MATERIAL SELECTION FOR GEARS: A COMPARATIVE ANALYSIS OF DEFORMATION, STRESS, AND STRAIN

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ABSTRACT

Material selection plays a crucial role in ensuring gear performance and durability. This study compares Structural Steel, Grey Cast Iron, and Aluminium Alloy for gear applications through finite element analysis (FEA). Each material was evaluated for deformation, stress, and strain under identical static loading. Results show that Structural Steel provides the least deformation and strain, Grey Cast Iron shows moderate performance with brittleness, and Aluminium Alloy, while lightweight, exhibits excessive deformation. Structural Steel emerges as the most suitable material for gears due to its superior mechanical properties.

Keywords: Gear analysis, Material selection, Structural steel, FEA, Deformation, Stress

1. INTRODUCTION

Gears are vital mechanical components used in various industries for power transmission and motion control. Their efficiency and lifespan depend heavily on material properties. This paper focuses on three commonly used materials: Structural Steel, Grey Cast Iron, and Aluminium Alloy. Using FEA, we compare these materials to determine their suitability for gear manufacturing under identical conditions [1-3].

2. LITERATURE REVIEW

2.1 Mechanical Properties

Structural Steel offers high strength and stiffness (E ≈ 200 GPa), making it ideal for high-load applications. Grey Cast Iron provides excellent damping but is brittle (E ≈ 130 GPa). Aluminium Alloy is lightweight but significantly less stiff (E ≈ 70 GPa), which affects precision and durability [4-6].

2.2 Prior Studies

Previous studies using FEA and Hertzian theory found that steel gears show lower deformation, cast iron moderate, and aluminium the highest. High stiffness materials like steel ensure better load handling and dimensional stability [7-8].

2.3 Recent Studies on Gear Material Analysis

Recent studies highlight the importance of material stiffness, fatigue life, and deformation characteristics in gear performance. Senthilvelan and Gnanamoorthy [9] conducted experimental and numerical investigations on steel and composite gears and reported that higher stiffness materials significantly reduce tooth deformation and improve load transmission accuracy. Bigdeli and Monfared [1] demonstrated through finite element simulations that material properties strongly influence stress concentration zones, confirming that steel gears provide superior stress distribution compared to lower-modulus materials. Pawar and Utpat [6] analyzed aluminium metal matrix composite gears and found that,