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Analysis of Spur Gear Dynamics Due to Backlash in Lathe Machine

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Abstract

The important parameters of mating gears design is contact stress, stiffness, friction, backlash etc. This paper deals with the reduction of contact stresses, vibration of the spur gear and pinion used in live centre of a lathe machine by introducing backlash of different values. In this paper the vibration analysis of mating gears of the spur gear with three different values of backlash and without backlash is done to determine the contact stresses and vibrations generated in the gear teeth. The results obtained from Finite Element Analysis (FEA) using Ansys are given. The materials of spur gear used for analysis are cast iron. On comparing the results after theoretical analysis i.e. through Ansys, very little but effective performance of the gear are measured with different vibration frequencies. This model will takes into account the gear mesh variable stiffness and backlash.

Keywords*:* Spur Gear, Finite Element Analysis, Ansys. Backlash

1. Introduction

Authors are advised to provide an introduction for their article. Introduction can be considered as the first detailed statement about the research topic being discussed in a general context. A good research article should answer several questions (Shaw, 2003), and the introduction is a good place to present those to the reader for the first time. It is not constrained such as the abstract; hence authors can express their ideas without worrying about the space. But, keep in mind, a good start can lead to a great journey!

The introduction is better when written in a brief manner with sufficient information to convince the reader at the early stage. However, try not to over explaining the same topic or repeat unnecessarily; instead use a separate background section if you have enough materials to discuss after the introduction.

Always end your introduction section with an outline of the paper with brief details on each. The section 2 of this paper explains about the Body of the article while several subsections are included to explain subsections, language use, and referencing. Section three explains formatting on Figures, Table and Equations with examples. Finally, the section 4, conclusion concludes the main text while references and author biography complete the article.

2. Body of the article

In this research work, vibration analysis using different values of backlash are tried. A finite element model of Spur gear and pinion of Lathe machine headstock with given data is considered for vibration analysis and the stress relieving feature of various types are introduced on gear teeth at the point of contact. The frequencies of vibration are different at different erosion values. The analysis has been done for the three values of backlash on cast iron.

Table No. 1. Details of meshing spur gears used for analysis

Sr. No.	Gear Material	No. of teeth	Dimensions in mm					
			Module	Pressure angle (ϕ)	diametral Pitch	Diameter	Width
1	C.I. SG700/2	50	1.65	20^0	0.60	82.50	20
2	C.I. SG700/2	65	1.65	20^0	0.60	107.25	20
3	C.I. SG700/2	110	1.65	20^0	0.60	181.50	20

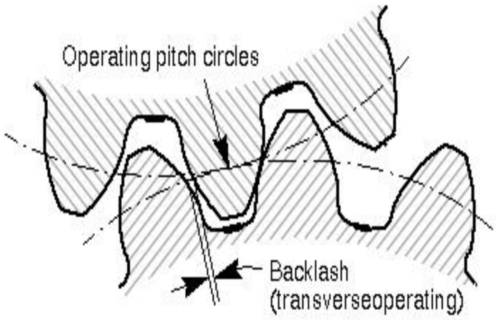

Figure.1: Backlash in meshing gear.

Stresses occurring in the gear teeth are

- Bending Stresses
- Contact Stresses
- Shear Stresses

The bending strength of a gear is defined as the allowable tangential force at the pitch circle based on the mutually allowable bending stress of two meshing gears under load.

2.1 Dynamic backlash model with effect of central distance error

Backlash, in a pair of gears, is the amount of clearance between mated gear teeth as shown in Figure1.5. In other words, it is the difference between the tooth space and the tooth thickness, as measured along the pitch circle. Theoretically, the backlash should be zero, but in actual practice some backlash must be allowed to prevent jamming of the teeth due to tooth errors and thermal expansion. This gap means that when a gear-train is reversed, the driving gear must be turned a short distance before all the driven gears start to rotate. Although gear backlash may cause many undesirable problems in applications, especially precision positioning, it is required to allow for lubrication, manufacturing errors, deflection under load and differential expansion between the gears.

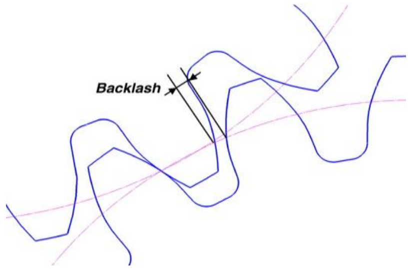

Figure. 2: Sketch of backlash, profile of meshing gears are denoted by blue lines and pink dot line is pitch circle.

