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IMPROVING DESIGN PARAMETERS OF DRIVING SYSTEMS

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Abstract

Based upon the literature survey and upon the professional experience of the authors, the main objective of the research has been determined. Through analysing the contact and bending stresses in gear set meshing, the dimensions and the volume of the elements of driving systems are to be significantly reduced. An advanced methodology in six stages has been created and validated. The authors introduce two main design variables through which the improvement of the ratio between volume and load capacity is to be implemented. The possible boundaries of changing the macro-geometry indicators are determined by the permissible stresses according to the criteria: contact and bending strength in the gear set meshing. A significant improvement of the design parameters and of ratio between the volume and load capacity of the mechanism investigated has been achieved. Practical recommendations and conclusions have been deduced.

Keywords: Design parameters; Driving systems; Volume and load capacity; Advanced methodology.

1. Introduction

Gear trains are important machine components in driving systems. In the area of engineering design, the optimization of driving systems is critical, concerning the development of energy efficient mechanical systems. Gear optimization and the investigation of weight, volume and load capacity of these components are important areas of scientific studies.

An interesting investigation of an objective function has been done in order to determine some limits on the volume/weight ratio of a gearbox in [1]. The advantages of Matlab have been used in this study. Significant improvements in the optimization process of a pair of cylindrical gears have been introduced by Marcelin [2] suggesting to find solutions using a genetic algorithm. The module, face width and number of gear teeth have been used as design variables. The weight of the gear pair was used to evaluate each unit (i.e., objective function). The process also includes consideration of additional design variables: helix angle of the meshing, addendum coefficients.

Gologlu and Zeyveli [3] suggest a solution of the problem of optimal weight of a two-stage reducer. Power, input frequency, helix angle and gear ratio are included in the input databases, while gear modules, face width, and teeth number of each gear pair are used as design variables. However, the specific way of introducing boundary parameters leads to contradiction in the results obtained. Different types of wear and cooling conditions and the influence of these phenomena on the quality of design components have been thoroughly investigated in [4]. An interesting point of view is presented in [5] concerning the surface roughness of mechanical components. Six different kinds of materials have been considered.

Later on, the authors' team of [6] has continued the investigation in this area, applying precision and conventional cooling systems.

Based upon the literature survey made, it can be concluded that the problem of the optimal ratio between weight and volume of the driving systems has been thoroughly investigated. However, most of the scientific papers have been focused on the results and efficiency of the algorithms applied [7], [8] and at the same time, no specific suggestions, offering definite guidelines and recommendations have been made.

Taking into account the literature analysis and based upon the professional experience of the authors' team, the research problem can be defined. It is possible to introduce practical approaches to improve the optimal usage of material and to reduce the volume of the driving systems by applying advanced methodology. The objective of the research is to achieve a maximum reduction of the dimensions and volume of the driving systems elements by analysing the contact and bending stresses in involute gear trains.

2. Prerequisite for solving the problem defined

The experience of the authors in the field of design theory, systems approach and new product development includes some contribution in the area of developing optimization procedures for improving the different parameters of transmissions. Original theoretical models supporting the improvement of transmission design have been presented in [9], [10]. The main objective of this research in the field of power transmissions is to improve the operating parameters of driving systems.

A study of planetary gear trains and internal meshing has been presented in [11]. Different methods for the complex analysis of internal meshing and for determining the permissible and optimal values of its geometry parameters according to different sets of criteria have been examined, applied and discussed. Improved and updated procedures for evaluation and comparative analysis of different design solutions to a certain problem, involving several main stages, are described in details in [12], [13] and [14].

