**ACADEMIC PARTNERSHIP**

Dassault Systems Foundation is dedicated to transforming the future of education and research with the learning and discovery capabilities of 3D technology and virtual universes. Dassault Systems Foundation supports projects in India to bring about transformation in Education and Research. It is working with the objective to improve engineering skills and supports Indian Academia/Research Centres to accelerate education transformation, to encourage scientific research, to encourage vocation for science and engineering among youg people and to support education programs for underprivileged & especially abled citizens. Dassault Systemes Foundation helps teachers, learners and scientist to leverage the power of 3D virtual world to stretch the limits of knowledge and to invent new ways to pass on this knowledge to current and future generations of Indian thinkers, inventors, builders and leaders. Mr Bernard Charles - Honorary Chairman, La Fondation Dassault Systemes says, "La Fondation Dassault Systemes leverages power of experience to transform the way we learn and discover, and ultimately stretch the limit of knowledge for benefits of all"

PROJECT TITLE; VR enabled content development facilitating effective study of Electrical Machines using Mixed Reality

Description : The project aims at introducing interactive and immersive learning experience in the engineering education system, using Mixed Reality. It will enable the students to have clarity on the internal structure, functional details of electrical apparatus such as, DC Machines, Induction Machines, Transformers etc. The project aims at developing innovative learning experience for 8 electrical machines. 3D models of the machines includes the assembly of the internal parts which are modelled using 3DEXPERIENCE platform, The electrical operation using Dimola and the thermal distribution and other mechanical aspects using SIMULIA and animated to give a holistic educative user interface on a mixed reality platform. This work is intended to provide an experiential learning to the students.

Funding :Dassault Systemes Foundation has provided generous funding to develop Mixed Reality Lab and developing learning experiences for engineering students.