2.2 Effect of Gear Backlash

A gear pair may have some amount of backlash either designed to provide better lubrication and eliminate interference or due to manufacturing errors and wear. The backlash may cause tooth separation and impacts in geared rotor systems which produces high stresses and noise radiation.

To study the effect of backlash, different backlash values are obtained for system. Backlash (in mm) on the dynamic factor at the gear mesh. The following important conclusions can be extracted from the study:

- As the backlash increases, the amplitude of the dynamic factor decreases at the gear mesh frequency and at its sub-harmonic. The amount of decrease depends on the clearance value.
- Introducing backlash causes a sudden jump at the mesh resonance frequency and its sub harmonics. The amount of jump depends on the backlash value but the location of jump depends only on the system parameters.
- Increasing backlash causes a left-shift on the mesh resonance frequency and its sub-harmonics.
- The shift depends on the backlash value.
- After a certain backlash value, there is no change on the dynamic factor even though the backlash is increased further.

Table No. 2. Necessary data of lathe machine under testing

Manufacture Name	Vimal Brand
Electric motor	1 HP, 3PHASE, 1440 rpm
Gear type	Parallel spur gear
Pressure angle	20^0
Module	1.65
Material	Cast Iron-SG700/2

Table No. 3. Properties of Different materials used for gear.

Sr. No.	**Property (unit)**	**Grey cast iron**	**High carbon steel**	**Medium carbon steel**
1	Density (Kg/m3)	7100	7480	7850
2	Poisson ratio	0.265	0.298	0.298
3	Young's Modulus (MPa)	108 x 10^3	195 x 10^3	200 x 10^3
4	Tensile strength (MPa)	195 x 10^3	800 x 10^3	685 x 10^3
5	Ultimate tensile strength(MPa)	310 x 10^3	996 x 10^3	987 x 10^3

2.3 Gear Mesh Formulation

The gear pair is modelled by two disks which represent the inertia of gears and by a non-linear spring damper system representing the gear mesh. The model includes the following important features:

- the excitation effect of time varying mesh stiffness
- backlash
- separation of teeth in mesh
- gear errors
- profile modifications

Friction forces at the mesh point will assumed as negligible. Also the damping coefficient will be assumed to be time-invariant. In the gear mesh model used, the effect of tooth separation istaken into consideration but tooth impact is ignored.

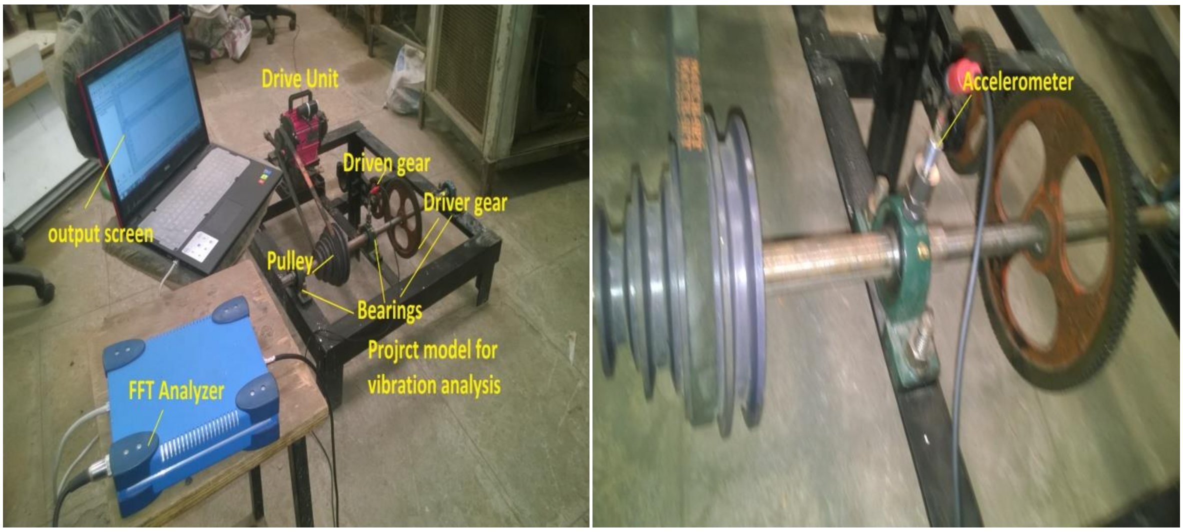

Figure.3: Model testing for vibration by using NV-Gate FFT analyzer

2.4 Advantages of Modal Analysis

The mode shapes and natural frequencies of a structure are its basic dynamic properties. Modal testing is used to rapidly identify these modes and their natural frequencies, and to provide the structural matrices, which govern the modes and natural frequencies. Thus the basic structural dynamic data, when obtained accurately from a valid test alsoprovides a true identification of the structural properties for the modes of interest. These derived matrices are based on the measured participation of the mass, stiffness and damping properties in the modes of interest, for the actual boundary conditions, which the structure is experiencing. These data can then be used directly in a finite element model for the structure or component, for subsequent problem solving, or re-designing

