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# Investigation on the Comparison Analysis of Gear Drive for Robots

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**ABSTRACT:** Collaborative robots specifically used in industry for the interaction with human and associated work environments. The prime factors such as high stiffness, stable structure, long life, and high repeatability, the materials selection is one of the important criteria for the gear grain analysis used in robots. In this research, carburized steel and aluminum are considered for the structural analysis in dynamic environment. An optimized gear ratio of 4 is adopted for the model generation and the number of teeth on pinion is selected as 18. Based on the yield strength point of view aluminum is 50.05% lesser than AISI 3140 normalized steel, but 7 times lesser cost and 3 times thermal conductivity in the optimization process. Results are compared with deformation, von-mises stress and the mode shapes using commercial software for both materials.

**KEYWORDS:** Robots, Yield strength, deformation, Von-mises stress Mode shapes.

## I. INTRODUCTION

In the present days, robots playing key role in industries to the functional operations where human interaction with the system is not recommendable. A gear train system of mechanical transmission elements like power and speed with a reduced weight to be used for robotics applications. The gear train can also amplify the torque and reduce the speed to meet the requirements of the load. The performance of conventional and emerging robotic gearbox technologies, for which the design criterion is strongly shifted toward aspects like weight and efficiency [1]. A gear train allows a designer to modify the power, speed, and torque for specific applications. Gear ratio is an important factor to be considered in transmitting the motion and power. An optimum gear ratio is to be adopted for the smooth drive. Gear train will isolate the driving source from shocks to the output of the actuator. Interference of gear is also an important phenomenon to be considered as it occurs when the number of teeth on pinion is less than a required minimum [2].

Table:1 Material Properties

S.No.	Material	Yield Strength (N/mm <sup>2</sup> )	Density, (kg /m <sup>3</sup> )	Poisson's Ratio	Young's Modulus (N/mm <sup>2</sup> )
1	AISI4340 Normalized Steel	710	7850	0.32	205000
2	2024 Aluminum Alloy	75.829	2800	0.33	73000

**Literature Survey:** Human – robot interaction is becoming customary in our day-to-day life for domestic and industrial applications. Pablo Lopez Garcia et.al., propose an assessment framework strongly conditioned by HRI applications, and we use it to review the performance of conventional and emerging robotic gearbox technologies, for which the design criterion is strongly shifted toward aspects like weight and efficiency. The framework proposes to use virtual power as a suitable way to assess the inherent limitations of a gearbox technologies to achieve high efficiencies. This paper complements the existing research dealing with the complex interaction between gearbox technologies and the actuators, with a new gearbox-centered perspective particularly focused on HRI applications [1]. Jia, Jian, M.S.E. in his thesis, chooses different from traditional gear train design method, which only determines gear teeth numbers according to reduction ratio requirements, the optimization design developed in this research seeks to achieve the best gear train performance based on the optimum assignment of all input parameters. An exhaustive method is applied to determine the constraint relationships between the input parameters and the design requirements. Several assumptions are made for the input parameters to simplify the design process and improve computational efficiency. In original robot actuator gear train design, the material is usually chosen from metal alternatives. However, the gear train can be made of various materials, including steel, cast irons, nonferrous alloys, and even plastics. Materials with lower density

