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DYNAMIC ANALYSIS OF FLYWHEEL IN ANSYS

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Abstract:

Abstract – Flywheels serve as kinetic energy storehouse and reclamation bias with the capability to deliver high affair power at high rotational pets as being one of the arising energy storehouse technologies available moment in colorful stages of development, especially in advanced technological areas, i.e., space- crafts. Substantially, the performance of a flywheel can be attributed to three factors, i.e., material strength, figure (sampling) and rotational speed. While material strength directly determines kinetic energy position that could be produced safely combined (coupled) with rotor speed, this study focuses on exploring the effects of flywheel material on its energy storehouse/ deliver capability per unit mass, further defined as Specific Energy. Proposed Computer backed analysis and optimization procedure results show that smart selection of flywheel material could both have a significant effect on the Specific Energy performance and reduce the functional loads wielded on the shaft/ comportments due to reduced mass at high rotational parts..

Keywords –Flywheel , CFD Simulations.

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I. INTRODUCTION

A flywheel used in machines serves as a force, which stores energy during the period when the force of energy is further than the demand, and releases it during the period when the demand of energy is further than the force.

In case of brume machines, internal combustion machines, repaying compressors and pumps, the energy is developed during one stroke and the machine is to run for the whole cycle on the energy produced during this one stroke. For illustration, in internal combustion machines, the energy is developed only during expansion or power stroke which is much further than the machine cargo and no energy is being developed during suction, contraction and exhaust strokes in case of four stroke machines and during contraction in case of two stroke machines. The redundant energy developed during power stroke is absorbed by the flywheel and releases it to the crankshaft during other strokes in which no energy is developed, therefore rotating the crankshaft at a invariant speed. A little consideration will show that when the flywheel absorbs energy, its speed increases and when it releases energy, the speed decreases. Hence a flywheel doesn't maintain a constant speed, it simply reduces the change of speed. In other words, a flywheel controls the speed variations caused by the change of the engineturning moment during each cycle of operation. In machines where the operation is intermittent like punching machines, shearing machines, engaging machines, clinchersetc., the flywheel stores energy from the power source during the lesser portion of the operating cycle and gives it up during a small period of the cycle. Therefore, the energy from the power source to the machines is supplied virtually at a constant rate throughout the operation. The function of a governor in an machine is entirely different from that of a flywheel. It regulates the mean speed of an machine when there are variations in the machine increases, it becomes necessary to increase the force of working fluid. On the other hand, when the cargo decreases, less working fluid is needed. The governor automatically controls the force of working fluid to the machine with the varying cargo condition and keeps the mean speed of the machine within certain limits. Therefore, the flywheel doesn't maintain a constant speed, it simply reduces the change of speed.

II. LITERATURE REVIEW:

According to **V. Suresh Babu (2009)**[1]It's generally necessary to draw the teeth on a brace of entrapping gears, to understand the problems involved in the meshing of the lovemaking teeth. Further, the delineations aren't used for producing the teeth in the shop. Hence, approximate constructions may be followed to draw the tooth biographies. These approximate construction styles are described latterly. These styles form the base for construction in CATIA.

Still accurate modeling styles can help to achieve accurate results and therefore ameliorate the graveness of study. The parametric modeling system serves thispurpose., parametric system provides accurate involute wind creation using formulas and exact geometric equations. It's amulti-platform CAD/ CAM/ CAE marketable software suite developed by the French company Dassault Systems. Written in the C programming language, CATIA is the foundation of the Dassault Systems generally appertained to as 3D Product Lifecycle Operation software suite, CATIA supports multiple stages of product development from conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE). CATIA facilitates cooperative engineering across disciplines, including surfacing & shape design, mechanical engineering, outfit and systems engineering.

