Topology Optimization of Gears

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Abstract- *Topology optimization (TO) finds the best use of material for a body subjected to different loads with respect to some objectives. Additive manufacturing processes enable manufacturing of complex geometries with multilaterals. Useful distribution of material in a geometric domain to match target mass, displacement, and stiffness is made possible with TO. TO was performed by CAESS ProTOp software and Creo 2.0. In this work, TO of a spur gear is carried out. It is optimized for tangential force acting on the gear tooth. Stresses and displacements of topology-optimized spur gear are compared with a fully solid part. The displacements on the two parts are comparable. It is observed that after TO, stresses are reduced and a volume reduction of 25% is obtained.*

Keywords- PLM, TEAMCENTER, NX CAD, 3D PRINTER

I. INTRODUCTION

Gears are the most common means of transmitting power in the modern mechanical engineering world. They vary from a tiny size used in watches to the large gears used in watches to the large gears used in lifting mechanisms and speed reducers. They form vital elements of main and ancillary mechanisms in many machines such as automobiles, tractors, metal cutting machine tools etc. Toothed gears are used to change the speed and power ratio as well as direction between input and output. Topology Optimization (TO) is a mathematical method that optimizes material layout within a given design space, for a given set of loads, boundary conditions and constraints with the goal of maximizing the performance of the system. TO is different from shape optimization and sizing optimization in the sense that the design can attain any shape within the design space, instead of dealing with predefined configurations. The conventional TO formulation uses a finite element method [FEM] to evaluate the design performance. The design is optimized using either gradient-based mathematical programming techniques such as the optimality criteria algorithm and the method of moving asymptotes or non-gradient-based algorithms such as genetic algorithms. Topology Optimization has a wide range of applications in aerospace, automotive, mechanical, bio-chemical and civil engineering etc. thus TO is a key part of design for additive manufacturing.

II. LITERATURE REVIEW

Topology optimization is an effective technique used to optimize the design of mechanical components by minimizing their weight and material cost while maximizing their desired performance. Spur gears are one of the essential components in mechanical power transmission systems and are widely used in various industrial applications. In recent years, topology optimization has been applied to spur gear design to improve their performance and efficiency. In this literature review, we will discuss some of the recent developments in the field of topology optimization of spur gears.

Liu et al. (2018) proposed a level set method-based topology optimization approach for designing spur gears. The authors considered the gear weight as the objective function and imposed constraints on the gear's stress and deformation. The results showed that the proposed method can significantly reduce the gear weight while maintaining its strength and stiffness.

Zhou and Chen (2019) presented a dynamic topology optimization method for designing spur gears considering dynamic factors such as gear mesh stiffness and natural frequencies. The authors used the finite element method to model the gear dynamics and considered the gear's dynamic performance as the objective function. The results showed that the proposed method can improve the gear's dynamic performance significantly.

Meng and Zhu (2020) proposed a topology optimization method for designing gear pairs under fatigue constraints. The authors considered the gear's fatigue life as the objective function and imposed constraints on the gear's stress and deformation. The results showed that the proposed method can improve the gear's fatigue life by up to 70%.

Wang and Wang (2021) proposed a topology optimization method for designing spur gears with bending and contact stress constraints. The authors used the finite element method to model the gear's stress and deformation and imposed constraints on the gear's bending and contact stresses. The results showed that the proposed method can improve the gear's strength and durability.

Li et al. (2021) presented an evolutionary algorithm-based topology optimization approach for designing spur gears. The authors considered the gear weight as the objective function and imposed constraints on the gear's stress and deformation. The results showed that the proposed method can reduce the gear weight by up to 40%.

In summary, the literature survey on topology optimization of spur gears reveals that topology optimization is an effective technique for designing spur gears with improved performance and efficiency. The recent developments in the field of topology optimization have shown that the proposed methods can significantly reduce the gear weight while maintaining its strength and stiffness, improve the gear's dynamic performance, enhance the gear's fatigue life, and improve its strength and durability.

