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Vibration Analysis of Spur Gear- FEA Approach

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Abstract— Gears are used for a wide range of industrial applications. They have varied application starting from textile to aviation industries. They are the most common means of transmitting power. They change the rate of rotation of machinery shaft and also the axis of rotation. For high speed machinery, such as an automobile transmission, they are the optimal medium for low energy loss and high accuracy. During operation, meshed gears" teeth flanks are submitted to high contact pressures and due to the repeated stresses, damage on the teeth flanks in addition to tooth breakage at the root of the tooth is one of the most frequent causes of gear failure. This fatigue failure of the tooth decides the reliability of the gear. In this paper, spur gear made up of EN9 material is designed and mode shape of respective gear is found out.
Keywords— Modal analysis, FFT analyzer, Finite element analysis.

I. INTRODUCTION

Toothed gears are used to transmit the power with high velocity ratio.During this phase, they encounter high stress at the point of contact. A pair of teeth in action is generally subjected to two types of cyclic stresses:Bending stresses inducing bending fatigue&Contact stress causing contact fatigue.Both these types of stresses may not attain their maximum values at the same point of contact. However, combined action of both of them is the reason of failure of gear tooth leading to fracture at the root of a tooth under bending fatigue and surface failure, due to contact fatigue. When loads are applied to the bodies, their surfaces deform elastically near the point of contact. The highest stresses exist at regions where the lines are bunched closest together. The highest stress occurs at two locations:At contact point where the force F acts&At the fillet region near the base of the tooth.Given the fact that most gearsystems in real engineering environment are multi-mesh with more than one pair of gears, some researchers have shifted theirresearch effort from single-mesh gear trains to multi-mesh ones including gear trains with two meshes and planetary gear trains.Al-shyyab and Kahraman [1,2] systematically investigated the response of a double mesh system which is a commonconfiguration in many applications with multi-term harmonic balance method. Based on the assumption that tooth separationtakes only small fraction of the mesh period, Liu and Parker [3] formulated the nonlinearity of clearance with a smooth functionand approached the problem with the method of multiple scales. Comparison was also made between the results obtainedthrough multiple scales method and that of harmonic balance method.Tobe, Sato and Takatsu [5,6] are believed to be pioneers in studying gear systems with random vibration theory. Theymeasured the transmission error of a gear pair and confirmed the existence of random components in it. Following that acombination of statistic linearization technique and moment equations was employed in the theoretical work [6]. Kumar, Osmanand Sankar [7] investigated the dynamic response of a gear pair with direct integration method, which is much easier to beapplied and understood. However, details on how to handle the clearance-type nonlinearity were not explained fully. Wang andZhang [8] also studied a gear pair, but modeled the random excitation as a speed dependent noise. More recently, Naess, Kolnesand Mo [9] and Mo and Naess [10] approached a similar system with path integration method. The random excitation wasmodeled as a white noise and the probability density of the response was given in the result. In this paper, spur gear made up of EN9 material is tested analytically and experimentally. Mode shapes of both the materials are compared for suitable natural frequency

II. DESIGN METHODOLOGY

Nomenclature		
m- mass	k- stiffness	w- fundamental frequency
$\ddot{x}$- acceleration	$\dot{x}$- velocity	x- displacement
f- natural frequency	J- polar moment of inertia	G- Rigidity Modulus
I – moment of inertia	E – modulus of elasticity	

In order to design the spur gear the CATIA V5 as modeling software has been used. Gear and Pinion are designed by following

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dimensional parameters.

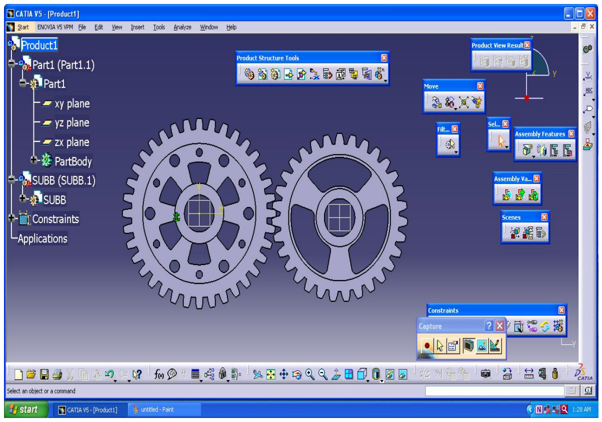

Fig 1 Previous Design of Gear and Pinion using CATIA as design software

A. Material IEN9

Table 1: Chemical Composition of EN9 material

C	Si	Mn	S	P
0.50 – 0.60 %	0.10 – 0.40 %	0.50 – 0.90	0.050 max %	0.050 max %

III. MODAL ANALYSIS OF GEAR

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, Finite element analysis may be used to help determine the design modifications to meet the new condition