According to **Bozidar Rosic(2004)**[2], there is vast possibility of3D modeling of flywheel using CATIA. The problem of making flywheel with desired dimensions is resolved.CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. According to a report by **David Roylance (2001)**[3], Finite element analysis (FEA) has become commonplace in recent years, and is now the basis of a multibillion dollar projects of an industry. Numerical solutions to even very complicated stress problems can now be obtained routinely using FEA. The most important function of theoretical modeling is that of sharpening the designer's intuition. Literature review is an assignment of previous task done by some authors and collection of information or data from research papers published in journals to progress our task. It is a way through which we can find new ideas, concept. There are lots of literatures published before on the same task; some papers are taken into consideration from which idea of the project is taken.

Francis Inegbedion(2019)[4]hadproposed, a computer-aided-designs of software for flywheels using object-oriented programming approach of Visual Basic. The various configurations of flywheels (rimmed or solid) formed the basis for the development of the software. The software's graphical features were used to give a visual interpretation of the solutions. The software's effectiveness was tested on a number of numerical examples, some of which are outlined in this work**.**

Sushama G Bawane(2012)[5]had proposed flywheel design, and analysis the material selection process. The FEA model is described to achieve a better understanding of the mesh type, mesh size and boundary conditions applied to complete an effective FEA model.

Shengxiang Deng [6] had conducted a similar study on identifying the influence of fins over the performance of the latent heat thermal energy storage system. The authors had undertaken a 2-dimensional CFD simulations with Lauric acid as phase change material in this research. The angle between the twin fins in their study was varied by 30°, 60°, 90°, 120°, 150° and 180° to compare the results against base model configuration. They had also extended the study by varying the fin length as well. From their results, they had observed an increase melting time of 66.7% for the optimum fin angle of 30°.

A finite-volume method based, fully implicit, numerical model for the melting process inside the enclosure of Octadecane, a phase change material, was developed by **NourouddinSharifi**[7] for non-uniform grids. The enclosure consisted of cavity for the PCM and horizontally oriented fins for the heat transfer enhancement. The authors had investigated the impact of fins such as number of fins, fin thickness and the fin length over the PCM melting mechanisms. For these transient process, they had concluded that the time-step of 0.01 seconds to be sufficient for the simulations.

Multiple shell-and-tube heat exchanger configurations for the Latent Heat Thermal Energy Storage (LHTES) system was studied using *ANSYS FLUENT* by **SoheilaRiahi**[8]. The configurations in their study were Fin Plate Vertical (FPV), Parallel Flow Horizontal (PFH), Counter Flow Horizontal (CFH), Parallel Flow

Vertical (PFV) and Parallel Flow Horizontal (PFH). The phase change material (PCM) in their study was Sodium Nitrate while air was circulated as heat transfer fluid (HTF). In their simulations, air-flow was modelled as laminar conditions while the density variations on both fluid and solids due to the heat transfer were considered to be negligible. Also, symmetry model approach was applied by the authors to model the LHTES system.

Zakir Khan[9] had investigated experimentally the latent heat storage system in a longitudinal finned shell and tube heat exchanger model with paraffin as the phase change material. The authors had focussed on the LHTES system's transient thermal performance and the effective heat transfer mode under these devices. They had identified the conduction mode of heat transfer as dominant among other modes in LHTESS. Also, low heat transfer at the bottom part of the LHTESS was observed as compared to the central and the top portion.

The influence of HTF inlet temperature and the flow rate over the melting process of a finned-LHTESS was experimentally studied by **Moe Kabbara**[10]. In their study, the authors had chosen Dodecanoic Acid as the phase change material due to its melting temperature (43 ± 0.5°C) and has low hysteresis along with lower cost. Based on their research work, the authors had observed that HTF inlet temperature to have significant impact on the PCM melting time as compared to the HTF flow rate. When the HTF inlet temperature was increased from 60°C to 70°C, the PCM melting time reduced by 3.5 hours. However, for an HTF flow rate increase of 0.7 liters/min to 1.5 liters/min, the authors hadn't observed any noticeable improvement in thermal performance of LHTESS although they were able to reduce the melting time by 1 hour by increasing the HTF flow rate from 1.5 litres/min to 2.5 litres/min.