The various parts of an Induction machine modeled by students using 3d experience platform
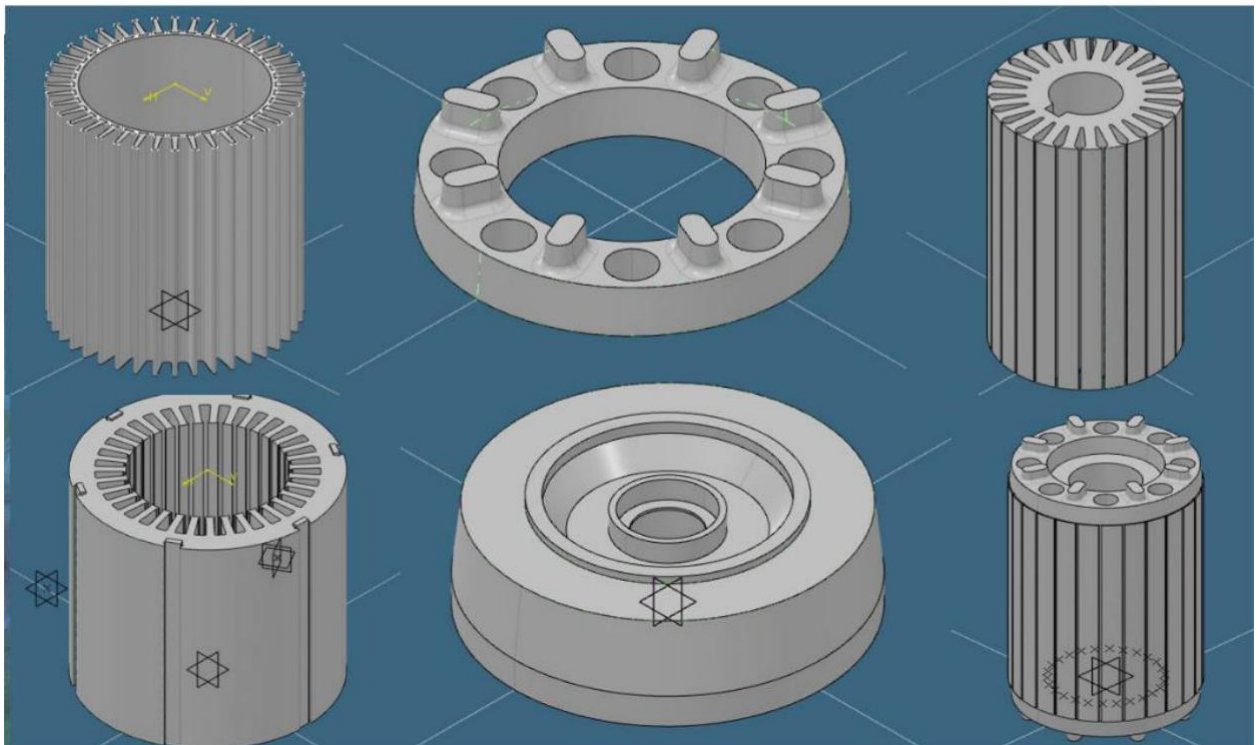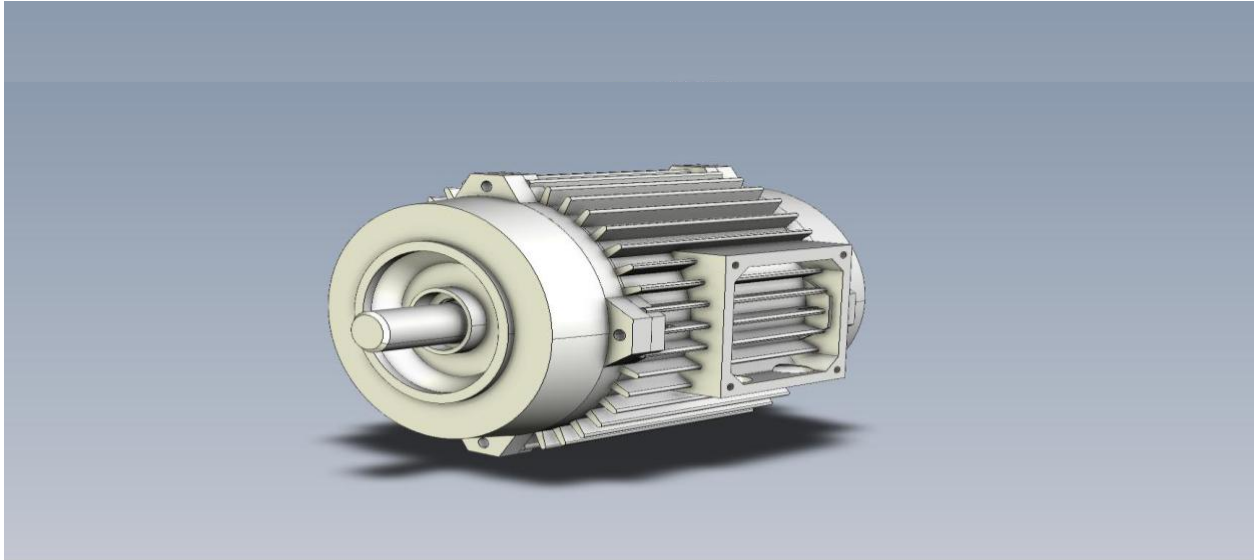
Faculty Involved: Dr.P.Meena , Prof. & HOD,EEE & Sreekanth N.V, Asst. Prof.MECH.

PHASE-I

Development of Content using 3D Experience Platform to study Mechanical and Electrical behavior of a 3 Phase Squirrel Cage Induction Motor

Team members: Kruthik H M, Guru Kiran Prabhu, Mukund Sunil.

Mentors: Dr. P Meena, Prof. Sreekanth Vasudev Nagar

Introduction:

- The application of 3D technology leverages the learning activities through the development of a virtual connection between classroom learning and practical training.

- This enables students to tinker with expensive machinery remotely without the risk of damage or injury.

- It provides the first-hand experience of complex mechanisms and mathematical concepts which thereby develops critical thinking abilities in students.

- This work involves developing content to visualize 3-Phase squirrel cage induction motor assembly, part visualization and development of learning module.

- This learning can be used in educational and vocational training institutes, providing a better learning outcome, and higher-skilled employees.