A. Modal Analysis

In many engineering applications, the natural frequencies of vibration are of interest. This is probably the most common type of dynamic analysis and is referred to as an 'Eigen value analysis'. In addition to the frequencies, the mode shapes of vibration which arise at the natural frequencies are also of interest. These are the un damped free vibration response of the structure caused by an initial disturbance from the static equilibrium position. This solution derives from the general equation by zeroing the damping and applied force terms. Thereafter, it is assumed that each node is subjected to sinusoidal functions of the peak amplitude for that node. The mode shapes are also of interest to the engineer. These are normalized to the maximum displacement of the structure. The input conditions which initiate the vibration control the amplitudes of vibration in any problem.

B. Mode Shapes And Frequencies Of Gearmaterial En 9(Existing Material)

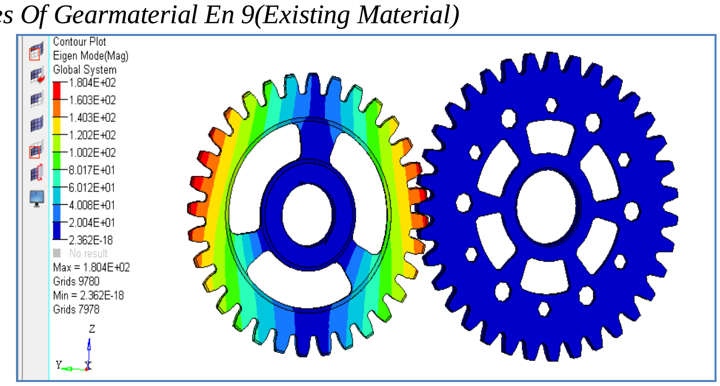

Fig. 2 Mode shape 1 in modal analysis at frequency (23611HZ)

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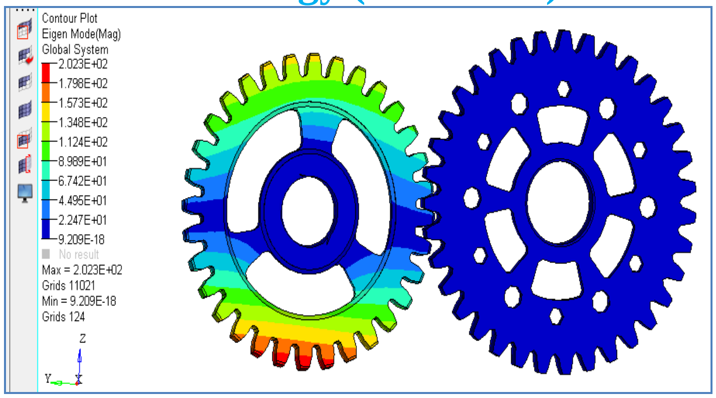

Fig. 3 Mode shape 2 in modal analysis at frequency(23664HZ)

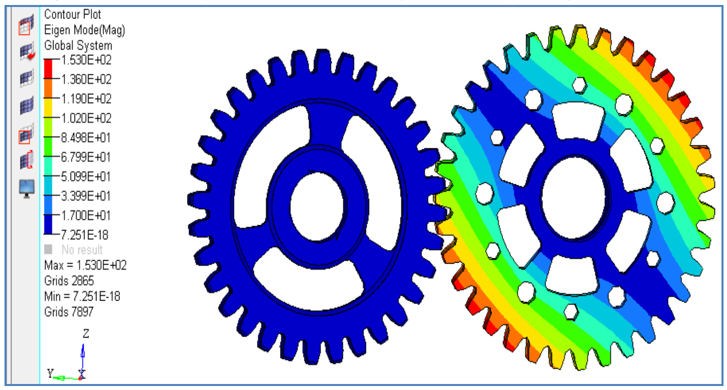

Fig. 4 Mode shape 3 in modal analysis at frequency(25682HZ)

