Design and Validation of Efficient Flywheel Cup of Magneto to Improve the Thermal Behaviour

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Abstract – *A flywheel magneto is an electromechanical device for generating AC electric power which is used to drive electrical loads in vehicles. The flywheel magneto is also responsible for generating signals for the ignition system of the vehicle. Flywheel magneto produces heat which makes thermal behaviour management complicated and very difficult. All losses from the flywheel magneto are converted into heat. The most of heat generated in magneto assembly due to winding copper losses & these losses increase the winding temperature.*

This paper demonstrates the design and validation of efficient flywheel cup of magneto to improve thermal behavior. The cup is designed with cooling holes in such a manner that those holes assist the cooling of the winding. To study the thermal performance (heat loss dissipation) due to peripheral holes, the thermal analysis is performed using Ansys software. The CFD analysis is performed for different scenarios, no flow (no holes on cup), maximum flow through axial holes and maximum flow through lateral holes aiming on the winding. CFD results are compared with physical testing results. The maximum air flow rate with lateral cooling holes condition indicates lower temperature generation compared to no flow with no cooling holes and maximum flow with axial holes of flywheel cup. The lower temperature achieved in copper winding ensures the winding insulation is not affected due to excess heat.

Key Words: *flywheel magneto, electromechanical, thermal behaviour, flywheel cup, copper losses, efficiency, Ansys software, etc.*

1. INTRODUCTION

A magneto is an AC power generator used for generating AC electrical power in automobiles (two, three wheelers). Magneto is working as per faraday's law of electromagnetic induction, which states that when a conductor is placed in a rotating (changing) magnetic field, e.m.f. is induced in it. Magneto is used in vehicles for electrical power generation to drive electrical loads such as: lighting loads, horn & electrical circuits (Ignition Circuit, Speedometer Circuits etc.) Apart from electrical power generation, magneto also generates signals which are used by the ignition circuit for the spark timing, duration etc. The signals are also used by the speedometer for engine RPM display. The magneto is the source of energy generation in the magneto ignition system. Magneto generates AC electrical power which will be used to drive electrical loads in vehicles. The AC power from magneto will be going to the signal conditioning part which is more popularly known as regulator. Based on the loads the power is getting processed in this signal conditioning & power is converted into Regulated DC, Regulated AC etc. The magneto is also responsible for generating signals for the ignition circuit. Magneto has a pulser coil which acts as a magnetic sensor & senses the position of the rotor with the help of pulser pip present on the rotor. As this function of the magneto of signal generation is directly related to the ignition of the vehicle, the same is very important. The components of magneto causing the signal generation are to be treated very much carefully as any defect in these components will make the engine to stop & the vehicle will not start at all. A magneto consists of a rotor assembly & a stator assembly as shown in fig. 1.1. A rotor assy. is a part which will be rotating with magnets fixed on it which will produce rotating magnetic field. Stator assy. will be a stationary part with conductor coils fixed on it. Because of rotating (changing) magnetic field, e.m.f. is induced in the conductor placed on the stator.

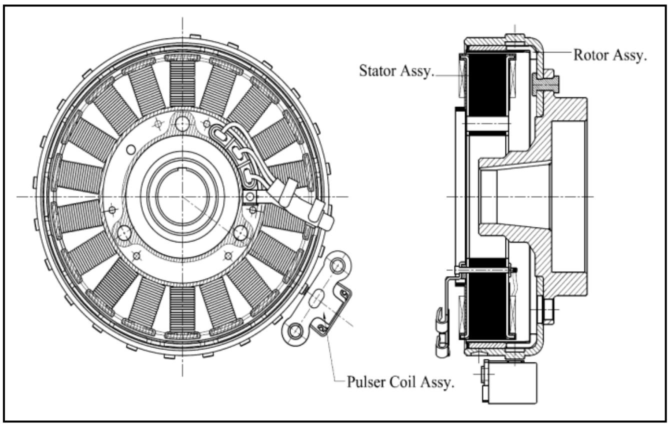


Fig -1: Flywheel magneto assembly

1.1 Flywheel Cup

The flywheel cup is a primary component of rotor assy. which will be used to cover the stator assembly with magnets as it will be responsible for holding the magnets. The overall construction can be understood from the figure shown aside. Along with holding the magnets it also has pulser pip projected on it which will be responsible for the signal generation from magneto.

