PREDICTION OF SHEAR STRESSES AND CRITICAL SPEED OF COMPOSITE FLYWHEEL BY VARYING DIFFERENT HUB ANGLES USING FEM

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Abstract* — *A rotating disc often undergoes severe vibrations at high speeds because of unstable joining between the disc and the drive shaft. The analysis has presented the effect of shear Stress with different profiles of the flywheel with different layered (0.5mm, 1mm) and different Hub angle (4˚, 5˚, 0˚). The natural frequency and modes of different materials and shear stress effects were analyzed on different profile and materials of flywheel and distribution along the flywheel was studied. The natural frequency along the flywheel profile is found to be maximum of the 4˚hub angle of T300 material profile with 1mm multi rim flywheel. The shear stress distribution along the multi rim flywheel is maximum for T300-EPOXY non layer and minimum for T300-EPOXY 1mm layered of a flywheel with different profiles. The magnitude of frequency is maximum in the case of T300 material profile with 4˚ hub angle. The nature of the natural frequency is maximum near its end in 1st 2nd and 3rd mode. The nature of the shear stress is minimum near its hub of flywheel with 1mm multi rim of T300-EPOXY and 4˚ inclined hub angle.

Keywords— Fly Wheel, Shear Stress, Hub Angle, Composites

I INTRODUCTION

A Flywheel is a rotating mechanical gadget used to store kinetic energy. Flywheels have been in use for quite a lot of functions for the period of human historical past for enormous quantities of years. In the beginning they had been used as a way to supply balance, corresponding to a potters wheel. During the financial Revolution, they have been principally integrated in steam engines. However, it was once not until the late 1960s/early 1970s, with the appearance of composite substances and an increased hobby in renewable vigor resources, that examine into the capabilities for flywheels as a plausible alternative to chemical batteries was once achieved. The construction of magnetic bearings inside the 1980s moreover exacerbated interest and research. Flywheels will also be separated into two training: traditional and high-overall performance (great flywheels). Conventional flywheels are constructed from popular substances, maximum probably steel, whilst excellent flywheels are composed of composite substances. The reward work includes evaluation on both varieties of flywheels, however with the number one center of interest located on traditional flywheels. A usual flywheel is proven in Fig. 1-1. Flywheels had been proposed as an alternative or complement to average chemical batteries for the duration of various areas. These comprise mobile purposes, such because the automobile and aerospace enterprise, or vigor law in electrical energy producing plants.

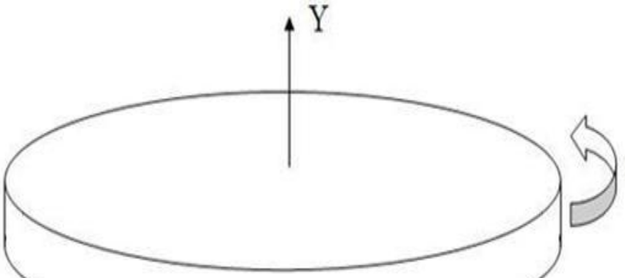


Figure 1.1 Basic flywheel diagrams

II ENERGY STORAGE

With the growing demand for oil world wide and dwindling non-renewable assets, curiosity in vigor storage has had an uptick in recent a long time. The current world power storage potential is 90GW from an entire advent of 3400 GW (i.E. Handiest 2.6% of general electric vigour inside the global is in a function of being saved) [1]. Energy storage gadgets add stability and reliability to electric grids. This in flip improves performance and reduces intake of assets. Instabilities in electrical grids are brought on with the aid of load editions because of various factors, much like fluctuating enter masses from renewable resources (wind and solar), frequency deviations, and discrepancies among top and common electric energy call for. The quite a number of methods of electricity storage comprise mechanical, electro-chemical, thermal, electro-magnetic, and chemical applications. Each of those distinct techniques is used depending on efficiency, cost/discharge expense, discharge time, storage capability, biking potential, self-discharge, environmental erects, and charges. Depending on their software, the programs can be divided into four classes [2]:

- Low-power application in isolated areas, essentially to feed transducers and emergency terminals.
- Medium-power application in isolated areas (individual electrical systems, town supply).
- Network connection application with peak leveling.
- Power-quality control applications.

III MATERIALS USED

- Most of Flywheel is formed from steel, either medium- or low-carbon. However, top Strength steel, typically heat treated, is additionally selected for powerful applications.
- Metals, like brass, stainless steel or Al, are used where Corrosion may be a disadvantage or lightness is required.
- Small, light-duty Flywheels, like in family appliances, are additionally injection shaped.
- In a plastic material cherish T300 or EPOXY.

IV APPLICATIONS

Flywheels are often used to provide continuous power output in systems where the energy source is not continuous. For Instance, a flywheel is used to easy speedy angular pace fluctuations of the crankshaft in a reciprocating engine. In this situation, a crankshaft flywheel stores electricity while torque is exerted on it through a firing piston, and returns it to the piston to compress a sparkling charge of air and fuel. Another instance is the friction automobiles which powers devices together with toy cars. In unstressed and inexpensive cases to save on cost the bulk of the mass of the flywheel is toward the rim of the wheel. Pushing the mass away from the axis of rotation heightens rotational inertia for a given total mass.