- Dassault Systemes 3DEXPERIENCE platform was chosen for the development of the project and to compare the results with a physical model.

Methodology:

The methodology involves integration of part modelling and functional behavior in electrical and mechanical domain. Applications used in 3DExperience:

1. Catia Part Design

2. Catia Assembly Design

3. Mechanical Systems Design
4. Mechanical System Experience

5. Functional and Logical Design

6. Dymola Behavior Modelling

7. Simulia Structural Scenario Creation

8. Physics Result Explorer

9. 3DExcite Creative Experience

Methodology: Block Diagram
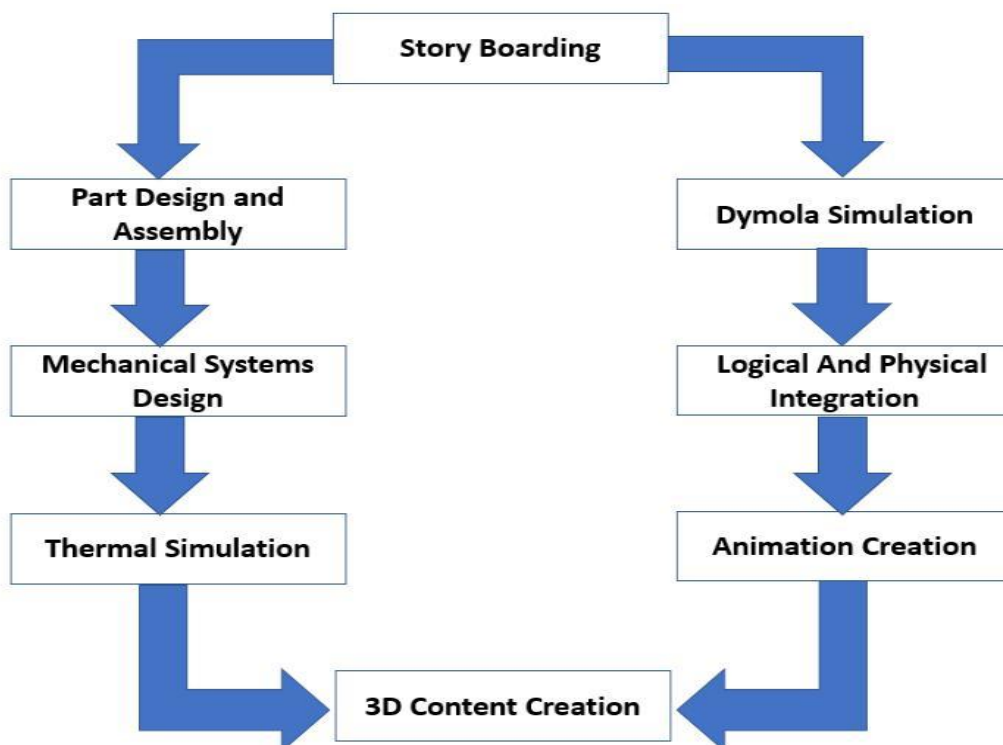
Dimensions of CAD model:

| Sl. No.	PART	DIMENSIONS	MATERIAL
1	Motor Body	OD – 146mm Length – 144mm	Cast Iron
2	Stator Lamination	OD– 138.068mm ID – 80.05mm Length – 120mm Thickness– 0.5mm Slotdepth-15.5mm	Hot Rolled Electrical Steel As per IS 648
3	Shaft	Length – 289mm	C40 Steel
4	Stator Winding	Winding factor-0.955	Copper
5	Rotor Laminations	Skew angle–1 degree Thickness – 0.5mm Length – 120mm ID – 30mm SlotDepth-15.65mm OD – 80mm	Hot Rolled Electrical Steel As per IS 648.
6	Cooling Fan	4 poles suitable	ABS
7	Bearings	ID -25mm OD -52mm	Stainless Steel
8	Rotor Bars	Length – 120mm	Copper
9	Rotor End-ring	OD -80 ID -30	Copper
10	Fan protector	According to motor Body Diameter	Mild steel
11	End Shield	According to motor Body Diameter	Cast Iron