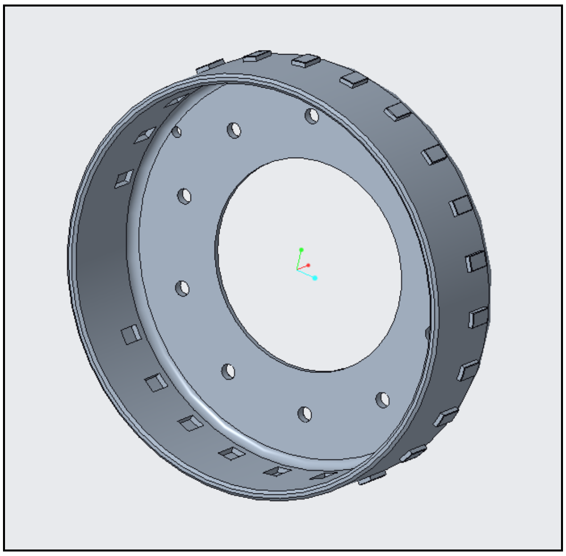


Fig -1.1: Flywheel cup

The cup is going to be application dependent and can have a different construction; normally the pulser pip can have a different construction. Even in some cases the pulser pip is not available on flywheel cup, in such application the same is present on any other component of the rotor depending upon the design of the Magneto.

2. PROBLEM DEFINITION

A magneto is an electrical generator that uses permanent magnets to produce alternating current. Magnetos that are adapted to produce pulses of high voltage electricity are used in the ignition systems of some gasoline-powered internal combustion engines to provide energy to the spark plugs. However existing flywheel magneto produces substantial heat especially at high operating speeds and makes the thermal behaviour management of these machines difficult and complicated. The temperature rise in the flywheel magneto leads to damaged insulation, demagnetization and reduced power output and efficiency. Power losses could cause an increase in the temperature of the windings and permanent magnets which reduces the efficiency of the flywheel magneto. To improve the thermal behaviour of magneto planned to design new cooling path of flywheel cup.

2.1 Objectives of the Project

The current project work aims to achieve the following objectives:

- Design and optimization of new cooling path.
- To Analyse the thermal behaviour of existing and proposed design in CFD
- To analyse the temperature difference of existing and proposed design with experimental
- To compare CFD result with experimental result.

3. DESIGN CALCULATIONS

In flywheel cup design following material selection and mechanical parameters are considered.

3.1 Material Selection:

Steel sheet/strip hot rolled; pickled & skin passed. Grade. EDD as per IS: 1079-1994.

3.2 Mechanical Parameters

- Selection of material sheet thickness is 3.2 mm.
- Electrically minimum thickness is = or >3.2 mm. It is minimum thickness for flux of flow. (Considering magnetic flux, material chemical composition-low carbon percentage, eddy current losses.) Thickness does not show change in outer diameter (Ø139.4) under rotation movement at high speed.
- Flywheel cup OD related dimensions not crossing the limits set by the customer based on the fit & function of magneto i.e. (Ø70 & 37.5). While selecting Ø70, bush mating diameter to be considered.
- Cooling Holes PCD as per customer requirement.
- The direction of piercing always from surface mating with boss to inner surface of cup.
- Pip position by punching method, projection is not more than 1/3 of the sheet thickness used for flywheel cup.
- Pip radius as per customer requirement.
- Selection of size of rivet, rivet PCD & no. of rivets depends on customer requirement of shear strength.
- Position of rivet always equal spaced.
- The minimum gap between two holes is 1.5 times sheet thickness or min sheet thickness.