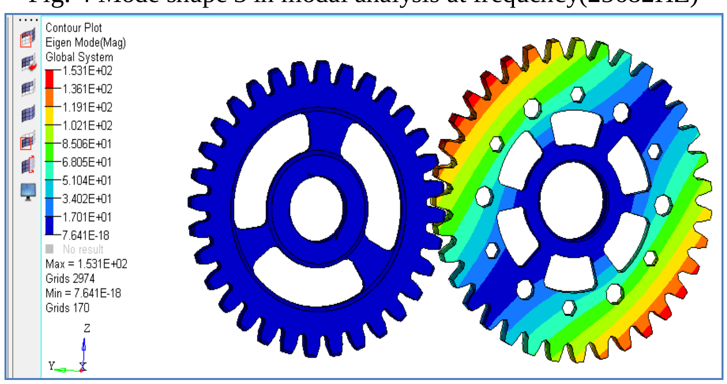

Fig. 5 Mode shape 4 in modal analysis at frequency(27518HZ)

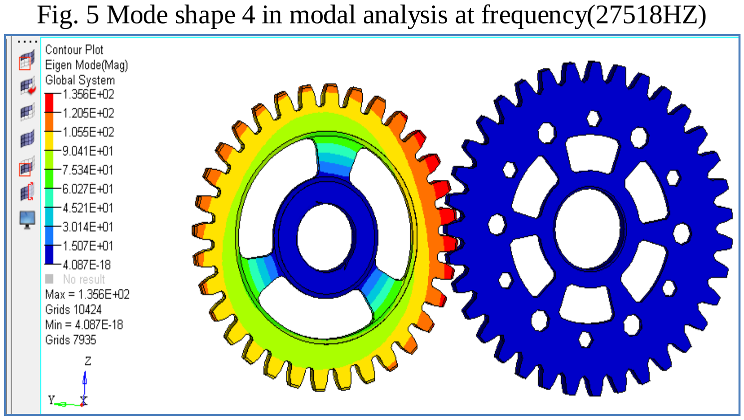

Fig. 6 Mode shape 5 in modal analysis at frequency(30430HZ)

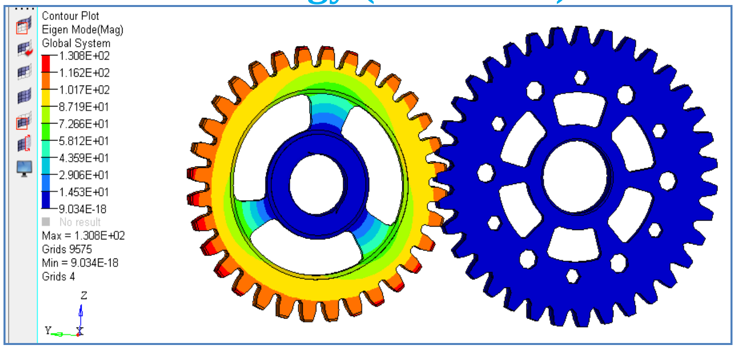

Fig. 7 Mode shape 6 in modal analysis at frequency(33706HZ)

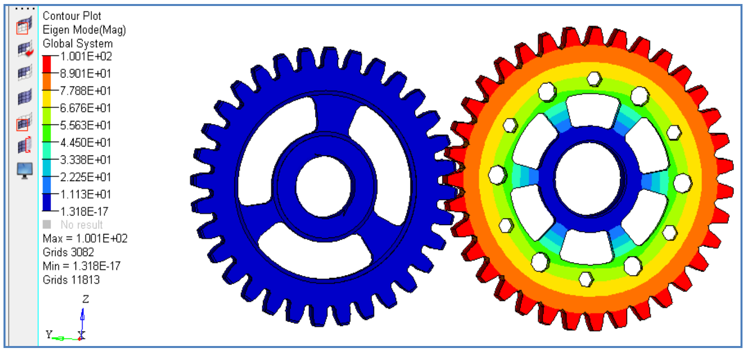

Fig. 8 Mode shape 7 in modal analysis at frequency(38184HZ)