Part Design:
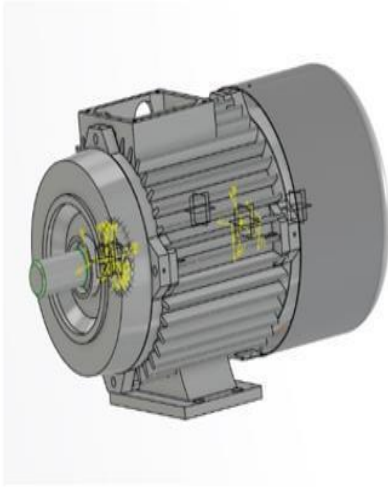
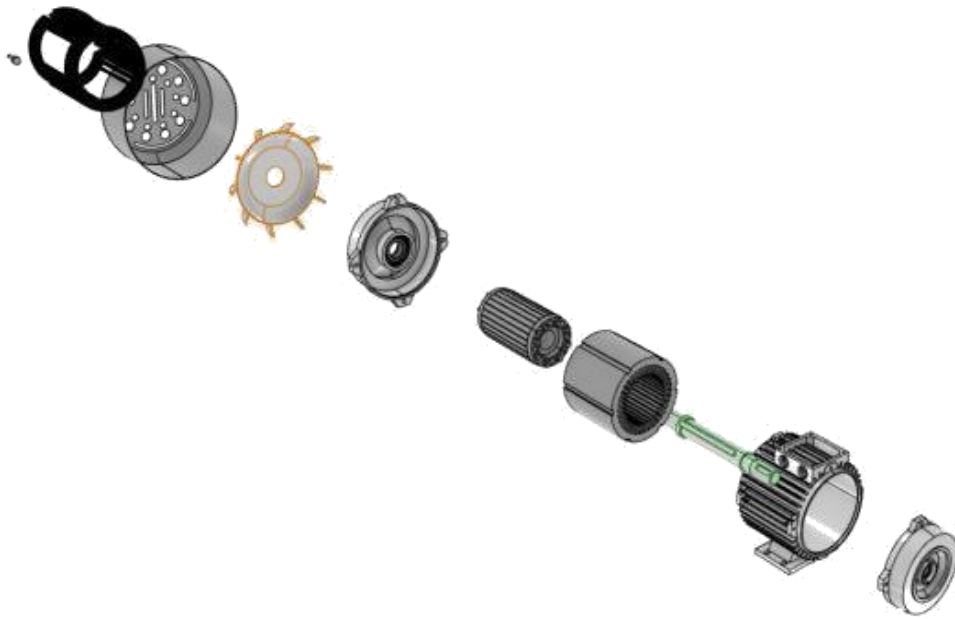Complete Assembly of 3-Phase Induction Motor.
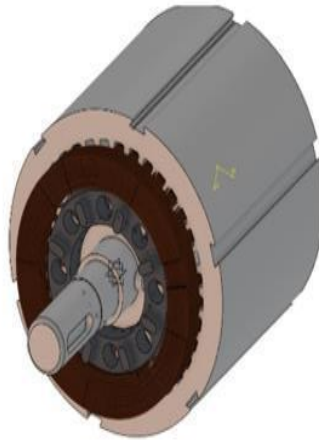
Stator and Rotor Assembly.

End shield with bearings to support shaft.
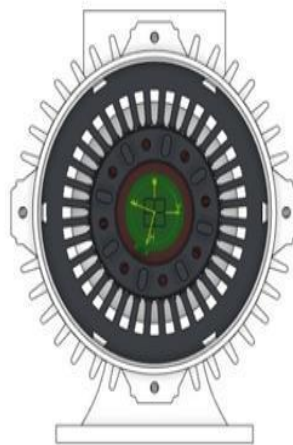
Section view of Induction Motor.

Exploded View of the Motor

Systems Engineering of 3 phase Induction Motor:

The Functional and Logical Design application consists of four nodes. They constitute RFLP. The requirements for 3 phase squirrel cage motor design. The main dimensions of the motor are obtained as follows.