- Position of magnet and location of spacer ring as per layout of rotor pole & stator pole alignment at T.D.C condition.

3.3 Velocity Calculations

Speed – 3000 rpm

Radius of Cup = 0.0697 m

Angular Velocity (ω) = 2 X 3.14 X 3000/60

$\omega = 314.159\ rad/s^2$

Coolant Velocity (Vc) = ω X Outer radius of cup (r)

Vc = 21.896 m/s

3.4 Proposed Flywheel Cup Design

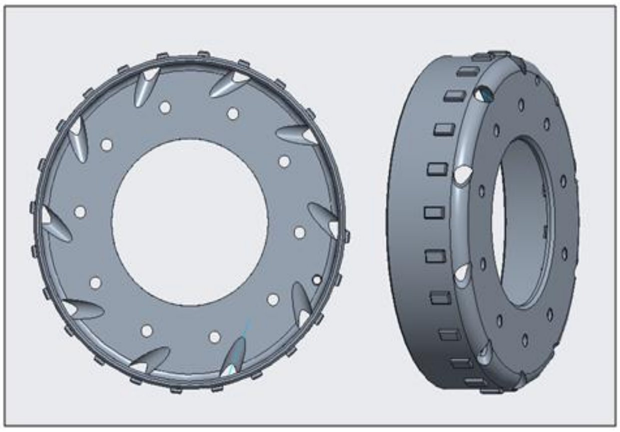


Fig –3.4: Proposed flywheel cup design

In proposed design lateral cooling holes provided with combining two different angles as shown in figure 3.4. These holes provided on peripheral side of flywheel cup. Pattern of holes direction shown in anticlockwise from front view of cup.

4. FINITE ELEMENT ANALYSIS

In automobile applications on various areas of interest commonly encountered in engineering include structural analysis, optical analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. Addressed the problems typically involves solving the geometry boundary value problems are associated with the partial differential equations. By formulating the problems by using the finite element method, a system of sum algebraic equations is obtained as the solution.

4.1 FEA Results

4.1.1 Boundary Conditions

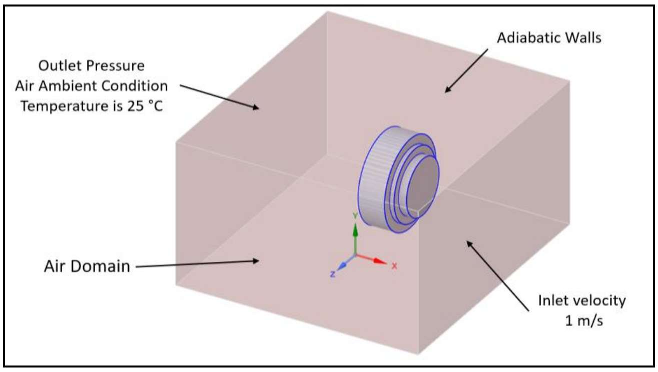


Fig -4.1.1 Boundary Conditions.

4.1.2 Baseline Design

In baseline design no cooling holes provided on flywheel cup bottom face.

4.1.2.1 Baseline flywheel magneto assy. with no holes

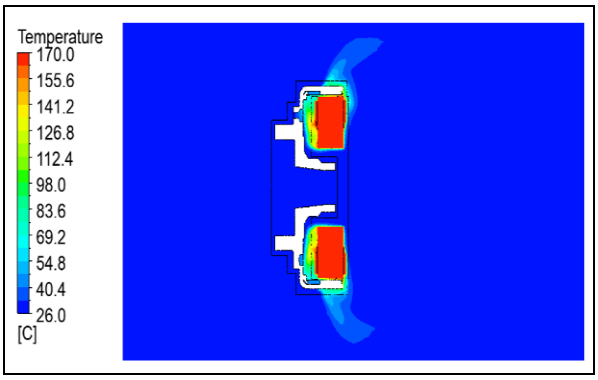


Fig -4.1.2.1: Thermal behavior of the baseline flywheel magneto assy. (No Holes) at 3000 RPM, at No flow