A flywheel will also be used to supply intermittent pulses of strength at energy tiers that exceed the talents of its electricity supply. This is done through the usage of gathering strength within the flywheel over a time frame, at a price that is well matched with the strength deliver, after which liberating power at a miles higher rate over a particularly brief time even as it's miles wanted. For instance flywheels are utilized in power hammers and riveting machines. Flywheels may be used to control route and oppose unwanted motions, see gyroscope. Flywheels in this context have a sizable variety of programs from gyroscopes for instrumentation to ship stability and satellite tv for pc TV for pc stabilization (reaction wheel), to maintain a toy spin spinning (friction motor), to stabilize magnetically levitated objects (Spin-stabilized magnetic levitation)

Objective of the Work

The main objective of the current work is

- Validation of the ANSYS models by comparing the present simulated results with the experimental result by N. Hiroshima.
- To predict shear stress effects for different layered flywheel (0.5mm, 1mm) and different Hub angle (4˚, 5˚, 0˚) on the flywheel.
- To simulate the flywheel of the different layered flywheel (0.5mm, 1mm) and different Hub angle (4˚, 5˚, 0˚) on the flywheel for variable modes and same RPM.
- Parameter sensitivity study of flywheel.
- To define natural frequency effects and shear stress effects for the flywheel of different layered and different hub angle and constant angular velocity of 35900rpm.
- To predict frequency distribution along the flywheel.

Problem Formulation

The study of various literatures we find the natural frequency is lower as compared to present study. The purpose of this study is to predict critical speed and natural frequency with different material on multi rim fly wheel at constant angular velocity of 35900 RPM, thus chosen different material flywheel for analysis, thus composite materials were chosen for flywheel as per base paper parameters and spin tests were performed to determine shear stresses, but a flywheel is an energy storage device so critical speed is also an major issue for energy distortion so critical speed is analyzed for flywheel with respect to natural frequency.

IV LITERATURE REVIEW

Hiroshima et.al. (2015) - this investigation suggests A rotating disk almost always undergoes extreme vibration at excessive rotation speeds considering of unstable joining between the disk and a pressure shaft. As described herein, three connection approaches between a using shaft and an annular rotation disk fabricated from three-dimensionally carbon-fiber reinforced composite were discussed to attain steady rotation at high rotation speeds by using changing the hub material and becoming a member of geometry: the connecting device. In two of the three methods, the vibration amplitude elevated at a tip speed better than 500 m/s. Key reasons that brought on the vibration had been analyzed.

Sara Caprioli et al. [2], In this paper Thermal cracking of railway wheel treads is investigated using a blended experimental and numerical technique. Results from manage destroy rig tests of repeated stop braking cycles for a not unusual railway wheel in rolling contact with a call referred to as rail wheel is supplied. Test situations are then numerically analysed the usage of finite detail (FE) simulations that basically account for the thermo mechanical loading of the wheel tread. For the studied wheel braking case, thermal cracks are located in the wheel tread after few brake cycles. Results from thermal imaging suggests a frictionally excited thermo elastic instability sample essentially known as “banding” in which the touch between brake block and wheel takes area best over a fraction of the block width

Rupp et al. [2], the creation of flywheel power garage tool in a mild rail transit train is analyzed. Mathematically operated models of the educate, driving cycle pattern and mainly flywheel electricity storage systems are developed. These sort of models are required to look at the power use and consumption and the running and going for walks cost of a light rail transit educate with and without flywheel energy storage capability. Results tell that most electricity savings of 31% may be acquired the use of flywheel electricity storage structures with the assist of electricity and electricity ability of two.9 kWh and 725 kW systematically. Cost savings of eleven% may be possessed via utilizing specific flywheel energy garage structures with energy score of one.2 kWh and 360 kW. The simple introduction of flywheel electricity garage structures in a mild rail transit educate can basically bring about large power and fee financial savings.

Xujun lyu et al. [3], Energy storage flywheels helps on active magnetic bearings (AMBs) have attracted much attention both in the academia and in the industry due to many of their advantageous features, such as short charging time, high specific energy, no pollution and long lifespan. Feedback controlling is essential in the operation of AMB support systems. However, actual types of AMB suspended energy storage flywheels are not widely available for research on feedback control design. To deliver an economic and efficient platform for the study of AMB supported energy storage flywheels, which includes research on the design of their feedback controllers, we propose in this paper to match or emulate the operation of such flywheels on a rotor AMB test rig we recently constructed

Daniel Jung et al. [3], the crankshaft angular velocity measured and calculated at the flywheel is a commonly used signal for engine misfire detection. However, flywheel manufacturing errors or defects result in vehicle-to-vehicle change or variations in the measurements and have a diverse impact on the misfiring detection performance. A misfiring detection algorithm must be able to compensate for this type of vehicle-to-vehicle changing if it is being used in production cars to assure that legislations are satiated. It is shown that flywheel angular variations between vehicles in the magnitude of 0.05° have a prominent impact on the measured or calculated angular velocity and should be compensated for to make the misfire detection algorithm robust. A misfire detection algorithm is basically proposed with the flywheel error adaptation in order to increase robustness and decrease the number of mis-classifications