Output in kilowatts, $Q = C_o D^2 L n_s$

Where D is the stator inner diameter in m,

L is the length of the stator in m,

n_s is the speed of shaft in revolution per second and

$$C_o = 11 \times K_w \times B_{av} \times AC \times 10^{-3}$$

Let, Winding factor K_w=0.955, electric loading AC=21750 AT and magnetic loading B_{av}=0.5 Wb/m.

The value of C_o is obtained as 114.3.

Solving the output for 3 HP machines, D^2L product is obtained as 0.000769 m^3.

Separation of D and L is done by using empirical relation for length to pole pitch ratio L/τ equal to 1.9. Solving this, the main dimensions are obtained as D is approximately 0.08005 m and L is 0.120 m.

If slot per pole per phase is 3,

Number of stator slots is equal to 3 x 4 x 3 giving 36 slots.

The recommended rotor slot number is 26.

Main Specifications of the Motor:

| SL. No.	PARAMETER	VALUE
1	Power	3 HP/2.2kW
2	Number of poles	4
3	Voltage	400 V
4	Synchronous speed N_s	1500 rpm
5	Rated speed	1440 rpm
6	Efficiency	0.81
7	Power Factor	0.82
8	Rated Torque	14.5 Newton meter (Nm)

Circuit Simulation was done for the two load profiles in Dymola.

