MECHANICAL ENGINEERING PORTFOLIO

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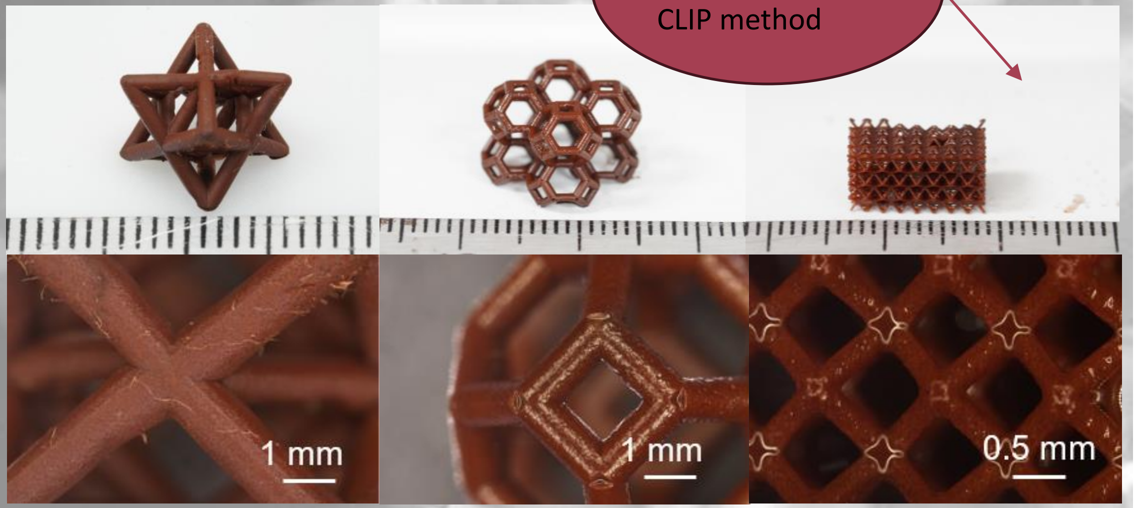
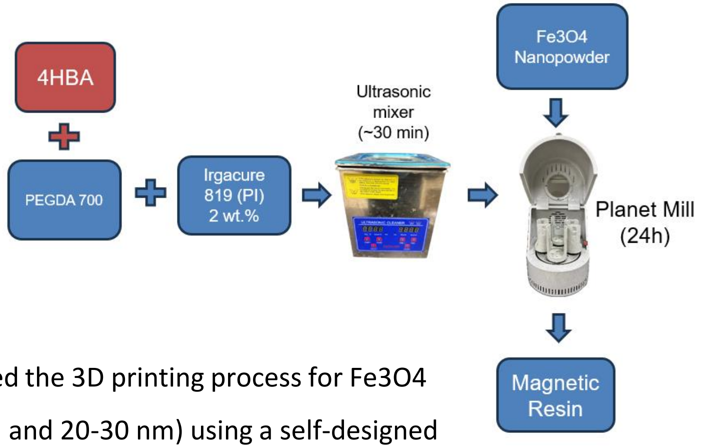
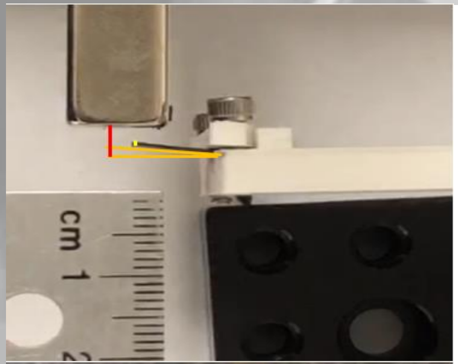
Complex truss 3D printed using CLIP method

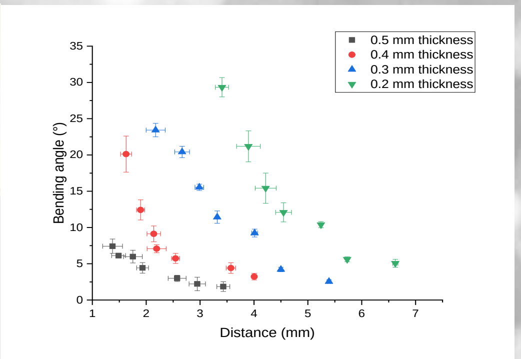


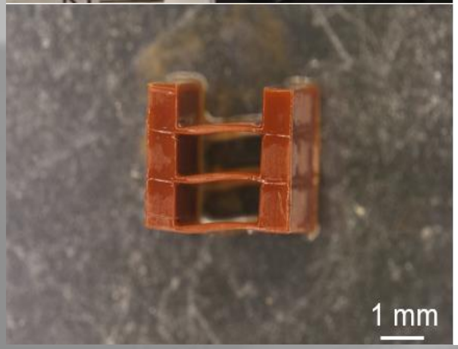
EXPLORE RAPID 3D PRINTING OF MAGNETICALLY ACTUATED MICROSTRUCTURES VIA MICRO-CONTINUOUS LIQUID INTERFACE PRODUCTION