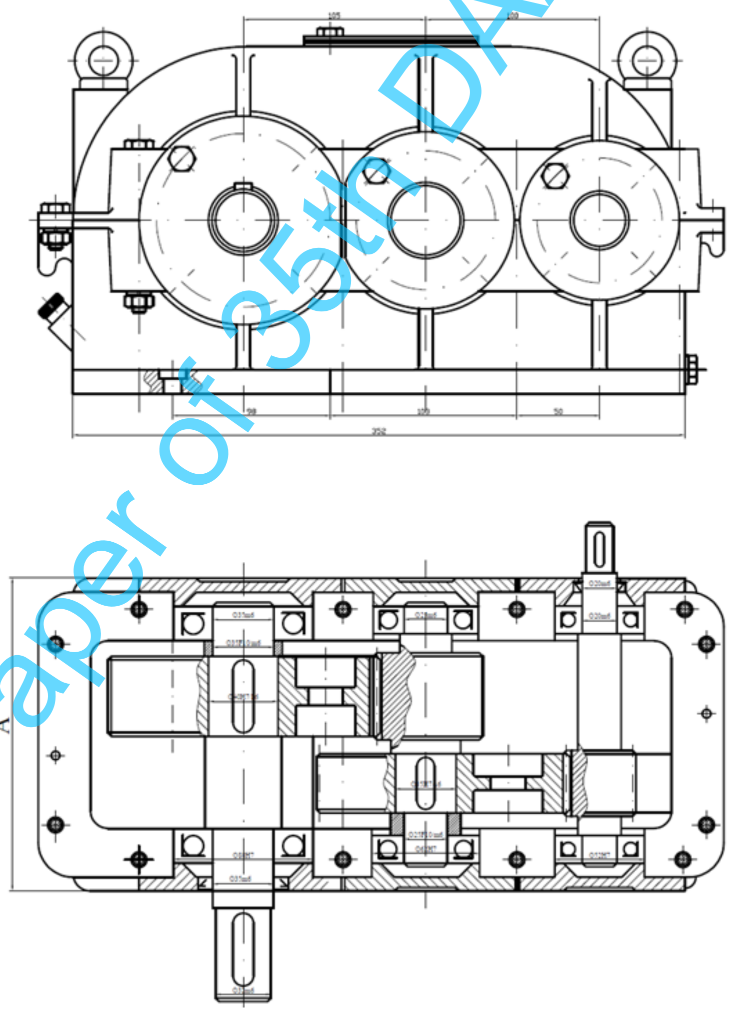

Fig. 1. Model of driving mechanism, [15]

Important components of optimization of involute gears have been considered in [15] and [16]. Models and drawings of various products have been presented as investigation results, Fig. 1. The contributions described are significant prerequisites for solving the problem defined and for creating an advanced methodology for improving the macro-geometry parameters of driving systems.

3. Advanced methodology

The methodology created goes through the following six stages:

During the first stage the driving system input parameters are set as a database.

The second stage includes verification calculations of the load capacity according to the criteria: contact strength and bending strength in the involute meshing.

Based upon the results of the analytical calculations, the permissible boundaries of the changes in the macro-geometry indicators are to be defined in the third stage.

During the fourth stage, main indicators are introduced as design variables, aiming to improve the ratio between volume and load capacity of the driving system components.

In stage five, sequences of calculations are to be carried out in order to determine the influence of the main design variables defined in the previous stage.

During the last stage, the results of the minimization of the volume and the geometry parameters of the driving system, obtained through defining permissible boundaries are to be presented and analyzed.

The authors' team considers that the research methodology presented is appropriate and adequate to the scientific problem which is to be solved. The selection of the determinant geometry parameter has a significant influence. A comparative analysis with the investigations presented in [15] and [16] indicates the application of similar optimization procedures. These procedures have been performed based upon the following geometry parameters: variation with the value of module; varying the total number of teeth; changes in the addendum coefficients of the involute profile: x_1 and x_2. The research presented in this publication considers the variation of meshing width as a function of the module to be a determining parameter in the design improvement of driving systems.

4. Application case study and results obtained

The methodology created has been applied for improving the design parameters of an involute two-stage reducer shown in Fig. 1. The input parameters are set as a database and include: rotational frequency and torque of the driven shaft, gear ratios, number of gear teeth and modules for both stages. The possible boundaries of the changes of the macro-geometry indicators are determined by the permissible stresses according to the criteria: contact strength and bending strength.

The authors introduce two main indicators as design variables through which the improvement of ratio between the volume and the load capacity is to be carried out: face width (for the first b_{w1} and for the second b_{w2} stage of the reducer) and the geometry parameter A (indicated in Fig.1). This geometry parameter represents the width of the two-stage gearbox housing.