Makbul A.M. Ramli et al. [4], this paper analyzes a hybrid energy system performance with photovoltaic (PV) as well as diesel systems as the main energy sources. The hybrid energy system is equipped with flywheel to store excess energy from the PV. HOMER software was employed to study the basic economic and important environmental benefits of the particular system with flywheels energy storage for Makkah, Saudi Arabia. The analysis focused on the impact of utilizing flywheel on the power generation, total energy cost, and the net present cost for certain configurations of the hybrid system. Analyses on fuel consumption and carbon emission reductions for the system configurations were also presented in this paper

Zanjhi Wei et al. [5], the micro vibrations generated by flywheels running at full speed onboard high precision spacecrafts will affect stability of the spacecraft bus and further degrade the pointing correctness of the payload. A passive vibration isolation type of platform comprised of multi-segment zigzag beams is proposed to isolate disturbances of the flywheel. By presuming the flywheel and the platform as an integral and undivided system with some gyroscopic effects, an equivalent dynamic model is developed and verified through eigen value and frequency response analysis. The critical speeds of the system are concluded and expressed as functions of some system parameters.

V MODELING AND ANALYSIS

Design procedure of Flywheel

The procedure for solving the problem is

- Modeling of the geometry.
- Meshing of the domain.
- Defining the input parameters.
- Simulation of domain.

Finite Element Analysis of Flywheel.

Analysis Type- Structural Analysis and Modal analysis.

3.9 Preprocessing

Preprocessing include CAD model, meshing and defining boundary conditions.

Table :*5.1 Dimension of Flywheel.*

Diameter of Flywheel 1	238 mm
Thickness at tip of Flywheel	4 mm
Thickness at middle of Flywheel	6.3 mm

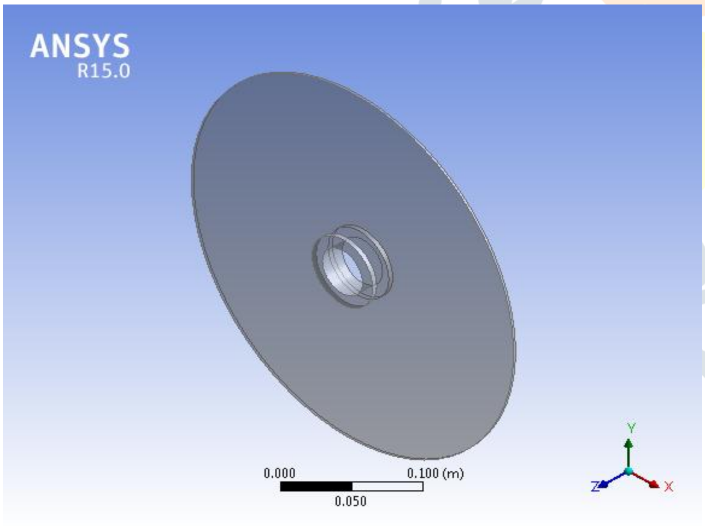


Figure*: 5.1 Model of Flywheel*

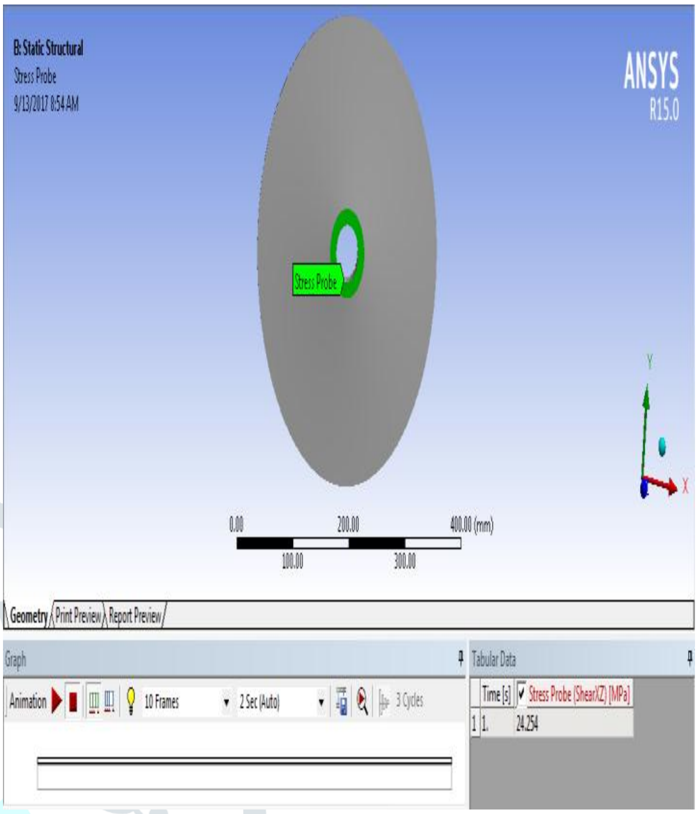
VI RESULT AND DISCUSSION

6.1 Shear Stress and Natural Frequency along the Flywheel with Different Layered Materials and Different Inclined Hub Angles.