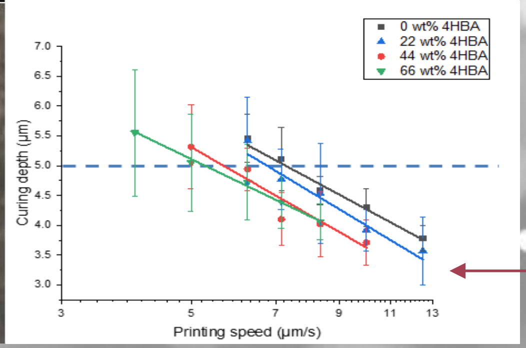
Material preparation





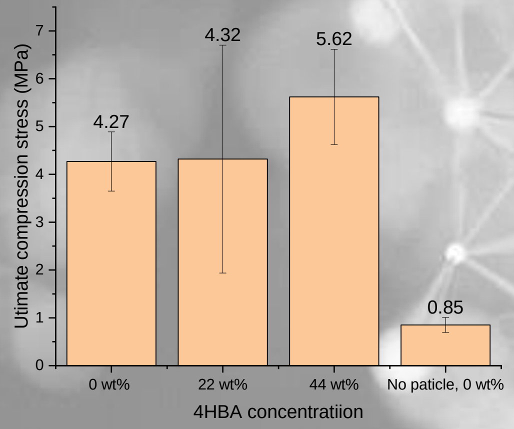


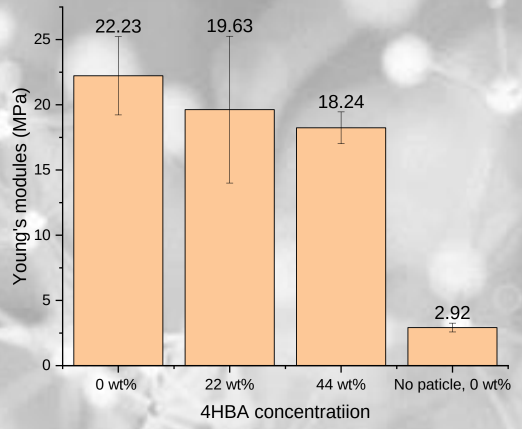


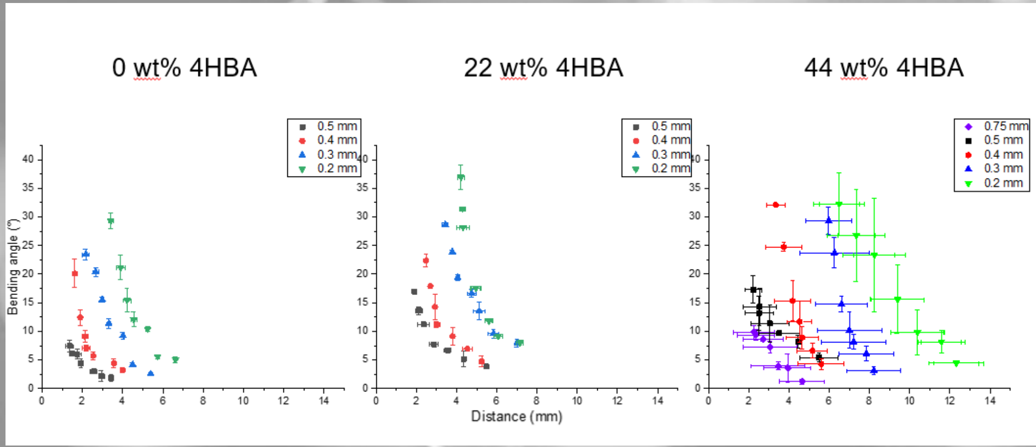


Speed working curve to optimize the print speed

1. **Study Objective:**
    1. Investigated and optimized the 3D printing process for Fe3O4 nanoparticles (50-100 nm and 20-30 nm) using a self-designed μCLIP system.
2. **Innovative Procedure Development:**
    1. Devised a comprehensive μCLIP-based 3D printing procedure, enabling the rapid production of magnetic actuated structures with superior efficiency.
3. **Material Formulation Expertise:**
    1. Formulated photo-curable resins by integrating commercially available magnetic nanoparticles (50-100 nm and 20-30 nm), ensuring precision in the printing process.







4. **Printing Achievements:**
   - Successfully printed intricate 3D structures with exceptional surface finishes, surpassing the speed of traditional PμSL and 2PP-based projects by a factor of 10.
5. **Comprehensive Performance Verification:**
   - Conducted systematic studies to validate mechanical compliance, magnetic actuation, and bending angle performance, ensuring the reliability and functionality of printed structures.
6. **Material Enhancement:**
   - Improved the flexibility and strength of PEGDA 700-based resin by incorporating varying concentrations of 4HBA, demonstrating a keen focus on material optimization.
7. **Versatility and Customization:**
   - Established a versatile platform through the developed procedure, facilitating the swift creation of customized magnetic microstructures and micro robots with enhanced properties.

- This project showcases my proficiency in advanced 3D printing technologies, materials science, and systematic performance verification, highlighting my contributions to innovative and efficient manufacturing processes.