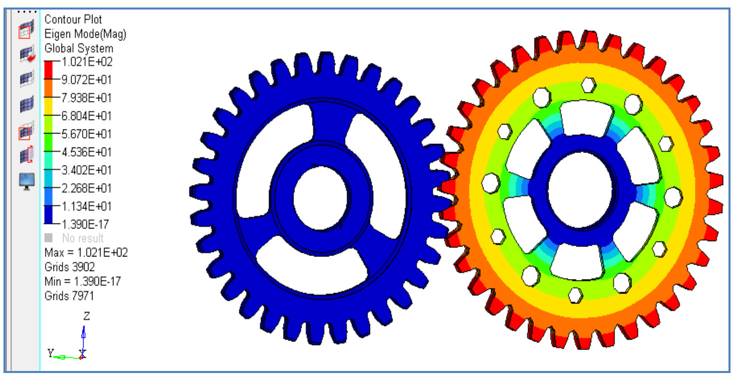

Fig. 9 Mode shape 8 in modal analysis at frequency(39975HZ)

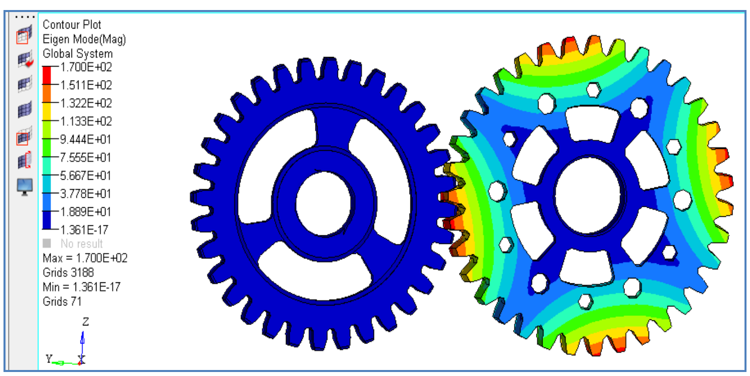

Fig. 10 Mode shape 9 in modal analysis at frequency(48730HZ)

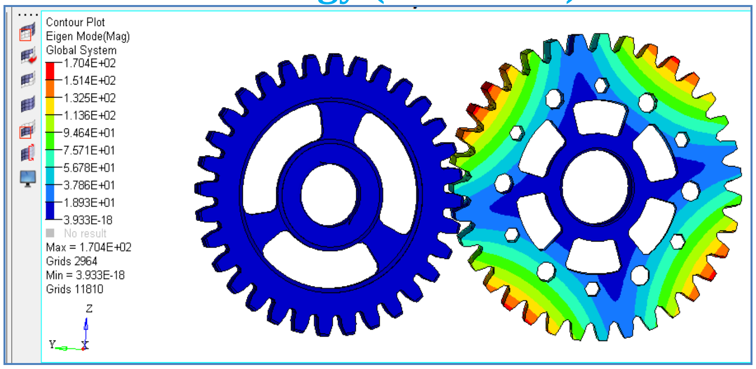

Fig. 11 Mode shape 10 in modal analysis at frequency(48736HZ)

Table 3: Frequencies Of Existing Gears(EN 9 Material)

Mode	Existing Gears frequencies in Hz
Material	EN9
1	23611
2	23664
3	25682
4	27518
5	30430
6	33706
7	38184
8	39975
9	48730
10	48736

IV. RESULTS AND DISCUSSION

Table 4: Comparison of Results

Particulars	Analytical Results	Experimental Results
Natural frequency Hz	2361.1	2502.8

It is seen that the comparative results shows decreasing trends for natural frequency, this variation is occurs due to the operating condition of the gears.

Fig 12 shows the graphical presentation of the analytical results and experimental results.

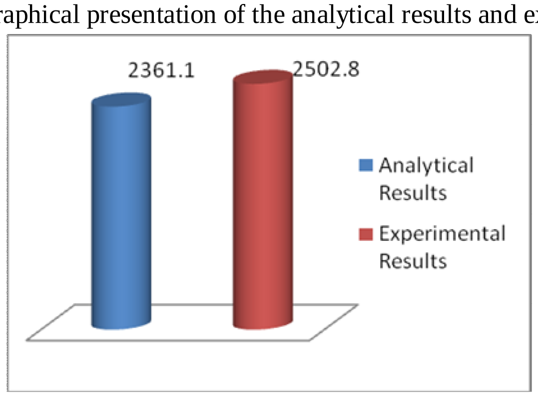

Fig. 12 Graphical Representation of Results

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V. CONCLUSION

Modal analysis result shows that the frequency value (23611 Hz) of existing gears manufacturing with EN9 steel is much higher as compared to engine frequency value and no resonance condition was found. Further modal analysis of gears made out of EN353 as per the design of existing gears (EN9) was carried out in order to reduce cost with performance at par.

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