A Structural and Modal - analysis was carried out to analyze shear stress of Flywheel with different Layered material and different inclined hub angle relation between natural frequency and spin speed two types of materials of T300, EPOXY, with flywheel to determine the frequency distribution along the Flywheel. Frequency distribution contours in case of flywheel are shown in figure, and the effect of different materials on Flywheel profile on the frequency and modes distribution for various materials are represented in the figure.

6.2 DIFFERENT LAYERS SHEAR STRESS IN (T300-EPOXY)

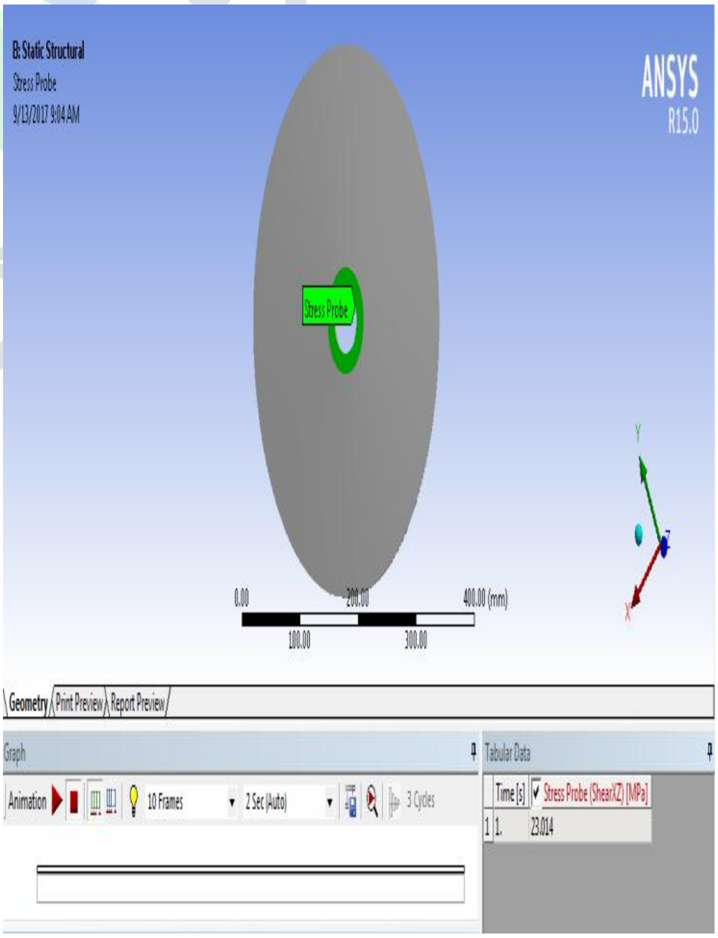
6.2.1 Shear stress of 0.5mm layer flywheel



	Time [s]	✓ Stress Probe (ShearXZ) [MPa]
1	1.	24.254

Figure: 6.1 Shear stress of 0.5mm layer flywheel of (T300-EPOXY) material.

6.2.2 Shear stress of 1mm layer flywheel



	Time [s]	✓ Stress Probe (ShearXZ) [MPa]
1	1.	23.014

Figure: 6.2 Shear stress of 1mm layer flywheel of (T300-EPOXY) material

Table6.1 Shear stresses on different layer materials of flywheel.