Francis Agyenim[11]have studied the sub-cooling process in the PCM melting on a Tube-In-Tube LHTESS. In their study, Erythritol with a melting temperature of 117.7 °C was chosen as PCM while air at 140 °C was chosen as HTF. The authors had studied three geometrical configurations – Control PCM system (no fins), Circular Finned PCM system and Longitudinal Finned PCM system. Based on the Cycle Time vs. PCM Temperature curve from their experimental studies, it was observed that the longitudinal finned LHTESS had high temperature gradient during the charging process followed by the Control system and then Circular finned system. At the Cycle Time of 100 minutes, the temperature on the longitudinal finned system was nearly 105°C while the circular finned system was at 78°C. This indicates the low thermal performance during sensible heat addition on the charging cycle of the LHTESS with circular fins.

A numerical simulation based investigation on thermal performance improvement on a triplex tube heat exchanger with PCM charging cycle was studied by **Abduljalil A Al-Abidi**[12]. The authors had studied two fin geometrical assembly – internal and external – along with fin parameters such as number of fins, fin thickness and fin length. The primary mechanism of heat conduction, melting and the natural convection in the PCM was modelled in *ANSYS FLUENT* with Boussinesq approximation. The PCM melting was found to be reduced with the increase in fin length however, for the increase in fin thickness resulted in negligible reduction in the melting time.

Conventional LHTESS are oriented either in vertical or in horizontal direction. **N Kousha**[13] had studied the impact of LHTESS unit' inclination angle over the PCM melting on a Tube-In-Tube heat exchanger LHTESS. The authors had studied four angle of inclinations - 0° [horizontal orientation], 30°, 60° and 90° [vertical orientation]. The authors had observed an initial high heat transfer on the horizontal orientation as compared to the vertical orientation. This was attributed the gravitational effects of natural convection of melting. However, after this initial stage, melting rate on the vertical orientation had increased relatively. They had concluded that inclination angle had a significant impact on the solidification process rather than on the melting process.

Thermal storage capacity of the LHTESS suffers due to the low thermal conductivity of the phase change materials (PCMs) such as Paraffin. Hence, various researchers had focussed on enhancing the heat transfer characteristics of the LHTESS. The most common approach has been the inclusion of fins on the HTF pipe. **Manish Rathod**[13] had investigated the influence of longitudinal fins on the thermal performance – in terms of PCM's solidification time – with the help of experiment studies. In their test model, three longitudinal fins that were made of brass were attached at an angle of 120°. The overall solidification time were reduced by 43.6% with the addition of these fins.

Conventional design of LHTESS are of cylindrical in shape. **SaeidSeddegh**[14] had compared the thermal performance of conical and cylindrical shaped LHTESS with the help of experimental studies. The advantage of conical shape – with the larger radius at the bottom – ensured the improvement in the natural convection mechanism during the charging process of LHTESS. However, the authors had observed minimal influence on the discharging process in their study on conical shaped LHTESS.

Most research on LHTESS are focussed on the thermal performance such as melting/solidification time. The cost associated in building a LHTESS often overlooked. **Ralf Raud**[15] had developed mathematical optimization method for the LHTESS to estimate the thermo-economic cost. In their optimization study, the authors had investigated the connection between LHTESS geometry that includes fins and their thermo-physical properties and cost for two different PCMs with the melting time as the constraint. Based on their research work, the authors had identified that the selection of fins with high thermal conductivity leads to significant reduction of LHTESS cost.

Saied Seddegh[16] had conducted experiments on shell and tube latent heat storage systems in which the PCM was stored on the shell-side. The authors had investigated the performance of this shell-and-tube-latent-heat-storage system for four cylinder diameter based on the shell-to-tube radius ratio and four operating conditions based on the heat transfer fluid inlet temperature. Based on the results obtained from this experimental study, they had concluded that the HTF inlet temperature had stronger influence on the LHTESS performance while the HTF flow rate had insignificant impact on the performance. Also, they had observed a reduction in charging time nearly 38% when the shell-to-tube-radius ratio was reduced from 8.1 to 2.7.