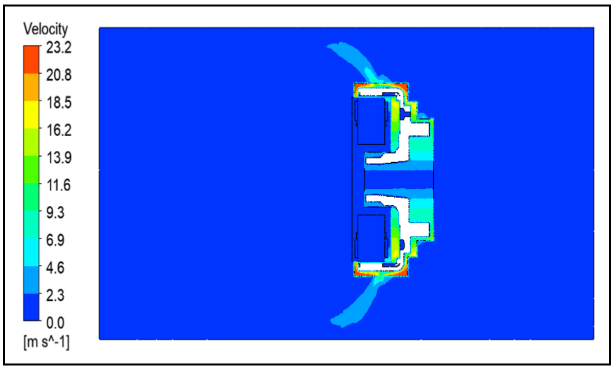


Fig - 4.1.2.2: Velocity distribution in baseline magneto assy. with No cooling holes, at 3000 RPM

The thermal behavior and velocity distribution in baseline flywheel magneto assy. (No Holes) at 3000 RPM shown in figure 4.1.2.1 and 4.1.2.2 In this case maximum temperature found 170°C & maximum velocity 23.2 m/s observed in rotation movement because no cooling path provided on flywheel cup.

4.1.3 Flywheel magneto assy. with Ø12 mm axial cooling holes

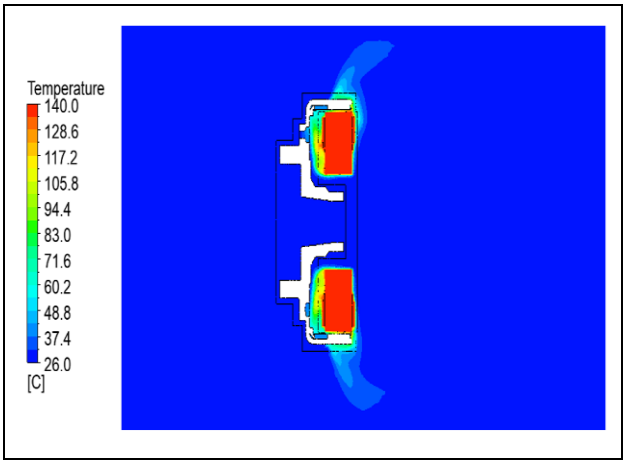


Fig -4.13.1: Thermal behavior of the flywheel magneto assy. with Ø12 mm cooling holes at 3000 RPM

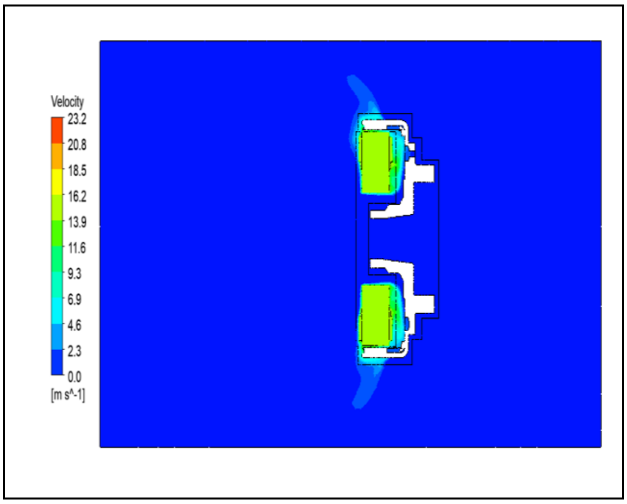


Fig -4.1.3.2: Velocity distribution in flywheel magneto assy. with Ø12 mm cooling holes at 3000 RPM

In this case axial holes are provided on bottom face of flywheel cup. The thermal behavior and velocity distribution in flywheel magneto assy. with Ø12 mm cooling holes at 3000 RPM shown in figure 4.1.3.1 and 4.1.3.2 In this case maximum temperature found 140°C and maximum velocity 23.2 m/s observed because rotating speed is constant & amount of flow increased as compared to baseline flywheel magneto assembly without holes.