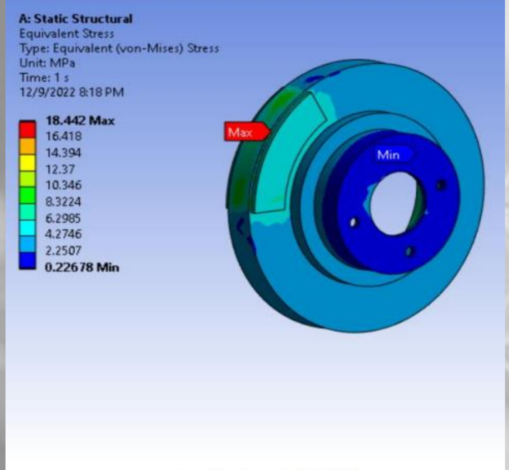


Figure 15 static structural simulations

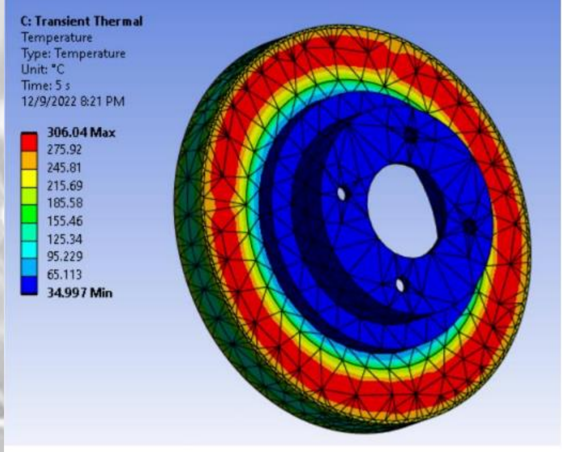


Figure 17 thermal analysis for optimised point

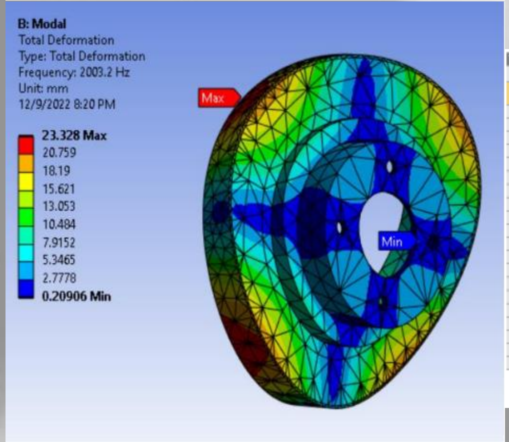


Table of Outline A2: Design Points of Design of Experiments

	A	B	C	D	E	F	G	H
1	Name	P1 - rotor_thickness (mm)	P2 - rotor_OD (mm)	P3 - rotor_ID (mm)	P4 - Total Deformation Reported Frequency (Hz)	P5 - Temperature Maximum (C)	P6 - Equivalent Stress Maximum (MPa)	P7 - Solid Volume (mm^3)
2	1	25.15	125.94	82.2	1877.6	310.75	15.081	9.4829E+05
3	2	26.35	131.61	69	2028.1	310.24	15.247	1.2309E+06
4	3	22.15	132.29	72.6	1888.9	320.35	15.602	1.0541E+06
5	4	25.75	122.84	71.4	2230.6	313.38	22.6	1.0073E+06
6	5	22.75	127.56	87	1683	318.81	15.212	8.7703E+05
7	6	27.85	128.24	83.4	1874.3	307.25	15.606	1.0717E+06
8	7	25.45	130.94	88.2	1665.2	310.42	15.546	1.0084E+06
9	8	27.55	129.59	76.2	2020.7	306.1	15.468	1.1663E+06
10	9	23.95	134.99	66.6	1837.1	313.05	15.875	1.2206E+06
11	10	23.65	123.51	70.2	2173.4	316.49	26.403	9.6235E+05
12	11	24.55	128.91	67.8	2046.4	313.49	15.379	1.1194E+06
13	12	23.35	130.26	84.6	1733.2	318.59	15.643	9.656E+05
14	13	24.85	126.89	89.4	1643.8	312.62	14.929	8.9728E+05
15	14	26.65	132.96	77.4	1896.5	310.03	15.406	1.1982E+06
16	15	24.25	124.19	73.8	2107.8	311.65	20.127	9.6716E+05
17	16	27.25	124.86	79.8	1993.9	304.77	13.724	1.0178E+06
18	17	26.95	135.66	81	1801	309.76	16.174	1.2353E+06
19	18	26.05	133.64	78.6	1858.4	309.77	15.701	1.1799E+06
20	19	23.05	126.21	75	2016.7	316.68	14.62	9.5747E+05
21	20	22.45	134.31	85.8	1634.6	319.31	16.23	1.0035E+06

Figure 1 Design points using latin hypercube method

Table of Schematic E4: Optimization

	A	B	C	D
1	Optimization Study			
2	Maximize P4; P4 >= 1200 Hz	Goal, Maximize P4 (Default importance); Strict Constraint, P4 values greater than or equals to 1200 Hz (Default importance)		
3	Minimize P5; P5 <= 400 C	Goal, Minimize P5 (Default importance); Strict Constraint, P5 values less than or equals to 400 C (Default importance)		
4	Minimize P6; P6 <= 1.5E+07 MPa	Goal, Minimize P6 (Default importance); Strict Constraint, P6 values less than or equals to 1.5E+07 MPa (Default importance)		
5	Minimize P7	Goal, Minimize P7 (Default importance)		
6	Optimization Method			
7	MOGA	The MOGA method (Multi-Objective Genetic Algorithm) is a variant of the popular NSGA-II (Non-dominated Sorted Genetic Algorithm-II) based on controlled elitism concepts. It supports multiple objectives and constraints and aims at finding the global optimum.		
8	Configuration	Generate 3000 samples initially, 600 samples per iteration and find 3 candidates in a maximum of 20 iterations.		
9	Status	Converged after 3509 evaluations.		
10	Candidate Points			
11		Candidate Point 1	Candidate Point 2	Candidate Point 3
12	P1 - rotor_thickness (mm)	27.769	27.817	27.899
13	P2 - rotor_OD (mm)	124.34	125.6	126.04
14	P3 - rotor_ID (mm)	79.012	76.641	74.926
15	P4 - Total Deformation Reported Frequency (Hz)	★★ 2047.2	★★ 2091	★★ 2123.9
16	P5 - Temperature Maximum (C)	★★ 305.44	★★ 306.37	★★ 306.8
17	P6 - Equivalent Stress Maximum (MPa)	★★ 14.278	★★ 12.834	★★ 12.467
18	P7 - Solid Volume (mm^3)	— 1.0294E+06	— 1.0822E+06	— 1.1112E+06

Figure 9 optimisation table with constraints

DESIGN OPTIMIZATION OF BRAKE DISC

1. **Problem Statement:** Objective: Optimize brake disc for emergency braking conditions.

- Minimize disc volume.
- Reduce maximum stress.
- Maximize first natural frequency.
- Minimize maximum temperature.

2. **Analysis Breakdown:**

- **Structural Analysis:** Endure pressure from brake pads. Minimize stresses due to friction and centrifugal forces. Parameters: rotational speed (250 m/s) and brake pad pressure (1.0495E7 Pa). Output: equivalent von Mises stress and disc volume.
- **Modal Analysis:** Ensure disc frequency exceeds engine firing frequency, preventing resonance-induced failure. Consider 10 modes, calculating 7th mode for deformation.
- **Thermal Analysis:** Minimize temperature increase during braking. Assumptions: convection coefficient (5W/m² C) and room temperature (35°C).

3. **Design of Experiments:** Latin Hypercube sampling with 20 points. Inner diameter constrained: 66 ≤ ID ≤ [Upper Bound].

4. **Contributions:**

- Developed a comprehensive optimization strategy for brake disc design.
- Conducted structural, modal, and thermal analyses, providing insights into stress, frequencies, and thermal behaviors.
- Implemented Latin Hypercube sampling for efficient design space exploration.