The profile where Torque is proportional to speed of the machine is presented here.All the components were taken from the Modelica Standard Library in Dymola Behavior Modelling app.
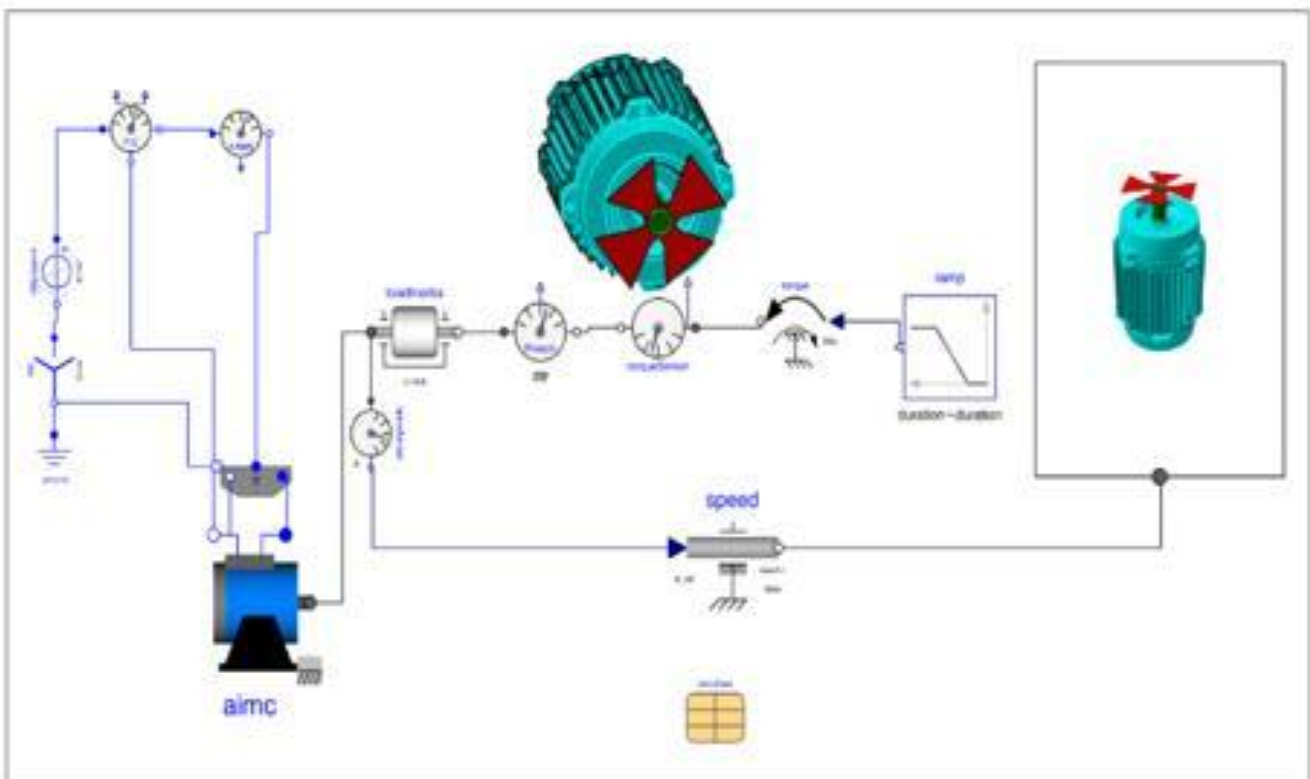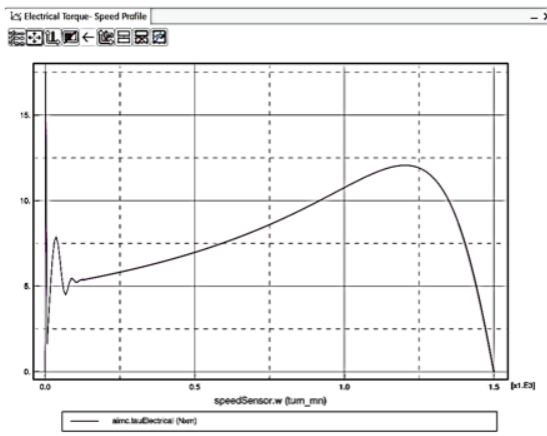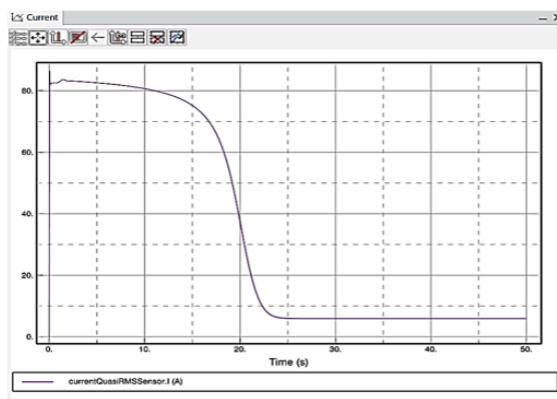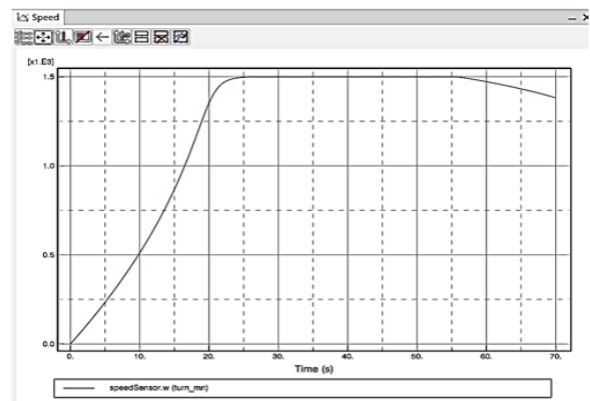
X axis : Speed (RPM)
Y axis: Electrical Torque (Nm)
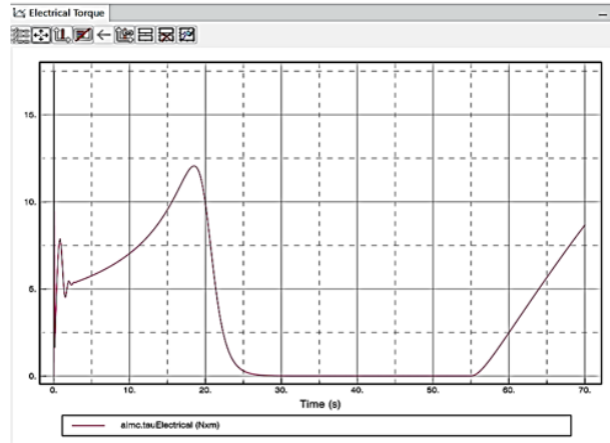
X axis: Time (s)
Y axis: Electrical Torque

X axis: Time (s)
Y axis: RMS Line Current (A)

