it will most probably be necessary to carry out part of the future experimental research of the PhD student in Romanian universities and laboratories.

The quality and opportunities of experimental equipment aimed at the problems of transport and the automotive industry have been described in a considerable number of publications of scientist from Craiova, Brasov and Pitesti, [34-43].

More than 40 modern scientific publications have been reviewed and they are systematized in Table. 1.

Table 1. Type and quantity of publications analysed.

Type	Quantity
Publication in the field of machine design	18
Publication in the field of automobile operational characteristics	25
Publication from the period from 2017 - 2023	16
Publication from the period before 2017	27

The thematic areas considered are current and topical. An extremely large number of scientists contribute with their research to the development of these areas.

It is determined that the following thematic areas are to be investigated within further research work of the PhD student: precise design applying CAD systems of elements of transmissions and gearboxes in order to improve their dynamic behavior.

Considering the technical state of the cars owned by Bulgarian citizens, approaches and criteria for improving the operational parameters of vehicles by methods that have not been analyzed in the world scientific literature are to be created.

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