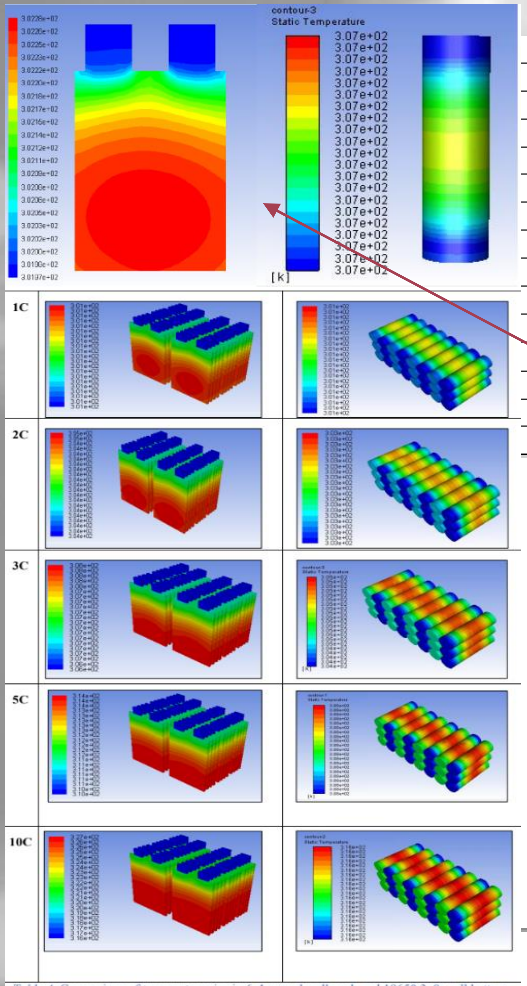


Table 4: Comparison of temperature rise in 6s4p pouch cell pack and 18650 3p8s cell battery packs at different C-rates

Cases to examine

Sr no.	Battery Model	Discharge rate
Case-1	Single Cell (Pouch Cell and 18650)	1C
Case-2		2C
Case-3		3C
Case-4		5C
Case-5	6s4p (Pouch Cell)	1C
Case-6		2C
Case-7		3C
Case-8		5C
Case-9		10C
Case-10	3p8s (18650 cell)	1C
Case-11		2C
Case-12		3C
Case-13		5C
Case-14		10 C

Single pouch cell and 18650 cell heat generation simulation.

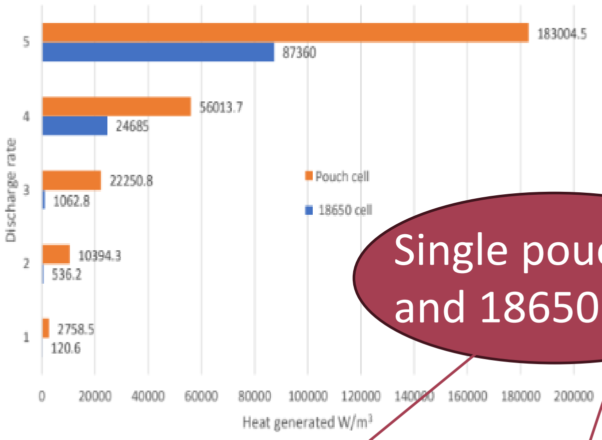
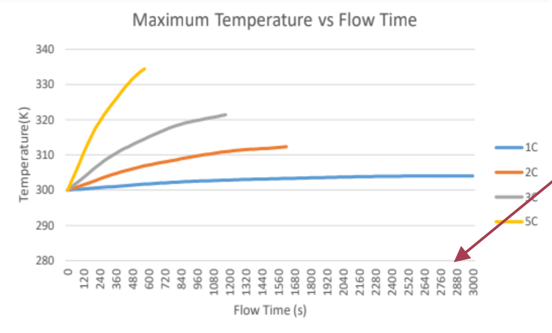
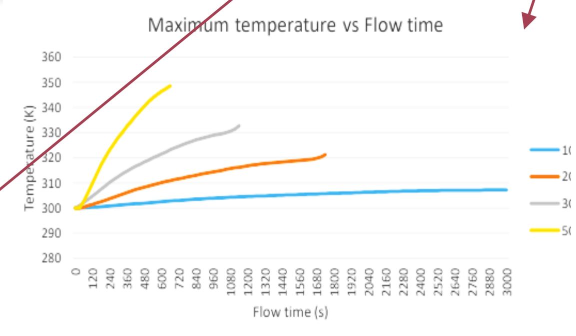


Figure 28: Heat generation v/s discharge rate for 6s4p pouch cell and 18650 cell

Single pouch cell and 18650 cell





A STUDY OF TEMPERATURE RISE FOR LI-ION POUCH CELLS AND 18650 CYLINDRICAL CELLS BY CHANGING DIFFERENT PARAMETERS

1. **Focused Analysis:**

   - Conducted detailed thermal analysis using ANSYS, specifically targeting the battery thermal discharge module, showcasing expertise in crucial battery performance aspects.

2. **Heat Generation Comparison:**

   - Compared heat generation between a 6s4p pouch cell pack and a 3p8s 18650 cell pack, revealing higher heat in the 6s4p pouch cell. This underscores the preference for cylindrical cells in high-power, limited-cooling applications.

3. **Pouch Cell Efficiency:**

   - Recognized the efficiency of pouch cells, emphasizing their high power-to-volume ratio, indicating suitability for specific applications.

ptimization Proposal:

   - Proposed enhanced utilization of pouch cell packs for high-power solutions with efficient cooling, offering an innovative approach to battery performance optimization.