M. J. Hosseini[17] had conducted a study the thermal performance of double pipe, longitudinal orientation, heat exchanger for various fin heights as well as Stephan Number for the charging process. RT50 was chosen by the authors as the PCM in their study due to its melting temperature (45 - 51°C) was found to be suitable for solar energy storage systems. In this study, both experimental and numerical (CFD) approach had been applied. For the numerical simulation, the enthalpy-porosity method that are available in common CFD softwares such as *ANSYS FLUENT* had been utilized for modelling the PCM melting. Based on their study, the authors had concluded that the increase in fin height resulted better thermal penetration in the PCM, leading to reduced melting time.

The concept of LHTESS was applied for improving the cooling coefficient of performance (COP) of the air-conditioner system by **Dongliang Zhao** [18] with numerical simulations. In their LHTES system, water (for charging process) and air (for discharging process) were used as heat transfer fluid. The authors had defined PCM heat storage system effectiveness as a ratio of actual-to-theoretical heat transfer in the system and is generally higher than 0.5. As the fin height was known to have significant impact on the thermal performance of LHTESS, the authors had recommended the numerical (CFD) approach to identify the optimal fin height.

With the help of 3-dimensional CFD simulations, **Mushtaq I Hasan** [19] had applied LHTESS for improving the heat transfer characteristics of micro-channels. In this study, air was flowing over the micro-channels while the PCMs were placed at the base of the micro-channel heat sink. The authors had compared four different PCMs (Paraffin wax, RT41, n-eicosane, P116) in this study. The application of PCM for the micro-channel heat sink enabled to maintain overall reduced surface temperature.

Sohif Mat [20] had conducted numerical and experimental studies for a triplex-tube LHTESS with a various fin configurations. Their 2-dimensional numerical simulations (CFD) were performed in *ANSYS FLUENT* with enthalpy-porosity approach with transient solver. The authors had applied 0.5 seconds as time step for their simulations. For these CFD solver settings, the PCM average temperature predicted from the simulations were in good agreement with the experimental approach. The authors had investigated the thermal performance of the LHTESS under three heat load conditions – heating from inside the tube, heating from outside the tube and heating from both sides. Of these there heating method, the authors had predicted that the internal heating resulted in maximum melting time while both-side heating method resulted in minimal melting time.

The PCM solidification inside the co-axial cylinder was studied by **ImenJmal**[21] using numerical simulations (CFD). In this study, Paraffin wax was chosen as the PCM while air was supplied as heat transfer fluid in two-passages. The authors had compared the solidification process with and without the natural convection on the PCM. Based on their results, they had concluded that the contribution from the natural convection was significant and must be included in numerical simulations.

A transient, laminar, 3-dimensional numerical simulation based approach was conducted by **M. Esapour**[22] to investigate the LHTESS geometrical parameters as well as operational conditions – HTF inlet temperature and flow rate - over the PCM melting time.

For the geometrical parameters, the authors had varied the number of HTF tubes as well as the positioning of the HTF tubes, resulting in 12 geometrical configurations. With the increased number of HTF tubes, the overall heat transfer surface area also increases. This resulted in faster melting time (10%) in their study. The HTF inlet

III. OBSERVATIONS:

The major observations from this literature review has been listed below.

- To reduce weight of automobile flywheel by using composite material.
- We take automobile flywheel and analyze it using ANSYS (finite element modeling and analysis software) to optimize weight and find out the resulting stresses.
- Manually calculate stress using design parameters for all three steel, carbon fiber and composite flywheel.

IV. CONCLUSION

- Steel flywheel design is safe as (17.826 < 178.17MPa) and the it's mass is 6.08 Kg
- Carbon Fiber flywheel is very light at 1.63 Kg but it fails as(47.916 > 46.19 MPa).
- Composite flywheel (Steel rim + carbon fiber body) is safe as
- (63.482 > 82.84 Mpa) and is lighter than flywheel at 2.8 Kg
- By using composite flywheel we found out through analysis and manual calculations that it is safe and at the same time it's lighter as compared to steel flywheel
- It is clear that, steel flywheels are highly safe and heavier. But composite material (Steel rim + carbon fiber body) can be used in flywheels to store energy with less mass. It can be also used in high speed applications

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