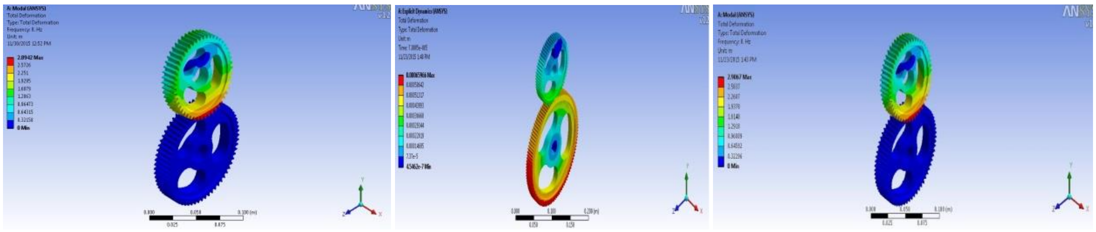

Figure 4: Analysis of gears without backlash with ANSYS.

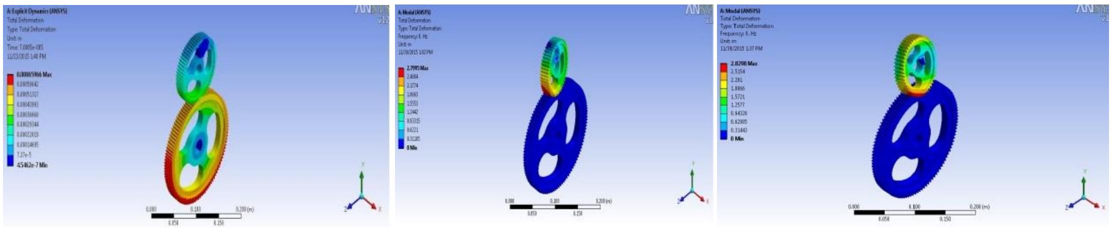

Figure 5: Analysis of gears with approx. 0.3 mm backlash with ANSYS.

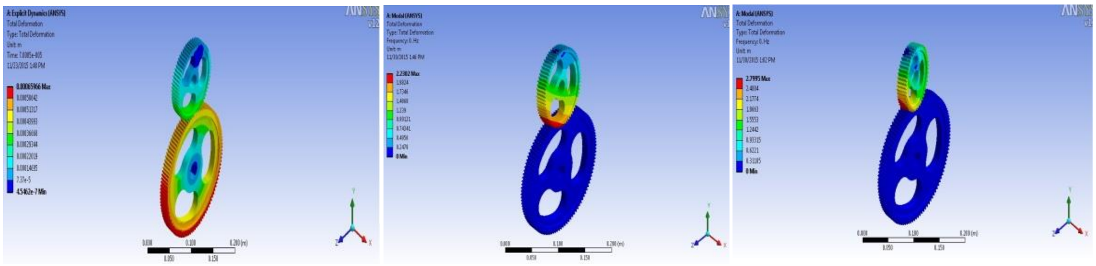

Figure 6: Analysis of gears with approx. 0.5 mm backlash with ANSYS.

the equipment for more optimum dynamic response. Modern modal analysis test equipment has been developed to provide the maximum convenience in testing and data reduction, and to provide the above-mentioned dynamic properties of the structure. All modal analyzers contain dedicated mini-computers for efficient high-speed dataprocessing, performed in a prescribed manner in accordance with a specialized test routine. In the hands of an experienced modal analyst, this leads to economical extraction of the data mentioned above. The advantages of modal analysis are, first, that a modal test provides the most rapid and effective procedure available for the acquisition of data on the dynamic properties of a structure. Such testing can often be performed by a skilled technician for later interpretation by a dynamics engineer. Second, modal analysis is an effective analytical procedure for the solution of large sets of structural dynamics equations because it reduces coupled matrix equations (which must otherwise be solved by some iterative procedure) to a set of independent linear equations, each with the well-known closed-form solution given above. Modal solutions can therefore be obtained directly, without further numerical operations. These solutions are then re-combined to form the complete solution to the structural response problem in question. It should here be noted that solutions to harmonic, transient, and random forced vibration problems can all be obtained using this modal analytical procedure, by means of simple extensions to the theoretical procedure outlined above.