4.1.4 Proposed Design

In this proposal lateral holes provided on peripheral sides of flywheel cup.

4.1.4.1 Flywheel magneto assy. with Ø8 mm lateral cooling holes

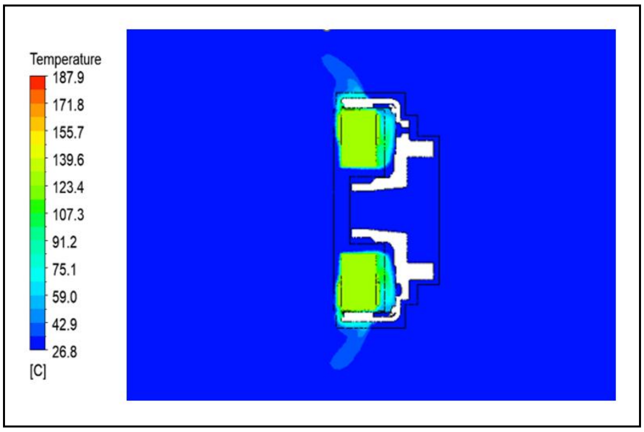


Fig -4.1.4.1: Thermal behavior of the flywheel magneto assy. with Ø8 mm lateral cooling holes at 3000 RPM

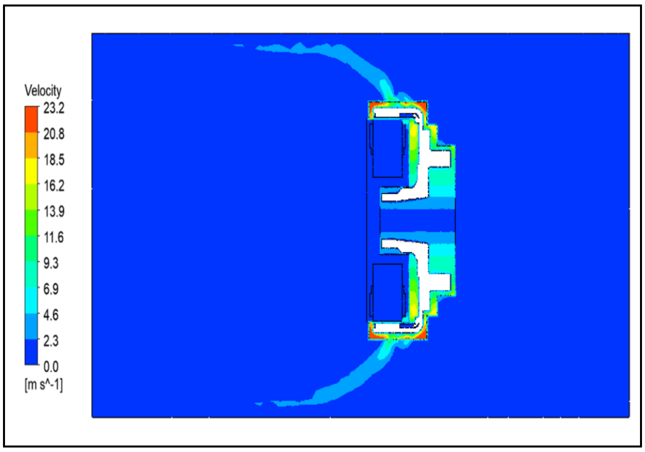


Fig 4.1.4.2: Velocity distribution in flywheel magneto assy. with Ø8 mm lateral cooling holes at 3000 RPM

The minimum temperature observed in the proposed design is 131.68 °C and coolant velocity observed constant is 23.2 m/s max. The air flow circulation improved as compared to baseline design and trails Ø12 mm axial holes proposal results.

5. EXPERIMENTAL VALIDATION

For experimental validation proposed flywheel cup with Ø8 mm lateral holes proto sample is manufactured as per design dimensions and this cup assembled in rotor assembly. Stator assembly used existing for experimental testing.

5.1 Experimental Procedure for Testing

The experiments are performed using a performance testing machine mfg. By MEA, where a temperature test is conducted at 3000 RPM. The Performance testing machine provides results that are compared with the analysis results obtained from Finite Element Analysis (FEA).

Figure 5.1 displays a picture of the complete experimental setup and temperature values displayed on the digital ammeter.