Combine material	**0.5 mm Layer**	**1 mm Layer**
T300-EPOXY	24.254	23.014

6.3 DIFFERENT HUB ANGLES SHEAR STRESS IN (T300) MATERIAL

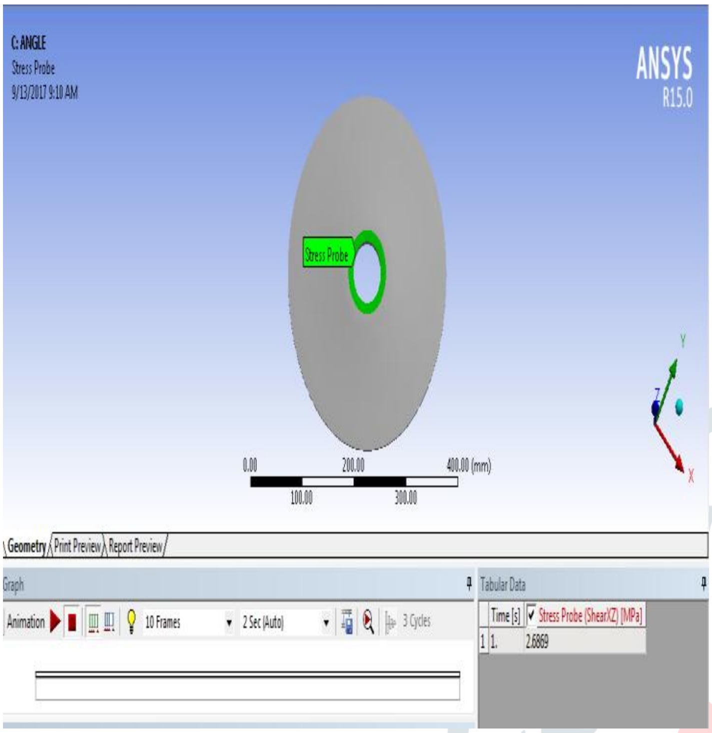


Figure 6.3 Shear stress of 4˚ hub angle flywheel of T300 material

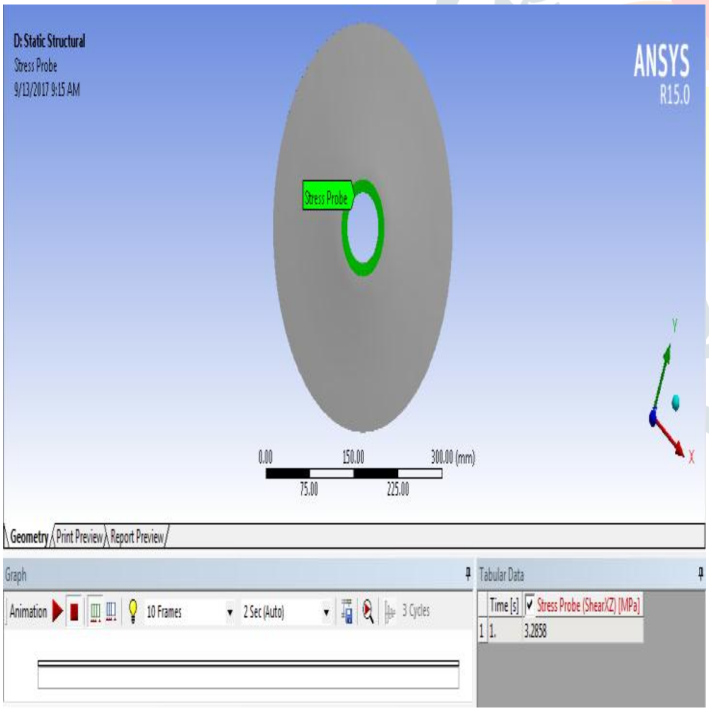


Figure 6.4 Shear stress of 5˚ inclined hub angle flywheel of T300 material

Table: 6.2 Shear stresses on different Angle of flywheel.

Materials	**4˚ Angle**	**5˚ Angle**
T300	2.5534	3.1272
EPOXY	3.2624	3.353

Materials	**0^0 Angle**	**1^0 Angle**	**2˚ Angle**	**3˚ Angle**	**4˚ Angle**	**5˚ Angle**
T300	27.613	2.8107	2.6255	3.2962	2.5534	3.1272
EPOXY	27.963	4.9941	3.6925	3.8692	3.2624	3.353

Comparison of Natural Frequency						
Modes	**0˚**	**4˚**	**5˚**	1°	2°	3°
1	119.8	120.48	120.12	121.8	118.68	117.01
2	119.86	120.83	120.18	121.66	118.69	117.70
3	121.87	124.06	123.19	121.87	119.86	118.68
4	125.06	127.51	127.19	126.66	119.99	118.05
5	125.09	127.93	127.49	126.48	120.89	119.85

Table - Comparison of Natural Frequency

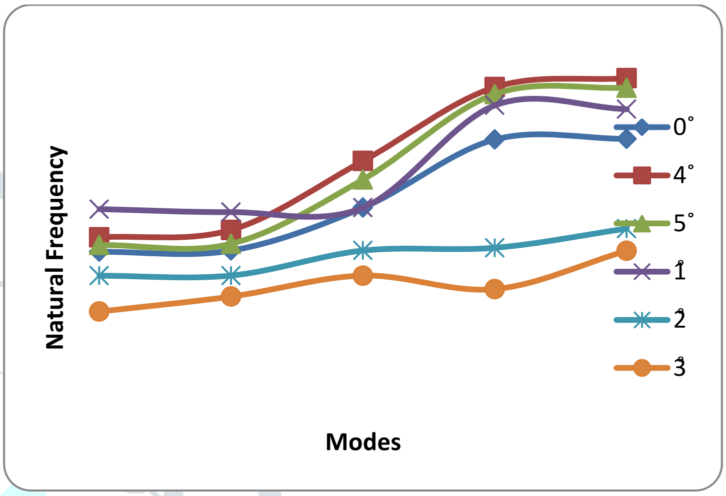


Fig – Comparison of natural frequency w.r.t modes of different hub angle flywheel

6.4 Critical Speed and Frequency along the Flywheel with different Diameter and Materials

A Structural and Modal – analysis was carried out to analyze critical speed of Flywheel with different material and inclined hub angle by using Campbell diagram and relation between natural frequency and spin speed a T300 with flywheel to determine the frequency distribution along the Flywheel. Frequency distribution contours in case of flywheel are shown in figure below, and the effect of different materials on Flywheel profile on the frequency and modes distribution for various materials are represented in the Figure below.