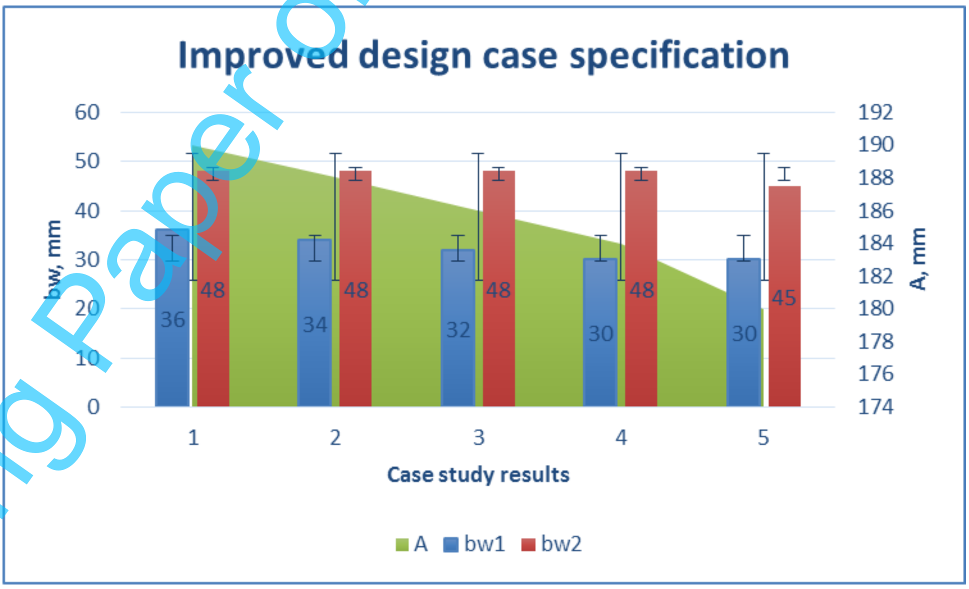

Fig. 2. Case study results

The results obtained are shown in a graphical way in Fig. 2. The reduction of the parameter "face width of the teeth meshing (for the first and for the second stage of the reducer)" is significant. It is decreased based upon its linear dependence on the module of the relevant stage. The recommendation is that the face width is to be reduced to the possible minimum value, defined by the strength calculation. Besides, this value is to be equal to or greater than 15.m (m – module of the relevant stage).

Applying the methodology described, the macro-geometry indicator "A" has been reduced significantly: with a value greater than 9%. The ratio between volume and load capacity in this application case study has been improved significantly, Fig. 2.

Therefore, the objective of the research presented has been accomplished: a maximum reduction of the size and volume of the elements of the driving systems has been achieved. The results obtained are clear, explicit and significant. Besides, they are presented in a comprehensible and unambiguous way, which makes them appropriate for further applications in the engineering practice and engineering design education.

The limitations of the research implemented are connected to the selected main macro-geometry indicator "A". The intentions of the authors' team are to distinguish the influence of this parameter in future studies in this area, and to establish the comparative impact factor of other parameters with influence on the load capacity, the material and energy efficiency in different design versions of reducers and driving systems.

5. Conclusions

The research problem is clearly and precisely defined: by analysing the contact and bending stresses in involute gear trains, a maximum reduction concerning the dimensions and the volume of the driving systems elements is to be achieved. Based upon the results obtained, the following conclusions can be deduced:

An advanced methodology including 6 stages has been created and applied for a specific application case study: involute two-stage reducer.

A significant improvement of the design parameters of this driving mechanism has been achieved (over 9%), which also leads to an improvement in the ratio between the volume and the load capacity of the mechanism investigated. It is recommended that the face width be reduced to the possible minimum value, defined by the strength calculation. Besides, this value is to be equal to or greater than 15.m (m – module of the relevant stage).

Applying the methodology presented, the expected results and their application will lead to improving the design versions of driving systems concerning their reduced overall dimensions and volume. These results will affect the total weight of the design versions and will lead to lightweight design. Theses outcomes achieved will contribute to the improvement of economic indicators, such as prime cost and price of the final product.

The future research work of the authors' team envisages further application of a methodology created through defining other main indicators and design variables. Investigations of two-stage involute helical gear trains and driving systems operating with different torque values are planned. Housing details will be presented and juxtaposed using CAD systems. Calculations of the volumes of the relevant housing are to be impelemented in order to realize the most accurate assessment of the efficiency, achieved as a result of the methodology applied.

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