X axis: Time (s)
Y axis: Speed (RPM)

A ramping external load torque of 10Nm is applied to study the loading effects. Various parameters can be plotted by the student as seen in the simulation results.Similarly, the simulation for the profile where Applied Torque is proportional to square of the speed is done.
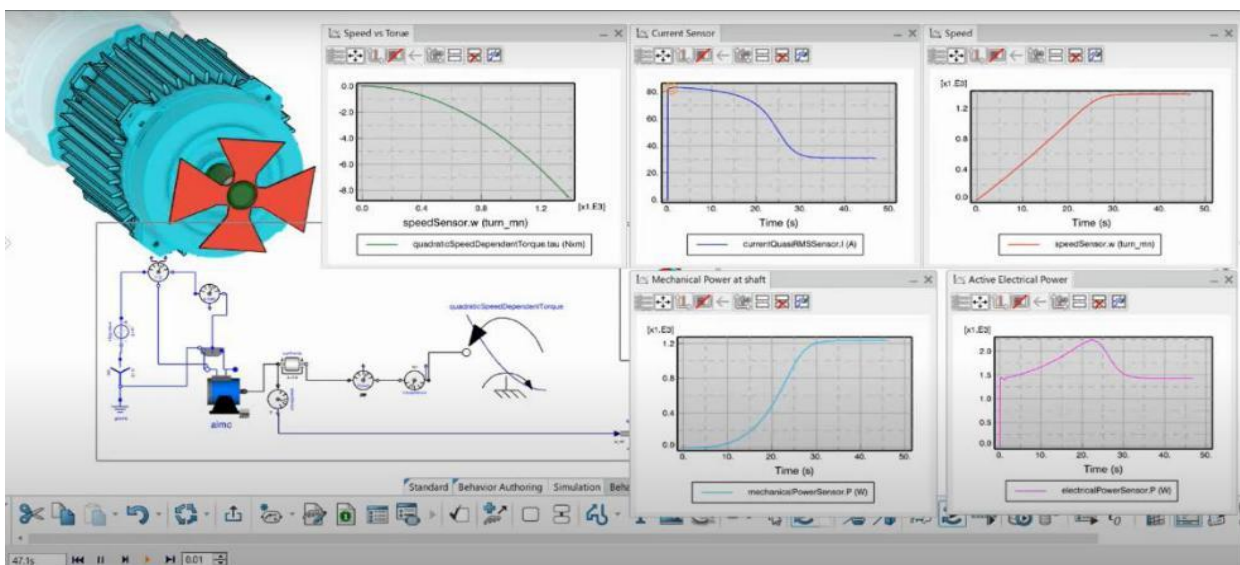
Dynamic Simulation of the motor with integrated kinematics from CAD model allows the student to understand variations in different parameters with respect to each other.

Thermal Simulation

Parts considered for thermal analysis were the rotor, stator and body frame of the motor. Suitable initial and boundary conditions were applied.

The heat is generated in the rotor core and it is propagated to the stator through conduction along the rotor body. As there is an air gap between rotor and stator, Taylor number (Ta) is used to decide whether the heat flow is through conduction or convection.

Taylor number tells us about the flow, whether laminar, vortex or turbulent in the air gap. The Taylor's number is given by the below equation,

$$Ta = Re \cdot (l_g/R_r)^{0.5}$$

Where,

l_g is the air-gap radial thickness=0.525 mm and R_r are the rotor outer radius = 39.5mm

$$Re = l_g \cdot v/\mu$$

Reynolds number, Re = 207.53
If Ta is less than 41, the flow is laminar and Nusselt number (Nu) is 2.

From calculations, Taylor number was found out to be 23.92. As Ta<41, Nusselt number is 2. Heat transfer between rotor and stator will be through conduction. From stator, heat flows to the body frame of the motor through conduction and later from the body frame to the ambient air through forced convection.

As there is forced convection taking place on the finned surface of the body frame because of a fan placed at the rear end, another empirical correlation was utilized to determine the heat transfer coefficient between the body frame and the ambient surroundings.