and lower cost, among other properties, can significantly improve gear train performance once basic strength and fatigue limit requirements are met. The author adopts ELECTRE III multiple criteria decision analysis method to compare material alternatives to facilitate material selection [2]. In the past years, the increment of the level of automation has been mainly dictated by the rising popularity of collaborative robots (cobots). Andrea Raviola et. al., reviewed in this present work about an overview of the failure modes in harmonic drives, largely used in robotics to convey the motion of the electric motor to the joint axis, and their impact on the robot availability and reliability using Failure Modes Effects and Criticality Analysis (FMECA) and Fault Tree Analysis (FTA). The root causes of such degradations are investigated to provide a clear understanding of the fault-to-failure evolution mechanism. The paper also introduces a high-fidelity model of the gearbox which will be used to simulate the most common faults and failures in harmonic drive gears for both diagnostics and prognostics purposes [3]. Harmonic gear reducer is widely used in industrial robots, aerospace, optics, and other high-end fields. The failure of harmonic gear reducer is mainly caused by the damage of flexible bearing and flexspline of thin-walled vulnerable components. To study the contact mechanical characteristics of flexible components such as flexible bearing and flexspline in harmonic gear reducer, the contact mechanical model of flexible bearing, vibration differential equation of flexspline, and finite element model of each component in harmonic gear reducer were established. Fanjie Li et. al., experimental analysis shows that the increase of cylinder length can improve the stress of flexspline in harmonic gear reducer; the wall thickness of cylinder bottom mainly affects the stress at the bottom of flexspline but has little effect on the stress of gear ring and smooth cylinder. Along the axis direction of the flexspline, the radial displacement, circumferential displacement, and angular displacement increase linearly with the increase of the axial distance between the cylinder and the bottom. When the excitation frequency is high, the vibration mode of flexspline shell is mainly axial vibration. The research results will provide a theoretical reference for the optimal design of harmonic gear reducer and improving the service life of flexible parts [4].

However, in this investigation, two different materials are chosen for structural analysis and frequency analysis. Results from the analysis are compared and concluded for the best feasibility of the material for robots.

## II. PROBLEM DESCRIPTION

A typical spur gear drive is taken and the power transmitted is 2 kW at 100 rpm. Module of the gears taken as 10 mm and the minimum number of teeth are 18 to avoid interference is chosen for a transmission ratio of 4 to reduce the speed of the gear when pinion is rotating at 100 rpm.

## III. MODEL GENERATION AND STRATEGY

A typical model of spur gear and pinion are developed using commercial software and are tested for feasible running of the gear train without interference. A torque of 190.98 N-m is applied in the pinion hub and taken fixed hinge boundary condition for pinion and fixed geometry is chosen for the gear and performed analysis for both materials.

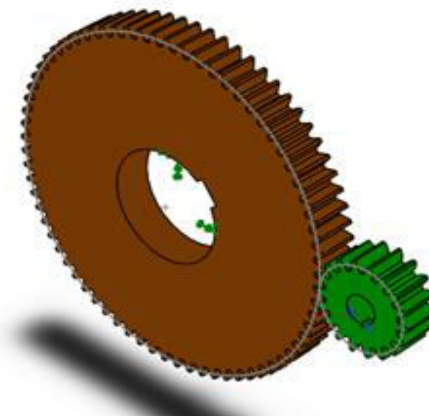


Figure: 1 Pinion and Gear assembly



IV. RESULTS AND DISCUSSION

A standard solid mesh is chosen for discretization and the boundary conditions are imparted to the models.

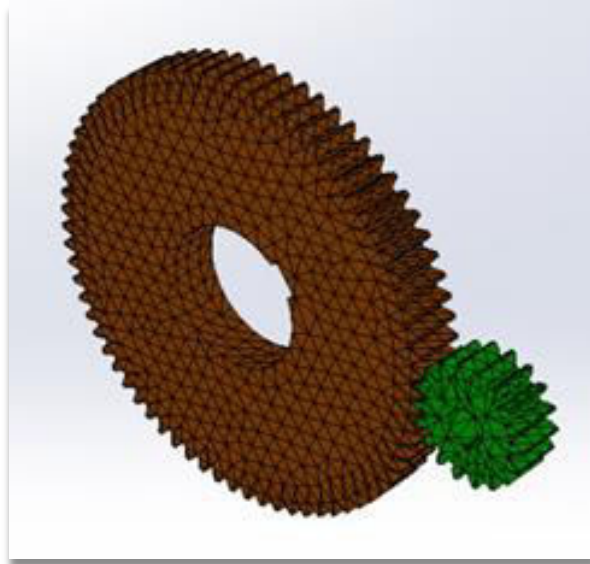


Figure: 2 Meshed model

A total of 12409 elements are created with a maximum aspect ratio of 7.3034. Toque is applied on pinion end and the results are interpreted as follows.