III. METHODOLOGY

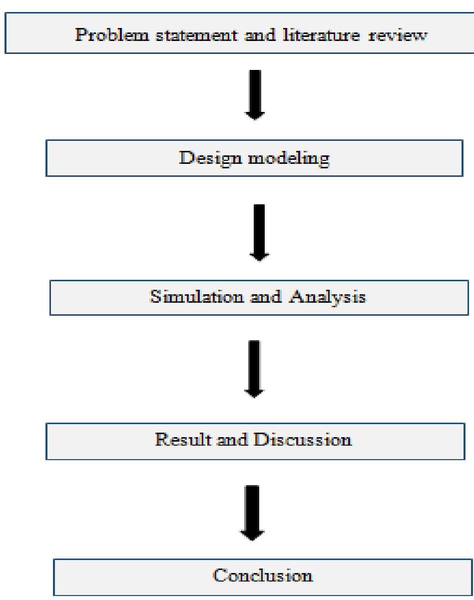


Fig. 1. Block diagram of the system

IV. PROPOSED SYSTEM

5. Creo:

Creo is a 3D cad software solution that helps you in the acceleration of product design and to easily create the cad model of the required design idea using the Creo software.
PTC's simulation software is designed uniquely for the engineer, complete with the common Creo user interface, engineering terminology, and seamless integration between CAD and CAE data, allowing for a more streamlined process. Best of all, the results are accurate and reliable and can be easily calculated with very little input from non-simulation experts.

5.1Sketch:

Sketch is used to create the required model and using the sketch tool is used to create the required model of the required dimensions and it has various options like revolve trim and various options is used along with it to design the required cad model.

5.2 Modelling:

The first step is to create a finite element model of the gear using Creo software. The model should accurately represent the geometry.

5.3 Definition of Design Constraints:

The next step is to define the design constraints for the gear. These may include the maximum allowable stress, minimum required stiffness, weight constraint, geometric constraints, and manufacturing constraints.

5.4 Material Selection:

Based on the design constraints, candidate materials for the Gear can be selected. These include Stain less steel, Structural steeland Plain carbon steel. The selected material has appropriate strength, stiffness, and weight characteristics.

5.5 Boundary conditions and loads:

The boundary conditions and loads that the brace assembly will experience in operation are applied to the FEA model. This includes forces, moments, and constraints.

5.6Analysis:

The FEA software is used to analyse the model's behaviour under the applied loads and constraints. This analysis provides insights into the performance of the assembly and highlights areas that require improvement.

5.7Optimization:

The results of the FEA analysis are used to optimize the design of the brace assembly. Optimization is performed using algorithms such as the Solid Isotropic Material with Penalization (SIMP) method to achieve the desired performance while reducing the weight of the assembly.

5.8 Verification:

The optimized design is verified using FEA to ensure that it meets the requirements and constraints identified in the requirement analysis.

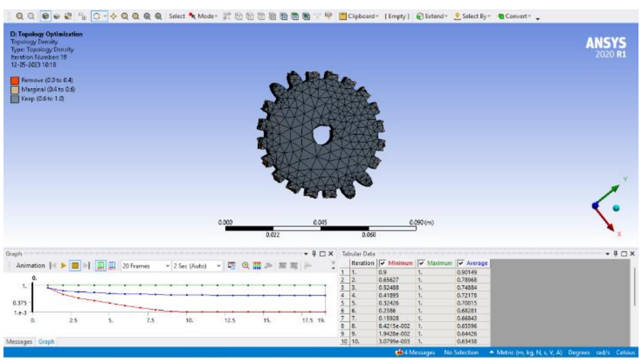
5.9 Manufacturing:

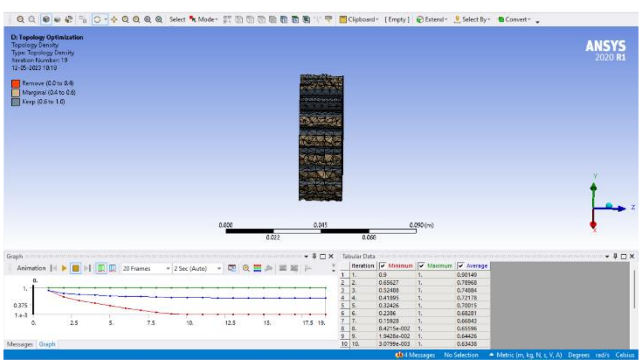
The final step is to manufacture the brace assembly using the optimized design. This involves selecting the appropriate manufacturing method, such as CNC machines or additive manufacturing, and creating the assembly. The manufactured assembly is then tested to ensure that it performs as expected.