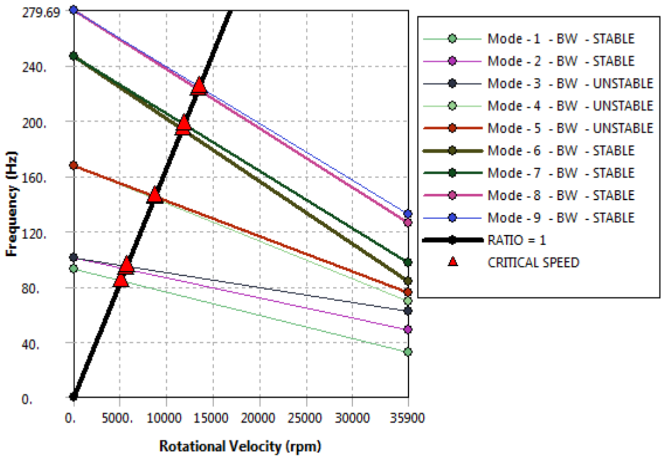
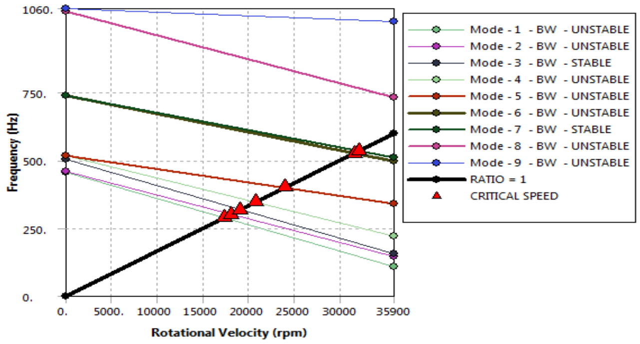
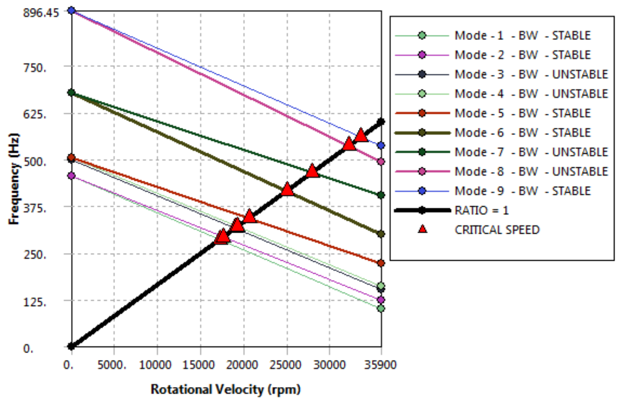


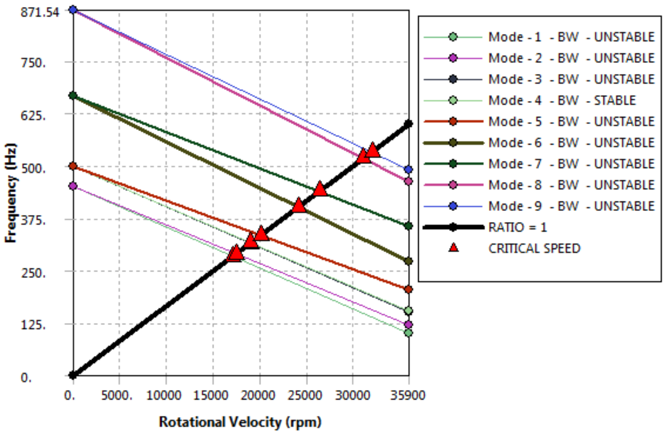
Figure 6.5 Result of Campbell diagram of Frequency and rotational velocity Distributions along the 4˚ inclined hub angle flywheel with T300 material



Result of Campbell diagram of Frequency and rotational velocity Distributions along the 1˚ inclined hub angle flywheel with T300 material



Result of Campbell diagram of Frequency and rotational velocity Distributions along the 2˚ inclined hub angle flywheel with T300 material



Result of Campbell diagram of Frequency and rotational velocity Distributions along the 3˚ inclined hub angle flywheel with T300 material

Table 6.3 Critical speed of different angle flywheel with T300 material

Critical speed of different angle flywheel with T300 material						
Modes	4˚	5˚	1^0	2^0	3^0	0˚
1	5034.9	5152.5	17147	17029	17341	6791.1
2	5544.8	5920.5	17551	17395	18087	7212.5
3	5663.6	6064.6	18975	18893	19104	7539.3
4	8612.5	9451.3	19244	18976	20823	8574.6
5	8697.5	9509.6	20533	20043	24033	8704.2