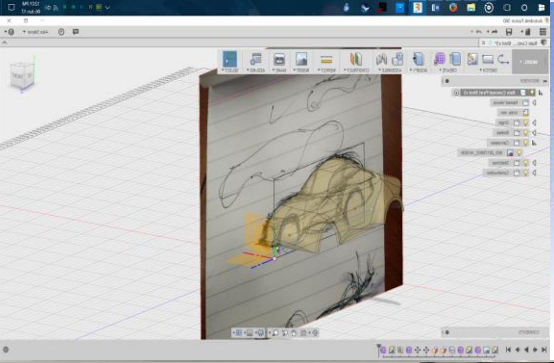
5. **Industry Validation:**

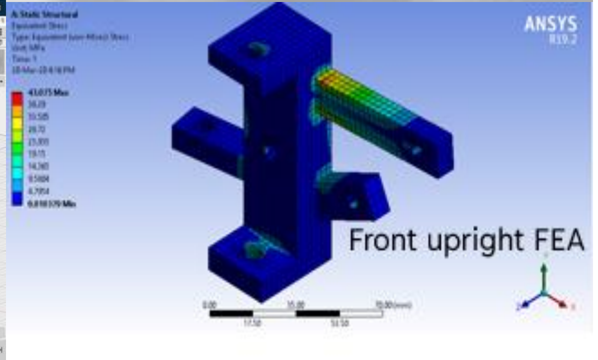
   - Cited examples of leading electric car manufacturers, GM, Hyundai, and Mahindra, using pouch cell packs beyond Tesla. This validates the potential of pouch cells in advancing electric vehicle technology.

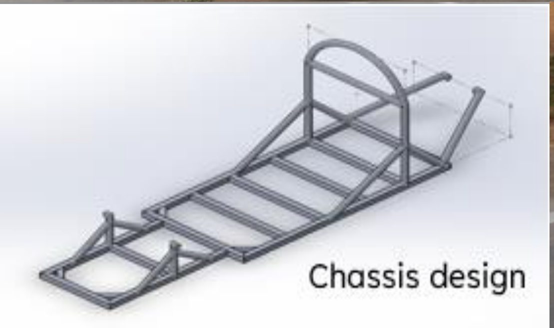
6. **Advancements Implication:**

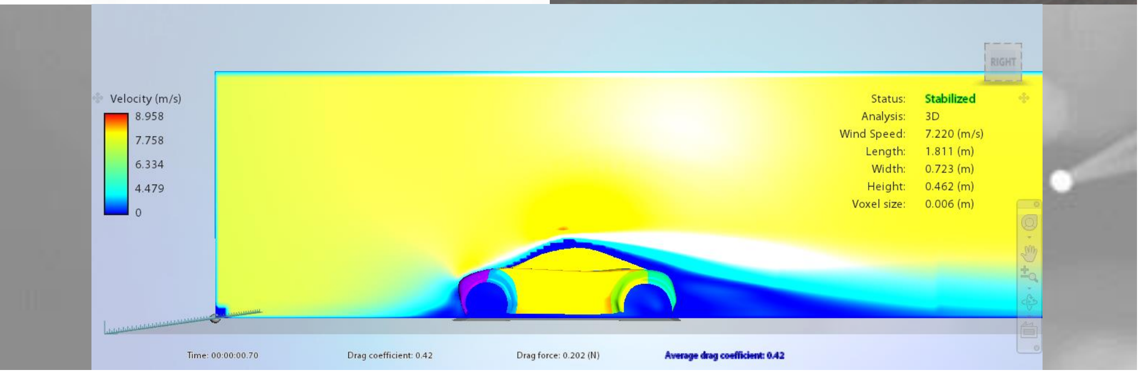
   - Concluded with a broader implication, highlighting the potential of pouch cells when paired with effective thermal management, contributing to electric vehicle technology advancements.

- This project demonstrates my expertise in thermal analysis and innovative thinking, aiming to optimize battery performance in electric vehicles.









TEAM KAIZEN: INNOVATING THE ELECTRIC PROTOTYPE VEHICLE FOR SEMA

- **Project Achievement: Electric Car Efficiency Enhancement**
- Significantly improved car efficiency from 70% to an impressive 191 km/kWh.
- Successfully managed the project with a budget of 20 Lakhs (~$27,000) secured through strategic sponsorships.
- Attained a remarkable 12th rank in Asia among 300 competitive teams, showcasing project excellence.
- **Role: Head Vehicle Dynamics and Analysis**
- Achieved a 55.9 % reduction in the overall car weight by integrating a carbon fiber-reinforced chassis, resulting in a final weight of 37kgs.
- Utilized ANSYS Fluent to optimize and reduce the car's drag coefficient to an impressive 0.048.
- Secured a design patent for a rectangular torque arm, designed for a 500W motor, coupled with a lightweight aluminum chassis for a prototype battery electric car.
- **Leadership: Team Manager**
- Spearheaded budget planning and timeline creation for the entire project, ensuring financial efficiency and timely completion.
- Orchestrated logistics planning, overseeing the successful shipment of the car from India to Malaysia, including necessary permissions.
- Proactively pitched the project to sponsors, demonstrating its value and successfully securing investments.
- Ensured the team's safety and health, maintaining a comprehensive log to uphold project well-being.
- **Conclusion:** This portfolio highlights my multifaceted contributions, ranging from technical advancements in vehicle dynamics to strategic leadership in project management. The demonstrated success in efficiency improvement, weight reduction, and patent acquisition underscores my capabilities in both engineering and managerial domains.

Database

Vehicle Dimensions	
Vehicle Weight (Including Driver)	130
Wheel base (cm)	145
Trackwidth(cm)	60
Vehicle Width (cm)	78
Vehicle Height (cm)	69
Frontal area of Vehicle	0.43
Coefficeient of Drag	0.043
Wheel radius (cm)	25.4
Brake Disc Radius (cm)	8
Coefficient Of friction(Calliper and Disc	0.9

Dynamic Characteristics			
Vehicle Speed - Straight Path(m/s)	8.333333333	Speed in kmph	30
Vehicle Speed While cornering (m/s	5.555555556	Speed in kmph	20
Deceleration While Braking(m/s2)	5		
Acceleration in Starting	0.0833333		
Accelaration While Running	0.1		

Environmental Conditions	
Coefficient of friction (Static)	0.6
Coefficient of Friction (rolling)	0.006
Density of Air	1.26

Steering				
Beta(Ackerman Angle)	0.185085556	10.61	Beta(Ackerman Angle)	10.61
r(Length of Tie-Rod)	7		Tie-rod Length	30
s(Steering link Length)			Length of Link(l)	57.4235712
h(Distance betweem link and trackwidth)			Distance between	6.88044357