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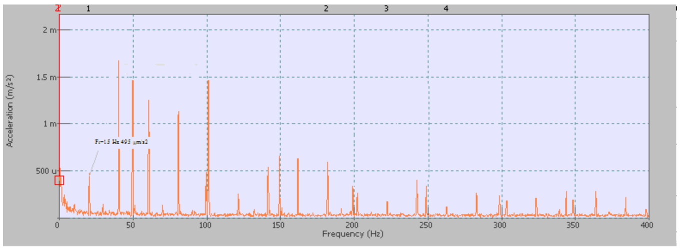

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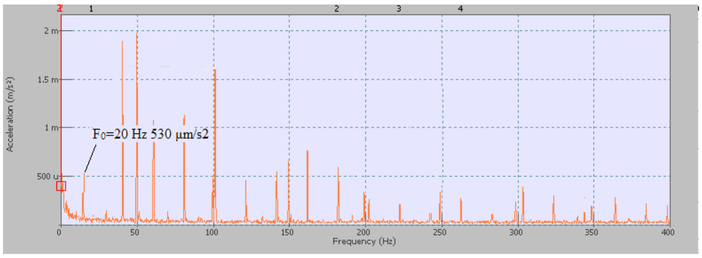

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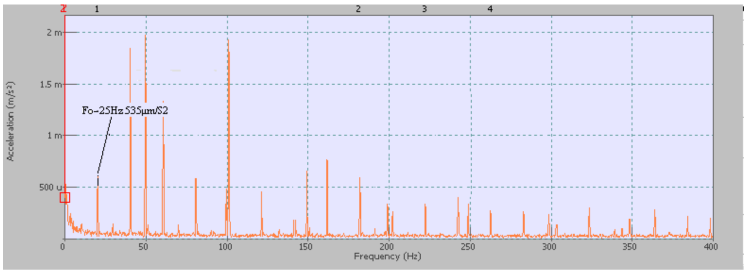
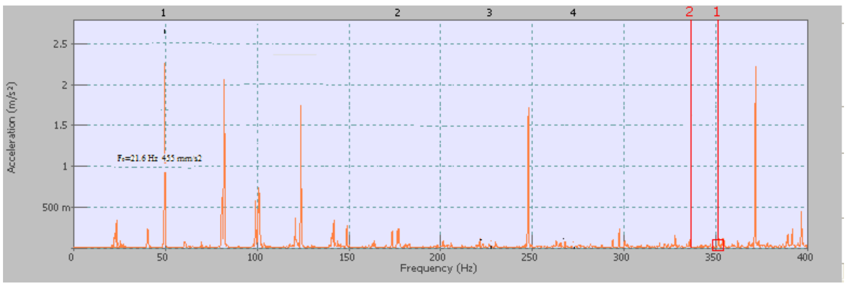


(c)

Figure 7: Signatures of Gear pair without backlash at different frequencies



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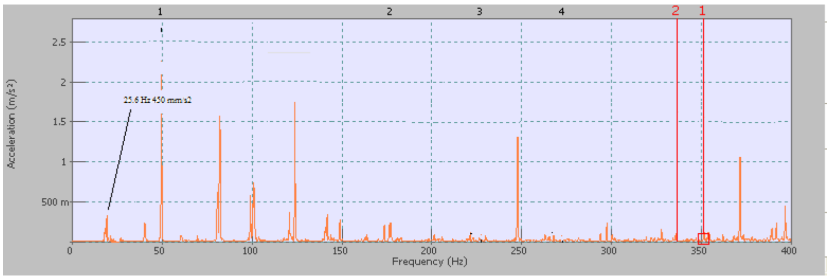

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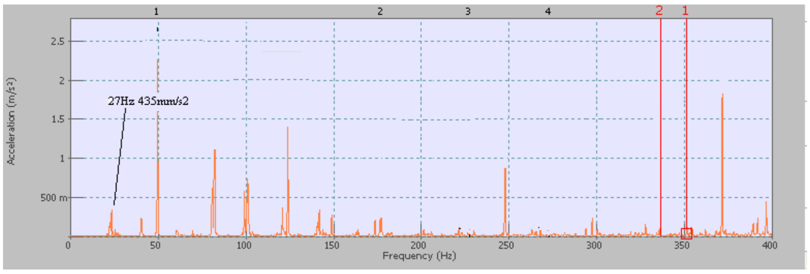

