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Explicit Dynamics of Helical Gear Frequency Analysis with Different Materials

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ABSTRACT: Helical gears are typically of cylindrical in structure and the teeth are curved into a helix shape. Compared to spur gears straight teeth, properly designed helical gears can have a larger total contact ratio which can improve vibration and noise. This paper aiming the comparison of helical gear dynamic analysis natural frequencies over forced frequencies with AISI4340 Normalized steel and 2024 Aluminum alloy steel. Results are compared for the frequencies with the commercial software for different materials. A weight reduction of 64.33% is observed from AISI4340 Normalized steel to 2024 Aluminum alloy and Manganese alloy. A weight reduction of 78.34% is observed from the AISI 3240 Normalized steel to Magnesium Alloy steel from the results. A slight variation observed for both materials from forced frequencies to natural frequencies proving material consistency for about 0.03%.

KEYWORDS: Helical gear, Dynamic analysis, Forced frequency and Natural frequency, Weight reduction.

I. INTRODUCTION

Current automotive sector gear transmission system is developing towards the direction of less weight, high precision, good strength and low noise. The new type of alloy helical gear with light weight, high strength, low noise and corrosion resistance has been widely used. They have gradually replaced the traditional steel gear in some products and have a broad application prospect. Aluminum in gear transmissions is used as material for gears. This application is designed to ensure high durability of gears, corrosion resistance and ensure weight reduction. The disadvantage of aluminum is the high coefficient of thermal expansion compared to steel. Gear pairs are widely employed in transmission system. Pitting, wear, spalling, root crack and local breakage usually come up when gears serve for certain time. Earlier diagnosis and condition monitoring are essential for assuring normal working of the transmissions [1]. The contribution of the structure-borne noise is pretty high for the gear noise related to dynamic load excites the gear pair, shafts, bearings and housing, and then the noise is radiated from the vibrating surface of the housing. To improve this structure-borne noise, many analytical methods of the vibratory behavior of the helical gear system, excitation forces caused by the tooth surface error and the variation of tooth mesh stiffness are incorporated [2].

In this context, materials like AISI4340 Normalized steel to 2024 Aluminum alloy and Manganese alloy are chosen to compare the materials weight for the same loading conditions. However, the comparison of frequencies is chosen in this research to investigate the material consistency towards no load to applied loading conditions. The material properties are given in table: 1.

Table:1 Material Properties

	Material	Yield Strength (N/mm ²)	Density(kg/m ³)	Poisson's Ratio	Young's Modulus (N/mm ²)
1	AISI4340 Normalized Steel	710	7850	0.32	205000
2	2024 Aluminum Alloy	75.829	2800	0.33	73000
3	Magnesium Alloy	20	1700	0.35	45000

II. LITERATURE SURVEY

Helical gears are often the default choice in applications that are suitable for spur gears but have non-parallel shafts. They are also used in applications that require high speeds or high loading. Regardless of the load or speed, they generally provide smoother, quieter operation than spur gears. It is desirable to use thrust bearings to absorb this force. However, combining right hand and left-hand helical gears making double helical gears will eliminate the thrust force. Helical gears are often used in automotive transmissions by replacing spur gears [3]. In the supercritical mesh frequency range, restorable free vibrations dominate in the frequency spectrum of gear system vibrations. These restorable free vibrations effectuate the increase of total vibration level with the speed of rotation increase. Also, in this frequency range the modal structure (natural frequency) of the gear system is not stable and effectuates super-critical resonances arising. Milosav Ognjanovic et.al., investigated and developed a mathematical model for experimental results synthesis is established. For this purpose, the theory of singular systems is used. Gear teeth mesh is treated as a singular system, with a continual process of load transmission with singularities caused by teeth impacts. Damping coefficients and energy attenuation is determined using the developed mathematical model [4]. Qian Ma et.al., investigated the helical gears in the gear box of cold rolling mill in a steel, using software SolidWorks to make one pair of meshing helical gears a solid model, and import the entity model into ADAMS to create a virtual prototype model, using IMPACT function to define the contact between gears, based on Hertz elastic collision theory, determine the parameters in the IMPACT function. By loading simulation, The speed characteristic curve of the drive shaft and the gear meshing force curve simulation are obtained, compared with theoretical analysis, the correctness of the simulation is verified [5]. Hao Dong et.al., studied the influence of backlash on the nonlinear frequency response characteristics of marine double-helical gear system, according to the structural characteristics of double-helical gear transmission, considering the time-varying meshing stiffness, backlash, damping, comprehensive transmission error, external load excitation, and other factors, a three-dimensional bending-torsional-axial-pendular coupling nonlinear dynamic modeling and dynamic differential equation of 24-DOF double-helical gear transmission system. The frequency response components obtained by numerical simulation are basically consistent with the experimental results, which proves the correctness of the theoretical calculation. It provides a technical basis for the study of vibration and noise reduction performance of double-helical gear for marine application [6].

However, the frequency analysis of helical gear for automotive industry has to be investigated for different alloy materials are considered for the study feasibility. This research aims on the weight reduction, variation in the frequency levels from natural frequencies to forced frequencies. The results are tabulated accordingly.