Slope For the brake test(%)		Radian	Degree
20	Angle	0.19739556	11.31566904

Cornering Radius(m) And Direction of turning(R and L)	Direction	Radius	Centrifugal Force	Effective Force
	l	13	308.6419753	-308.6419753

Position Of COG	X - Coordinate	Y - Coordinate
	93.25	12.871

Weight Distribution(Static)	Rear	Front	Right	Left
	819.3137931	454.686207	637	637

Weight Distribution @ Braking	761.6162069	512.383793

Weight Transfer Cornering	Right	Left
	703.2088477	570.791152

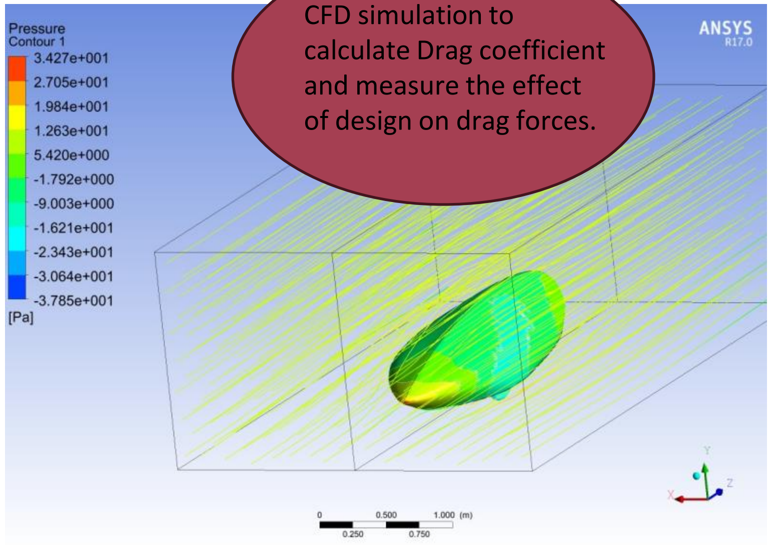
Braking Force required To Complete The break test	Rear	Front	Rear Torque	Front Torque
	468.7350208	280.820848	119.0586953	71.3284953

Force Required by Brake Calliper	
Rear	Front
1653.59299	990.67355

Starting torque	10.39566557	Starting Torque(Lower)	4.693241566
Maximum Torque required in running conditions	7.849470125	Running Torque (Lower)	5.449046125
RPM Required	313.4560409	Angular Velocity(Rad/s)	32.80839895
Power requirement For running conditions(Watts)	257.5285474		

Datasheet		
Trackwidth(Front)(cm)	60	
Trackwidth(Rear)(cm)	0	
Axle length	6	
Wheelbase(cm)	145	
Turning Radius(m)	7.3	
Turning Radius at centre of Rear trackwidth	6.854544	
	Radians	Degrees
Ideal Aackerman Angle	0.1640301	9.4029999
Internal Steering Angle	0.2177142	12.480434
External	0.19996	11.462676

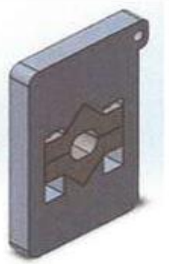
Database for Computing Initial Torque, Braking Forces, and Center of Gravity (COG) Values to Aid in Vehicle Dynamics



CFD simulation to calculate Drag coefficient and measure the effect of design on drag forces.

Patent published for torque arm for 500 W and 1000 W motor.

DESIGN NUMBER	333623-001
CLASS	12-16
PANDIT DEENDAYAL PETROLEUM UNIVERSITY, KNOWLEDGE CORRIDOR, RAISAN VILLAGE, GANDHINAGAR - 382007, GUJARAT (STATE), INDIA	
DATE OF REGISTRATION	25/09/2020
TITLE	TORQUE ARMS FOR VEHICLE
PRIORITY NA	



DESIGN NUMBER	333625-001
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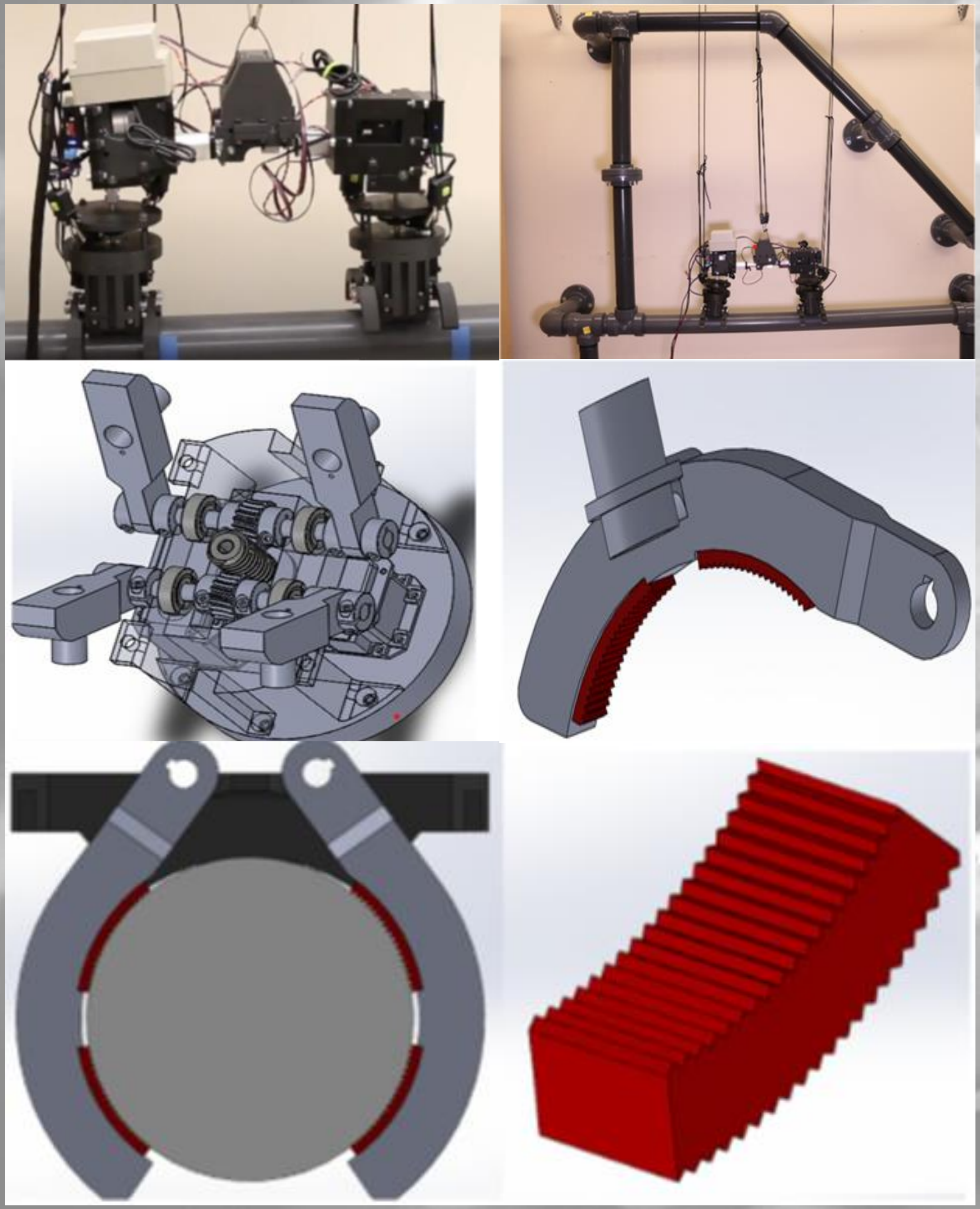
DATE OF REGISTRATION	25/09/2020
TITLE	TORQUE ARMS FOR VEHICLE
PRIORITY NA	