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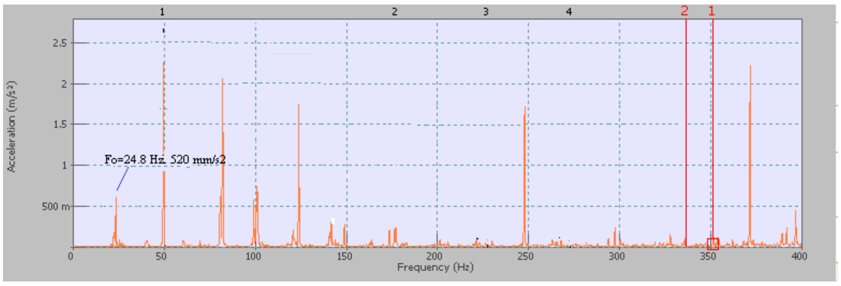
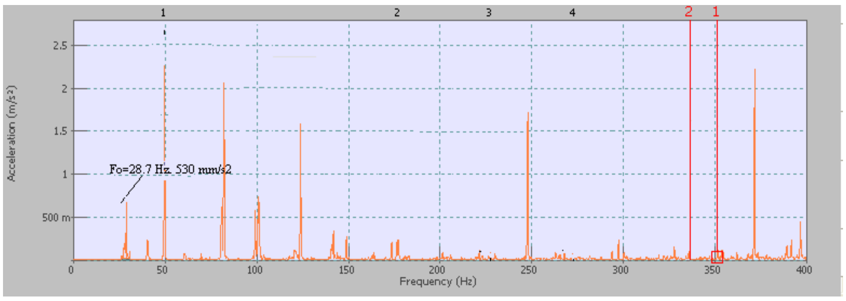
Figure 8: Signatures of gear pair with approx. 0.3 mm backlash at different frequencies.





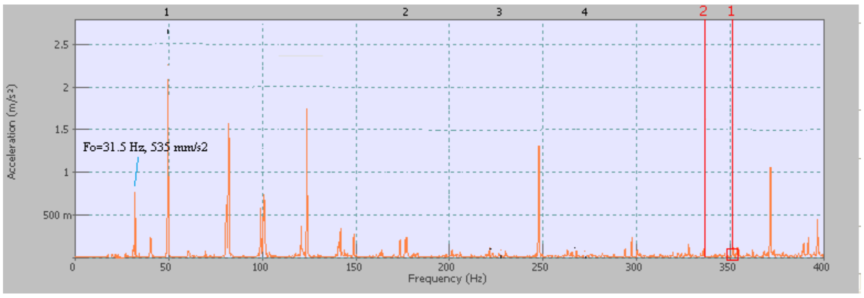


Figure 9: Signatures of gear pair with approx. 0.5 mm backlash at different frequencies.

Table No.4. Acceleration Vs frequencies results without and with backlash.

Sr. No.	Gear pair without backlash		Gear pair with approx. 0.3 mm backlash		Gear pair with approx. 0.5 mm backlash	
	Accl^n. in m/s^2	Freq. in Hz	Accl^n in m/s^2	Freq. in Hz	Accl^n in m/s^2	Freq. in Hz
1	**535**	**25**	**535**	**27.0**	**535**	**31.5**
2	**530**	**20**	**530**	**25.6**	**530**	**28.7**
3	**520**	**15**	**520**	**21.6**	**520**	**24.8**

4. Conclusion

The main emphasis of this study will be focussed on some issues related to the adverse effects caused by the nonlinear characteristics of dynamical systems on efforts directed towards accurate identification of their parameters. This model will takes into account the gear mesh variable stiffness and backlash, the static transmission error and the deformability of the bearings. Based on information regular and irregular dynamic response of the system that will examine, it will possible to explain some unusual results obtained by the application of an appropriate parametric identification methodology.Simulations will carried out with the same set of parameters and reveal a very close fit with experimental measurements.

From the result i.e. experimental and FEA, as backlash increases the frequency goes on increasing and vibration also increases, so it is helpful for the choice of better material for spur gears. Due to vibrations the more wear and noise is also extend.

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