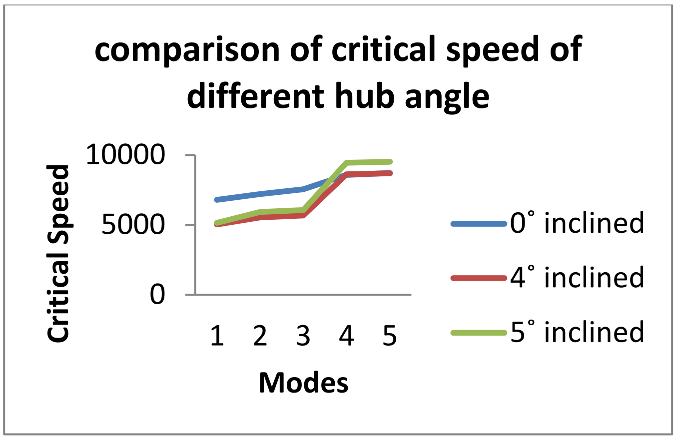


Figure: 6.6 comparison of critical speed of different hub angle

6.5 CONTOUR PLOTS OF NATURAL FREQUENCY OF 4˚INCLINED HUB ANGLE WITH T300 FLYWHEEL WITH THEIR DIFFERENT MODES

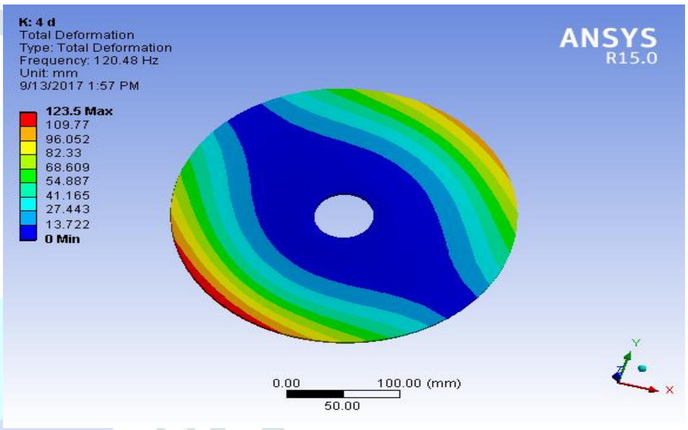


Figure:6.7 First mode frequency of T300

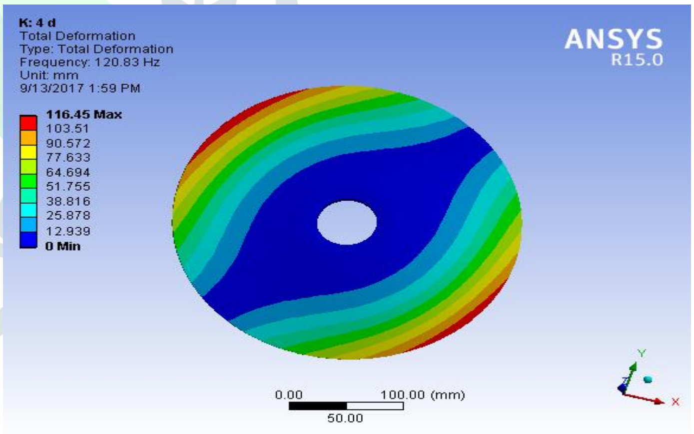


Figure: 6.8 Second mode frequency of T300 flywheel

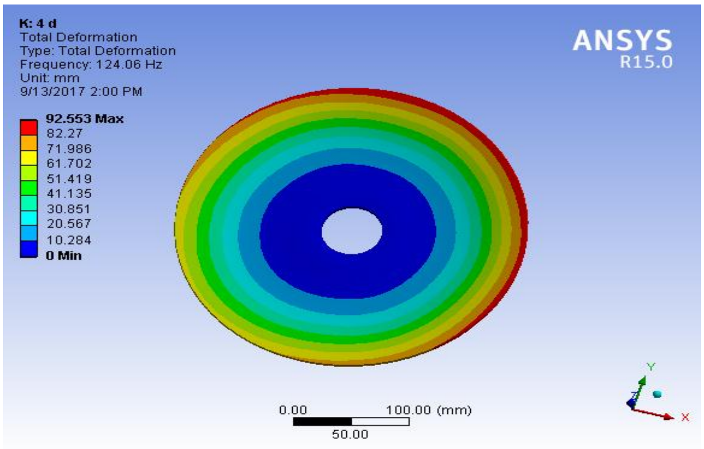


Figure: 6.9 Third mode frequency of T300

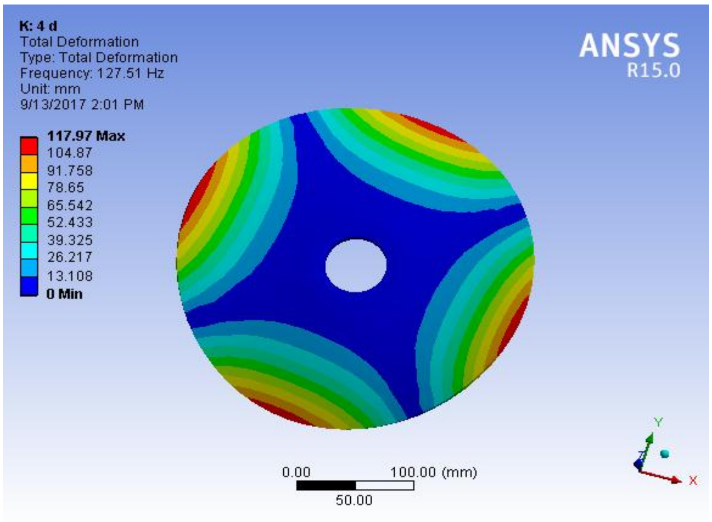


Figure: 6.10 Forth mode frequency of T300 non- layer flywheel

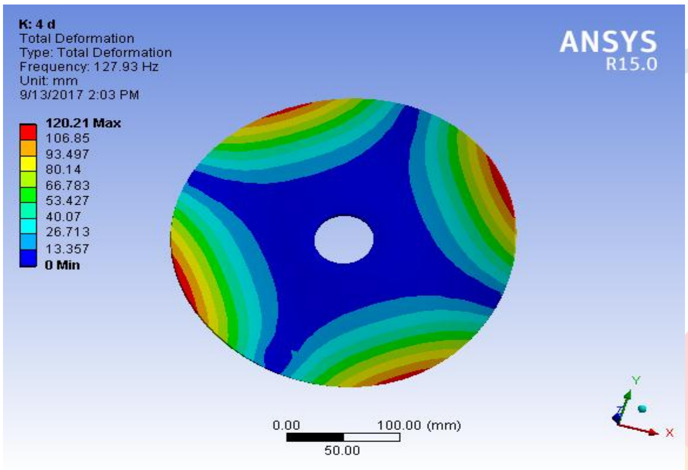


Figure: 6.11 Fifth mode frequency of T300

6.6 Comparison of Natural Frequency of flywheel with different material

Table: 6.4 Natural Frequency of Variable Materials with their different modes

Comparison of Natural Frequency of T300 Material			
Modes	**0˚**	**4˚**	**5˚**
1	119.8	120.48	120.12
2	119.86	120.83	120.18
3	121.87	124.06	123.19
4	125.06	127.51	127.19
5	125.09	127.93	127.49

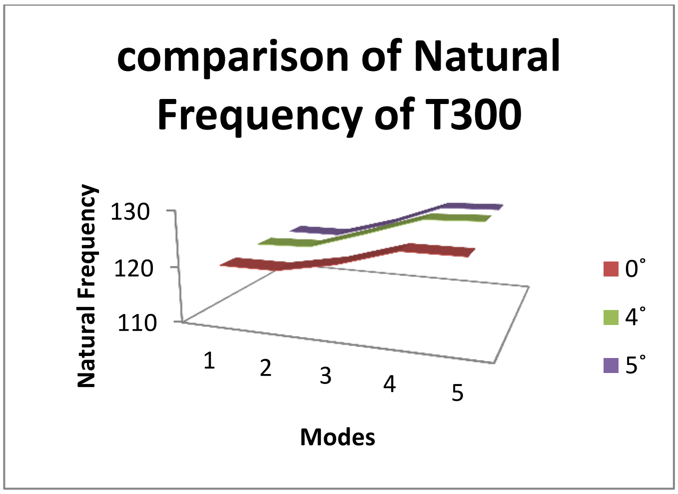


Figure: 6.12 Graph shows modes and frequency of a Flywheel with different angle.

VII CONCLUSION

The current analysis has presented a study of natural frequency characteristics of a Flywheel of different hub angles. Modal analysis was carried out on T300 system. The effect of critical speed of the Flywheel on the natural frequency and modes of different angles and critical speed effects were analyzed profile and materials the distribution along the Flywheel was studied. From the analysis of the results, following conclusions can be drawn.

7.1 Influence of different Flywheel profiles

- The natural frequency along the Flywheel profile is found to be maximum of the 4˚inclined hub angle with T300 material profile with Flywheel diameter 238 mm and varies along the circumference up to the Flywheel profile. The critical speed distribution along the Flywheel is maximum for 0˚ hub angle and minimum for 4˚inclined hub anglle of a Flywheel profile.
- The magnitude of frequency is minimum in the case of T300 material profile. The nature of the natural frequency is maximum near its end in2nd, 3rd and 4thmode.
- The nature of the critical speed is maximum near its masses and hub of the Flywheel where masses are high of Flywheel and changes with respect to Flywheel hub angle profile towards the end and between masses of the Flywheel for the same RPM and different modes of natural frequency.

7.2 Future Scope

- Solid Flywheel and thicker Flywheel could be used to analyze critical speed for different dimensions.
- Different materials can be used for analyzing frequency and critical speed for different types of Flywheel.
- Different masses could be also analyzed for different RPM to predict critical speed for Flywheel for save design.
- Stiffness of bearing should be changed and also with damping coefficient for study of Flywheel system on Campbell diagram..

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