Negative mold construction for carbon fiber shell of the vehicle.

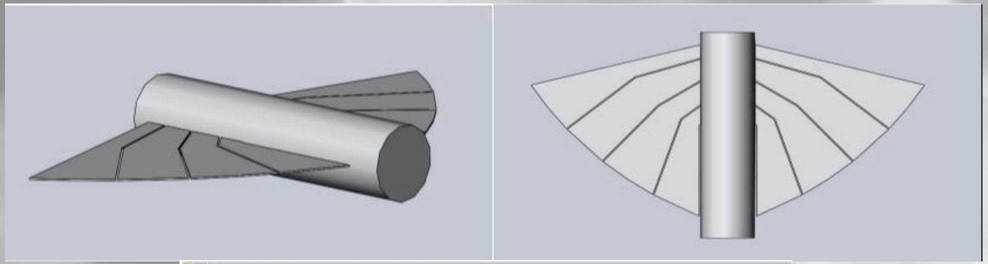


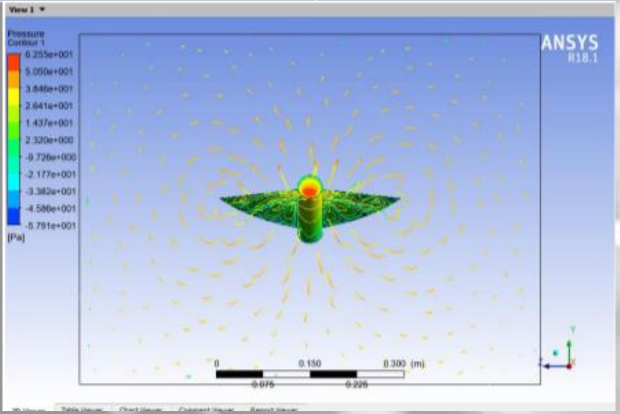
LIZARD TUBE INSPECTION ROBOT

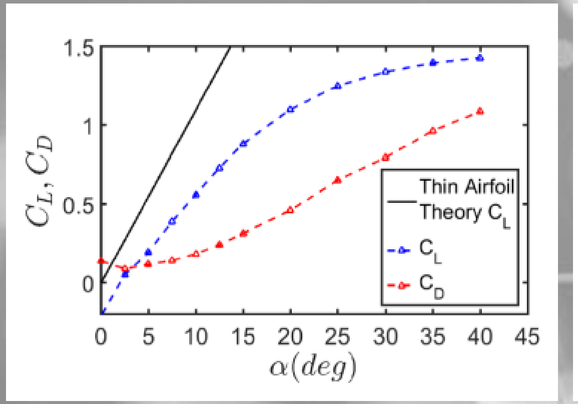
1. **Design Leadership:**
    - Spearheaded the design process for the feet of a Lizard-inspired Tube Inspection (LTI) robot in Autodesk Fusion 360, showcasing a meticulous approach aimed at enhancing overall functionality.
2. **Significant Grip Enhancement:**
    - Achieved a noteworthy 20% increase in the robot's overall grip capability, empowering it to withstand a substantial gripping force of 40 lbs-f. This critical improvement has significantly enhanced the efficiency of tube inspection operations.
3. **Comprehensive Design Optimization:**
    - Undertook a thorough reassessment of the LTI robot's design, with a focused emphasis on weight optimization. Successfully implemented modifications resulted in a substantial 15% reduction in overall weight, contributing to heightened mobility and operational efficiency.
4. **Systematic Parameter Exploration:**
    - Applied a systematic and data-driven approach by employing Design of Experiments (DOE) for both experimental and design validation of various body parts. This methodology facilitated the exploration of a wide range of parameters, ensuring the identification of optimum configurations for the final design.
5. **Validation Excellence with ANSYS:**
    - Executed a meticulous validation process on ANSYS, leveraging data obtained from the Design of Experiments. This rigorous validation ensured the reliability and performance of the redesigned components, affirming the effectiveness of the proposed modifications.