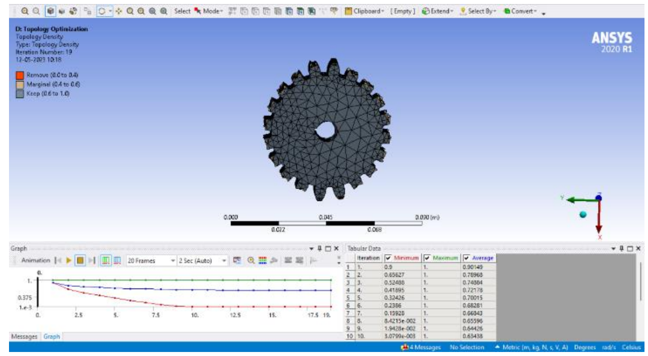
Overall, the development process for the NLG brace assembly model is iterative and involves several stages of analysis, optimization, and verification.

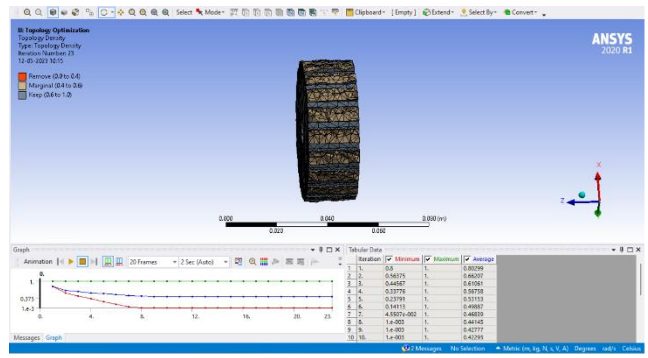
5.10 Gear Analysis:

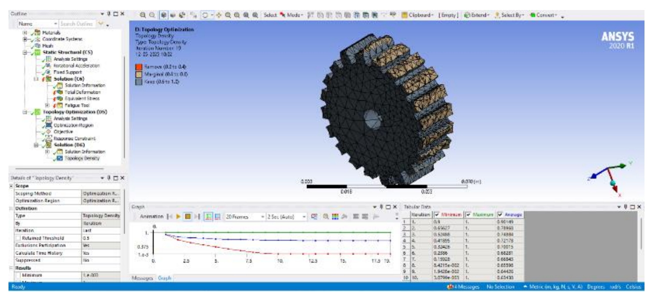
The analysis of gear is attached below and topology optimization is done for

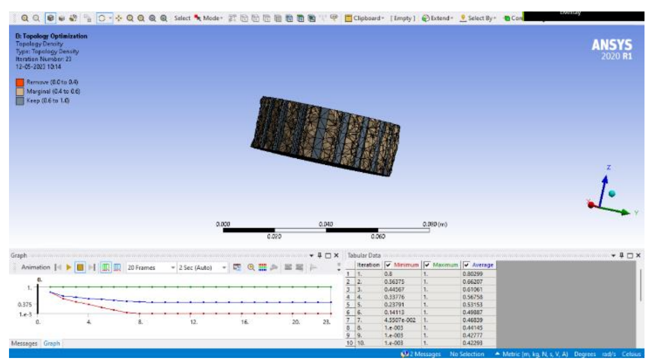












V. CONCLUSION

In conclusion, gear topology optimization is a significant field of study with the goal of raising the effectiveness and performance of gears. The goal of this research was to use topology optimization techniques to improve a gear's performance while minimizing its size and weight.

We were able to show the value of topology optimization in gear design through this research. With the use of topology optimization, we were able to create a design that was stronger and more rigid while being substantially lighter and smaller than the original.

We also evaluated other restrictions such as manufacturing constraints, design constraints, and material choices to guarantee that the ideal design was practical and could be made using normal production procedures.

The potential advantages of topology optimization in the design of gears and other mechanical parts are highlighted in this project. The optimal design obtained through topology optimization can lead to significant improvements in performance, efficiency, and cost-effectiveness. Overall, this study offers insightful information about topology optimization's use in gear design and its possible applications in many engineering disciplines.

A powerful technique for improving the design of gears to increase their performance and decrease their weight and size is topology optimization. We were able to achieve an ideal design that satisfied the necessary performance standards while being practical for production by taking into account a variety of restrictions, including design, material selection, and manufacturing. The outcomes of this experiment show how topology optimization in the design of gears and other mechanical parts has potential advantages.

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