III. METHODOLOGY AND RESULTS

A helical gear transmission system has the characteristics of smooth transmission, strong bearing capacity and high speed. It has been widely used in aerospace, ships, automobile transportation and other fields. In this context, a helical gear from the tool box with some arbitrary dimensions have adopted as a model. A solid mesh is chosen and the direct sparse solver is incorporated in the frequency analysis. Discretization of the model is performed for an aspect ratio of 11.881 with the element's aspect ratio less than 3 and remaining with an aspect ratio more than 10. Total elements of 11358 and 18136 nodes are involved in the analysis.

TABLE: 2 AISI4340 NORMALIZED STEEL VOLUMETRIC PROPERTIES

Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
<helical_gear_3_am>- <Keyway>	Solid Body	Mass:10.3841 kg Volume:0.00132281 m ³ Density:7850 kg/m ³ Weight:101.764 N	

TABLE: 3 2024 AL ALLOY VOLUMETRIC PROPERTIES

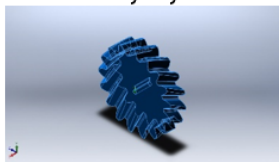
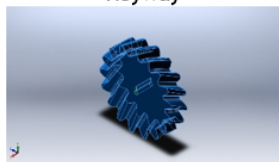
Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Keyway 	Solid Body	Mass:3.70387 kg Volume:0.00132281 m ³ Density:2800 kg/m ³ Weight:36.2979 N	C:\SOLIDWORKS Data\browser\Ansi Metric\power transmission\gears\helical gear_3_am.sldprt Jul 14 19:48:38 2016

TABLE: 4 MAGNESIUM ALLOY VOLUMETRIC PROPERTIES

Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Keyway 	Solid Body	Mass:2.24878 kg Volume:0.00132281 m ³ Density:1700 kg/m ³ Weight:22.038 N	C:\SOLIDWORKS Data\browser\Ansi Metric\power transmission\gears\helical gear_3_am.sldprt Jul 14 19:48:38 2016

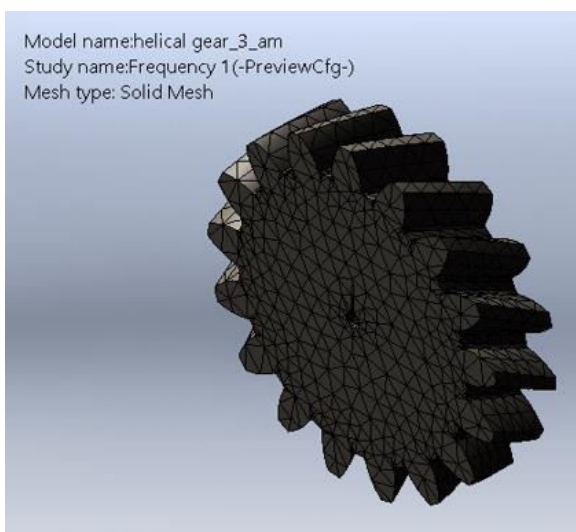


FIG:1 DISCRETIZED HELICAL GEAR

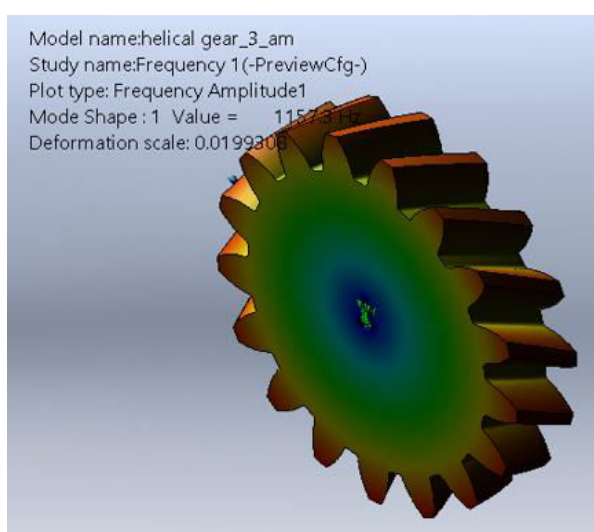


FIG: 2 FORCED FREQUENCY – MAGNESIUM ALLOY

TABLE: 5 NATURAL FREQUENCIES

Frequency Number	NATURAL FREQUENCIES (Hz)		
	AISI4340 NORMALIZED STEEL	2024 ALUMINUM ALLOY	MAGNESIUM ALLOY
1	1075.8	1152.5	1157.3
2	2097.6	2179.1	2196.1
3	2110.8	2198.4	2219.7
4	3295.5	3383.6	3424.8
5	4685.1	4680.3	4686.2

TABLE: 6 FORCED FREQUENCIES

Frequency Number	FORCED FREQUENCIES (Hz)		
	AISI4340 NORMALIZED STEEL	2024 ALUMINUM ALLOY	MAGNESIUM ALLOY
1	1072.7	1152.5	1157.3
2	2092	2179.1	2196.1
3	2110	2198.4	2219.7
4	3293.5	3383.6	3424.8
5	4685.2	4680.3	4686.2

IV. CONCLUSIONS

- A weight reduction of 64.33% is observed from the AISI 3240 Normalized steel to 2024 Aluminum Alloy steel from the results.
- A weight reduction of 78.34% is observed from the AISI 3240 Normalized steel to Magnesium Alloy steel from the results.
- A slight variation observed for both materials from forced frequencies to natural frequencies proving material consistency for about 0.03%.

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