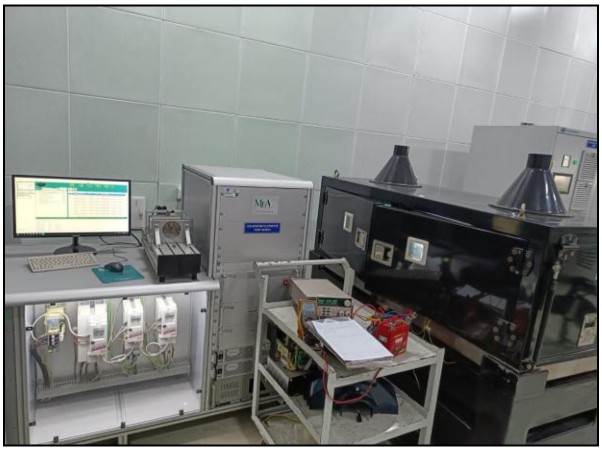


Fig -5.1 Experimental set-up

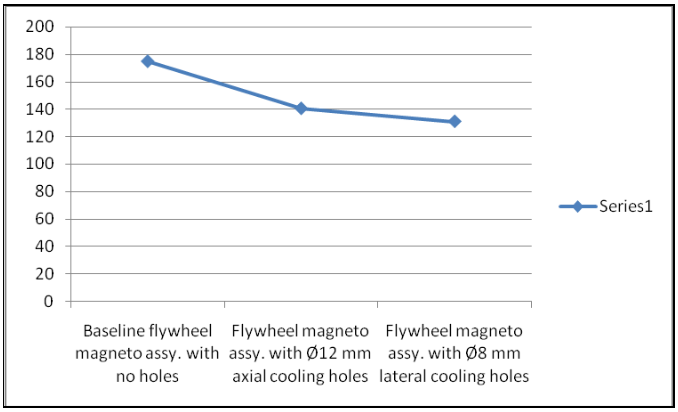
5.2 Experimental Result Summery

Table 5.2 Experimental result summery

Experimental Sample Description	Maximum Temperature at Winding °C
Baseline flywheel magneto assy. with no holes	175
Flywheel magneto assy. with Ø12 mm axial cooling holes	140.5
Flywheel magneto assy. with Ø8 mm lateral cooling holes	131

Experimental test result shown in table 5.2, in this table clearly mentioned the maximum temperature shown at winding.

5.3 Graph of Temperature Variation



5.3 Graph of temperature variation

6. RESULT AND DISCUSSION

The finite element analysis result table shown a comparison between the baseline, modified design and proposed design of flywheel magneto assy. For analysing the results, the following observations can be made:

Table 6.1 FEA And Experimental Result Summery

Description	FEA Temp. °C	Experimental Temp. °C
Baseline flywheel magneto assy. with no holes	170	175
Flywheel magneto assy. with Ø12 mm axial cooling holes	140	140.5
Flywheel magneto assy. with Ø8 mm lateral cooling holes	131.68	31

The summery table of the finite element analysis (FEA) results shows that the minimum temperature 131.68 °C observed in the proposed flywheel magneto assy. with Ø8 mm lateral cooling holes. The Experimental results also shows that the minimum temperature 131°C observed in the proposed flywheel magneto assy. with Ø8 mm lateral cooling holes.

Both result shows proposed flywheel magneto assy. with Ø8 mm lateral cooling holes are meets the results and found minimum temperature in copper winding.

7. CONCLUSION

The cup is designed with cooling holes in such a manner that those holes assist the cooling of the winding. To study the thermal performance (heat loss dissipation) due to peripheral holes, the thermal analysis is performed using Ansys software. The CFD analysis is performed for the different scenarios, no flow (no holes on cup), maximum flow through axial holes and maximum flow through lateral holes aiming on the winding. CFD results are compared with physical testing results. The maximum air flow rate with lateral cooling holes condition indicates lower temperature generation compared to no flow with no cooling holes and maximum flow with axial cooling hole of flywheel cup. The lower temperature achieved in copper winding ensures the winding insulation is not affected due to excess heat.

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