RESEARCH ARTICLE OPEN ACCESS

Modal analysis of a clutch plate with optimized discretization

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Abstract:
Clutch plates have an important role in the manual transmission vehicles of automotive industry. It is a design challenge to have a legitimate fatigue life to actual working conditions. Fatigue life is influenced by material, loading conditions, temperature and environmental conditions. To investigate the effectiveness of optimizing the discretization, the modes of the clutch plate is evaluated and compared for the frequencies spectrum. It is observed that 0.08% variation in the elements, the frequency is varied by 0.019% proving that the increasing the elements beyond the optimal discretization has no effect.

Date of Submission: 22-03-2025 Date of acceptance: 04-04-2025

I. Introduction:

Fatigue life is an essential aspect of clutches, as it is a key factor in judging the reliability, safety, and overall lifespan of the clutch when used in vehicles or machinery [1]. When the clutch works with cyclic loading, it is continuously engaged and disengaged repeatedly in the operation. When it fails suddenly due to fatigue, control over the vehicles will become difficult. In the same way, the longevity and durability of a clutch are essential to justify the genuineness of the clutch for its performance and cost-effectiveness [2] . To achieve overall control, wear resistance, fatigue, and sustainability, material optimization should be adopted. The cyclic stresses generated in the clutch plate during operation should be less than the ultimate strength of the material [3]. The actual fatigue life of the clutch will change significantly with variations in the nature of the application and operating conditions.

Clutch plate analysis is an essential process in the design and development of the automotive industry. To have an efficient design, a stress analysis and modal analysis is performed by Barve and Kirkire, the results are analyzed for good understanding with the limiting stresses and mode shapes [4]. Yang et al. evaluated critical diverging speed and dimensionless friction co-efficient for the dynamic stability of friction clutches. This investigation narrates the thermoelastic coupling transverse vibrations with three different boundary conditions are calculated and thermoelastic coupling coefficient and dimensionless angular speed are analyzed [5]. Karthik Virmani et al. performed FEA analysis of various friction lining materials from SolidWorks model and the results are tabulated and discussed in detail to optimize the design [6].

Problem description: An automotive single plate clutch consists of two pair of connecting surfaces. The inner and outer radii of friction plate are 140 mm and 280 mm respectively. The co- efficient of friction is 0.22 and the total axial force is 30 kN. Evaluated the capacity of the clutch plate at 1200 RPM uniform pressure theory for the modal analysis.

II. Methodology:

A typical clutch plate is modeled using commercial SolidWorks software, and its modal properties are analyzed under an applied pressure of 0.65 MPa, following the conventional clutch calculation method. For this methodology, modal analysis for the resonant frequencies and related six mode shapes are analyzed and tabulated with respect to elements number. Spring steel material is chosen for the clutch plate, with 210 GPa modulus of elasticity, poisons ratio of 0.28 and density of 7861 kg/m^3. Appropriate boundary conditions are applied at the inner radius of the clutch and 0.65 MPa pressure is applied on the mating surface of the clutch plate. The results are tabulated and as indicated in table:1.

Table:1 Resonant frequencies for different element sizes

MODES	E-22264	E-22583	E-23327	E-23690	E-23825	E-24363
1	10601	10427	10398	10400	10508	10405
2	10632	10459	10435	10438	10552	10444
3	10657	10484	10458	10458	10575	10461
4	10924	10739	10720	10719	10792	10725
5	10997	10797	10770	10773	10904	10781
6	11718	11509	11483	11486	11591	11491

III. Results And Discussions:

A typical clutch plate is analyzed for its modal analysis by varying the element size and according to the discretization process, total number of elements from 22264 to 24363 are tabulated from the modal analysis. The frequencies are evaluated for 6 mode shapes and one among them is furnished in fig:1.