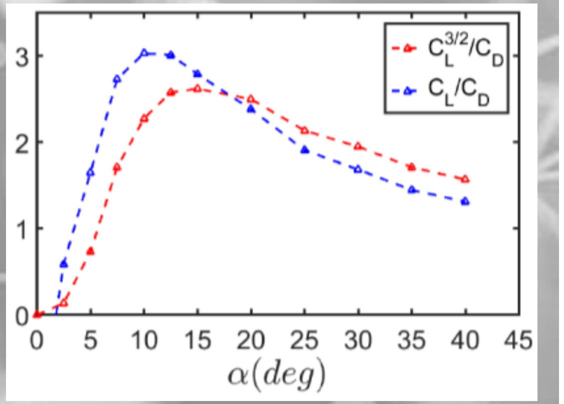
- This project underscores my leadership in design, showcasing a combination of innovative solutions, optimization strategies, and thorough validation processes in the development of a high-performance robotic system.

MINIATURIZATION OF UNFOLDING MECHANISM FOR ROCKET LIFTING SURFACES









$$Endurnace = \frac{m_{batt}E_{density}\eta}{W_{total}^{3/2}}\left(\frac{CL^{3/2}}{C_D}\right)\sqrt{\frac{\rho S}{2}}$$

$$Range = E_{density}\eta\left(\frac{C_L}{C_D}\right)\left(\frac{m_{batt}}{W_{total}}\right)$$

1.Innovative Design Concept:

- Conceptualized and designed a bio-inspired folding mechanism tailored for rocket lifting applications, drawing inspiration from the efficient fins of flying fish.

2.Advanced Computational Analysis:

- Executed Computational Fluid Dynamics (CFD) analysis using Ansys Fluent to precisely calculate the coefficient of lift and coefficient of drag for the designed folding mechanism.

3.Performance Quantification:

- Utilized the outcomes of the CFD analysis to quantitatively assess the endurance and range of the biomimetic wing design, providing crucial insights into its aerodynamic performance.

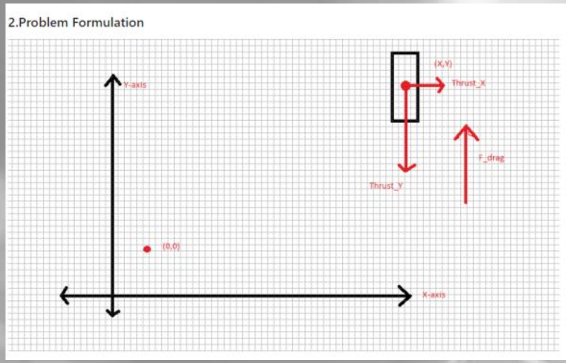
4.Biomimicry in Action:

- Applied a biomimetic approach, integrating nature-inspired principles to significantly enhance the efficiency and functionality of the folding mechanism, specifically tailored for optimal rocket lifting.

5.Aerodynamic Proficiency:

- Demonstrated a high level of proficiency in using Ansys Fluent for detailed aerodynamic analysis, contributing to a comprehensive understanding of the performance characteristics of the biomimetic design.

This project reflects my innovative approach to engineering challenges, showcasing my ability to blend biomimicry with advanced computational analysis to develop efficient and high-performance solutions for complex aerospace applications.



Objective function

$$\min_{\theta} ||s(T)||^2$$

where,

$$s(T) = (x(T), y(T), v_x(T), v_y(T))$$

Parameters g: Gravity acceleration,

a_m:maximum acceleration,

T: Total time,

d_t: Time increment,

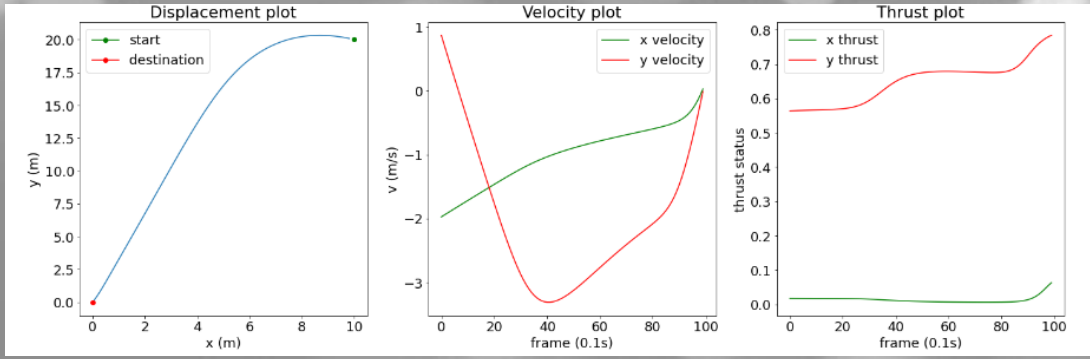
```
A = pi * 12 feet ^2 (Diameter of falcon 9) = 34 m^2
r = 850 kg/m^3 (Density of steel)
V = velocity = delta state
m = 549054 Kg (Mass of falcon 9)

D = 0.25 * 34 * 0.5 * 850 * delta_state^2

now from figure , force body diagram

m * drag_decel (deceleration due to drag) = D
drag_decel = 0.00658 * delta_state^2
```

OPTIMIZED RESULT OF ROCKET LANDING FROM START TO FINISH



GRADIENT-BASED ALGORITHMS AND DIFFERENTIABLE PROGRAMMING

Objective: Optimize the trajectory of a rocket landing using gradient-based algorithms and differentiable programming.

1. Introduction:

- Rocket state represented by distance to the ground (x) and velocity (v).
- Control input: Acceleration (a).
- Closed-loop controller: Neural network with parameters (θ).
- **2. Problem Formulation:**
- Optimization Problem: Minimize with respect to θ.
- The rocket is supposed to land at (0,0) at a stable base. The forces acting on the rocket body are the thrust forces by thrusters in X and Y directions. The rocket is at (20,10) meters and is descending with a velocity of (-2,1)m/s.
- **3. Design and Implementation:**
- Implemented in PyTorch.
- Dynamical constraints considered: Gravity, thrust forces, and drag forces.
- **4. Results:**
- Optimized trajectory achieved with minimal loss.
- Convergence achieved with a learning rate of 0.005 and 100 epochs.
- Neural network architecture: 3 hidden layers, each with 10 neurons.
- Trajectory and velocity graphs demonstrate successful optimization, reaching the final position (0,0).