The convection heat transfer coefficient h is calculated as

$$h = \frac{\rho.C_p.D.v}{4L}(1 - e^{-m})$$

Where,

h - Heat Transfer Co-efficient

C_p – Specific Heat = 1005 J/kgK

m – Mass flow rate (kg/s)

$$m = 0.1448 . \frac{L^{0.946}}{D^{1.16}} . \left(\frac{k}{\rho.c_p.v}\right)^{0.214}$$
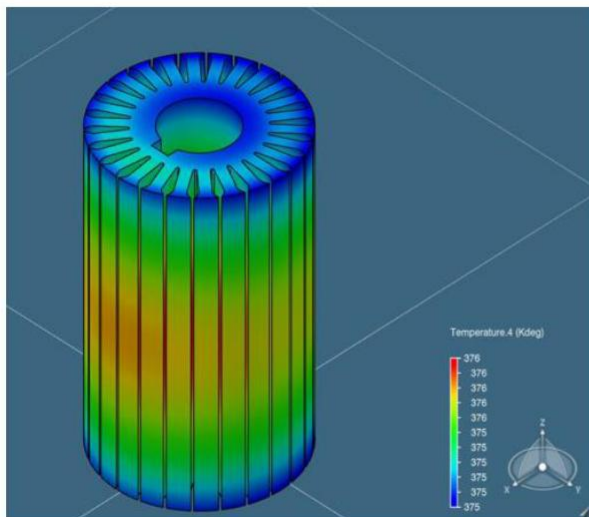
Where,

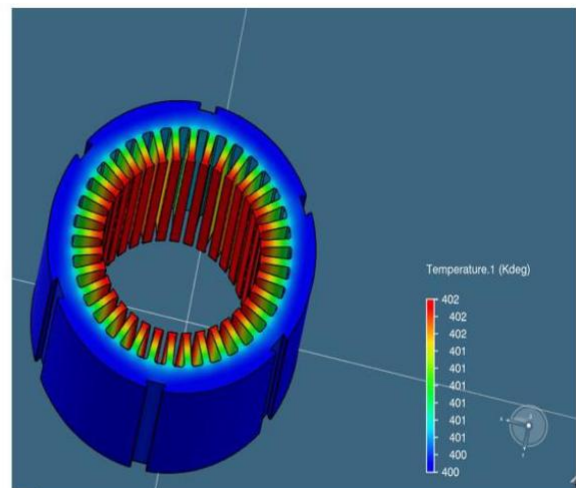v is the inlet air velocity in the fin channels =

10.55m/s D is the hydraulic diameter = 136mm L is

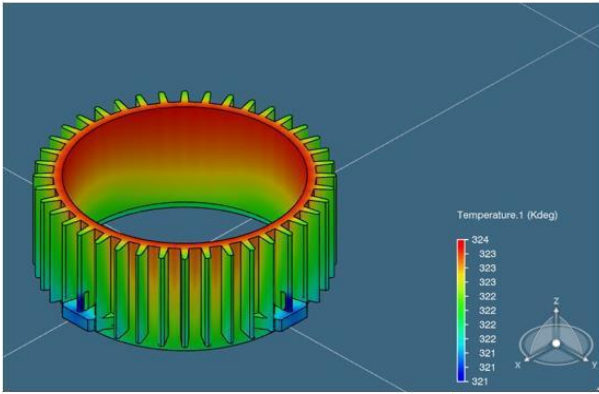the axial length of fins. = 161.5mm

The mass flow rate was determined to be 0.01579 kg/s. With this value heat transfer co-efficient was determined to be 42.137 W/m^{2}K.

Temperature distribution in rotor core

Temperature distribution in stator core

Temperature distribution in body frame

Conclusion:

- The developed mechanical and electrical model of the motor has been tested for its expected behavior in both mechanical and electrical domains under steady-state and dynamic conditions and is found to be best suitable for learners and facilitates exploration of self-study and troubleshooting.

- The 3D model-based learning has the potential to transform engineering education by enhancing design thinking and promoting a multidisciplinary approach towards subjects like Electric Machines.

Link to the Video Demo of the Project:

https://youtu.be/Cx1qpJcYpm4