Table: 2 Static Analysis Results

S.No.	Material	Deflection (mm)	Von-mises stress (N/mm <sup>2</sup> )	Strain
1	AISI4340 Normalized Steel	0.2282	6.105	0.00002355
2	2024 Aluminum Alloy	0.2368	6.302	0.00006351

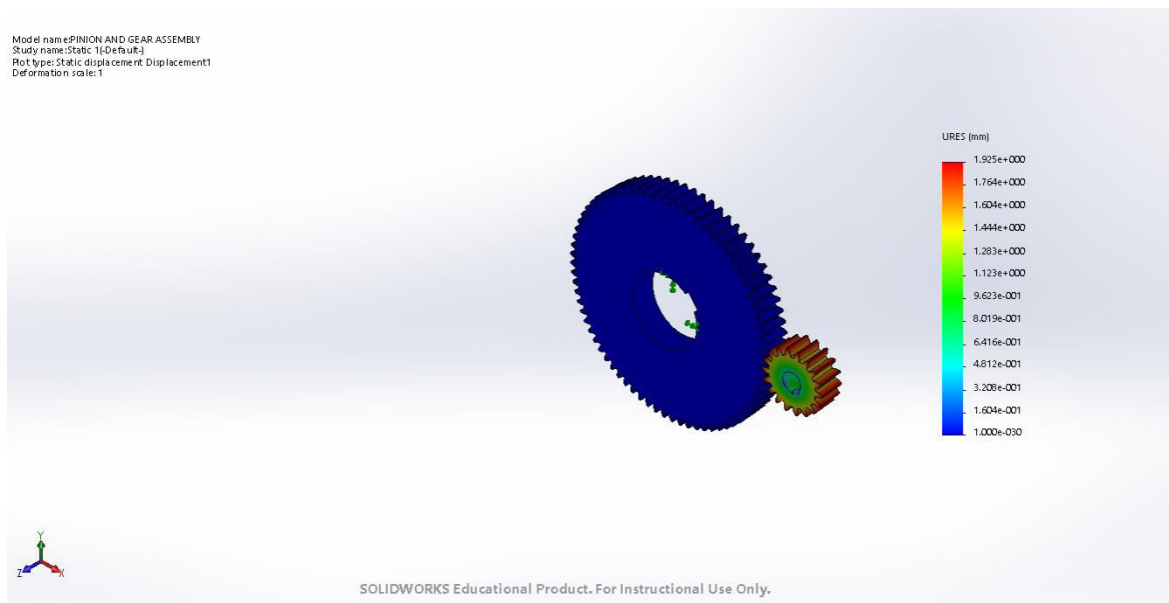


Figure: 3 Deflection contour of 2024 Aluminum Alloy



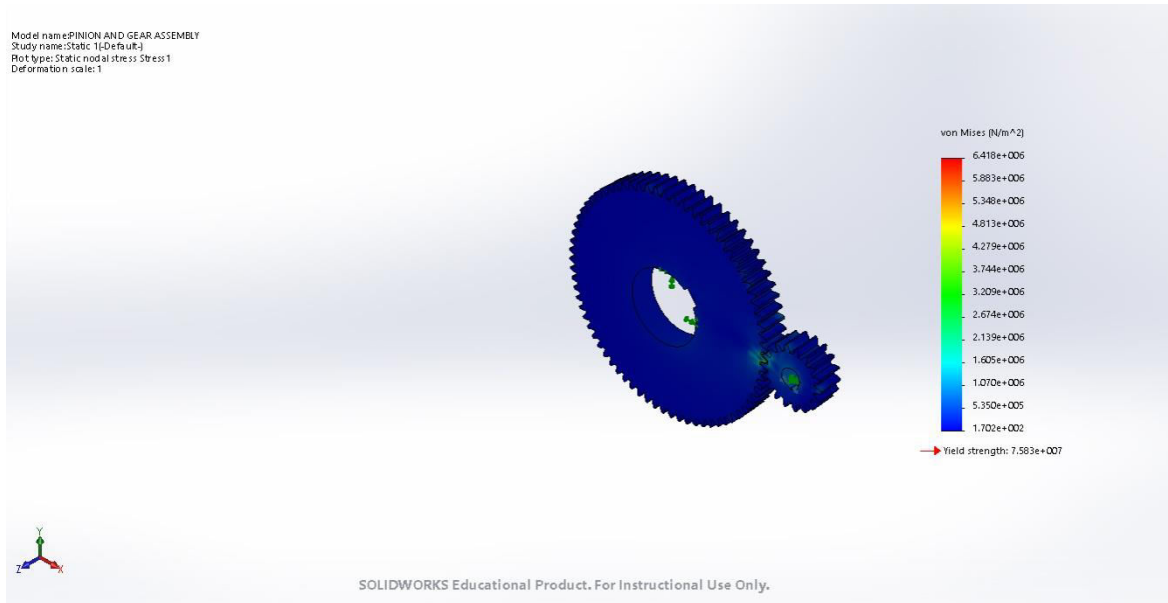


Figure: 4 Von-mises stress contour of 2024 Aluminum Alloy

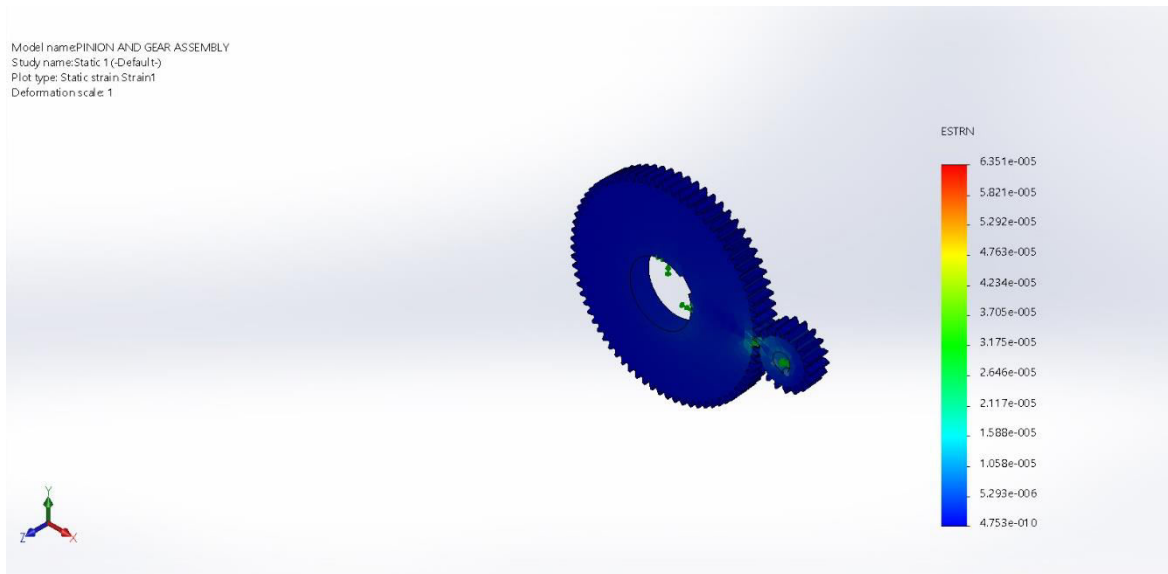


Figure: 5 Strain contour of 2024 Aluminum Alloy

Table: 3 Frequency Analysis Results

S.No.	Material	Mode-I (Hz)	Mode-II (Hz)	Mode-III (Hz)	Mode-IV (Hz)	Mode-V (Hz)
1	AISI4340 Normalized Steel	0.0029957	924.87	980.38	1018.1	1091.3
2	2024 Aluminum Alloy	0.0030013	648.12	816.73	976.56	1086

**Conclusions:** In the gear train analysis, the variation in the deflection, von-mises stress and strain is comparatively very less. Frequency levels are little not in good agreement, but the cost and weight of the 2024 Aluminum Alloy is very much lesser than the AISI4340 Normalized Steel and proving it as the better option for robotic gears applications.



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