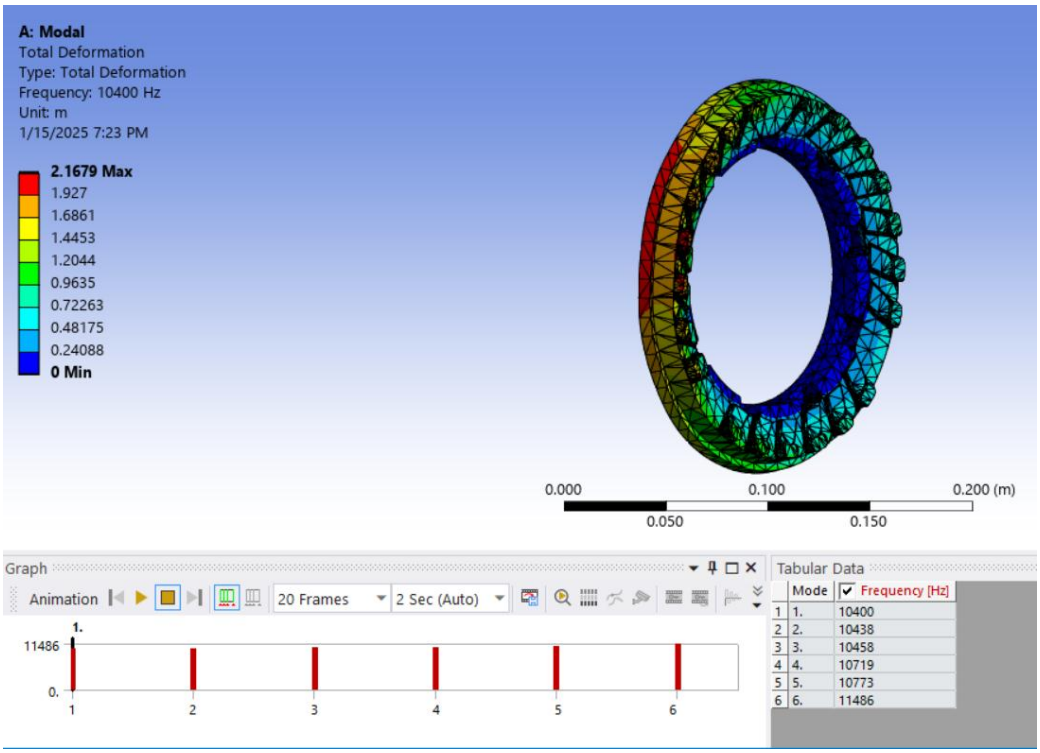

Fig: 1 frequency spectrum for E-23690 elements

A typical graph is plotted from the results of table:1 and compares its scenario of discretization process. Fig:2 represents modes on X-axis and element size on Y-axis for spring steel clutch modal analysis.

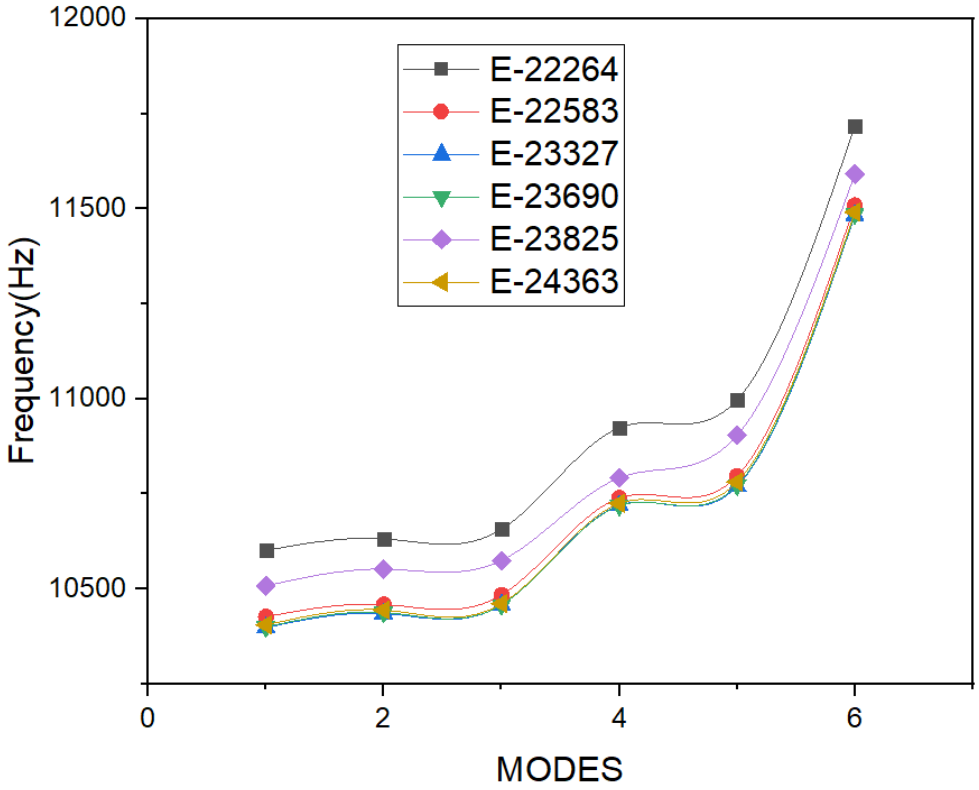

Fig:2 Frequency plot for the mode shapes of the clutch modal analysis

IV. Conclusions and Future scope:

This SolidWorks 3D model is analyzed for modal analysis and the modes are extracted. For the elements of E-23327 show the minimum resonance frequency of 10398 Hz and E-22264 show the maximum resonance frequency of 11718 Hz and other frequencies are more or less with good understanding, proving that the convergence is achieved successfully.

The same type of analysis can also be performed with couple field analysis and with different materials can be done in future analysis.

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