

MECHZONE



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Department of Mechanical Engineering
SCMS SCHOOL OF ENGINEERING AND TECHNOLOGY
Karukutty, Ernakulam, Kerala

December 2023 · Vol 3 · Issue 2

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EDITORIAL BOARD — MECHZONE Dec 2023

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From the Editor's Desk

As December 2023 arrives and the year draws to a close, the Department of Mechanical Engineering at SCMS School of Engineering and Technology pauses to reflect — and to celebrate. The articles in this issue reflect the intellectual energy of a department fully engaged with the challenges of its time. Mr. Francis Thomas examines the fourth industrial revolution with the scepticism of an engineer — not asking 'is Industry 4.0 real?' but 'what exactly does it demand from the mechanical engineer of 2024?' Dr. Raghav G R brings his composite materials research to a wider audience, and Mr. Nikhil Asok N makes the compelling case that additive manufacturing has finally crossed the threshold from prototyping tool to production technology.

Our student contributors have outdone themselves. Abin's gear reduction unit project is a model of methodical mechanical design. Shaun's heat pump analysis applies rigorous thermodynamics to a system of growing importance in a warming world. And Rajat's Tata Motors internship account is, frankly, one of the most honest and useful pieces of writing about industry transition that I have read from a student.

Dr. Rag R L

Editor-in-Chief, MechZone 2023

Professor & Head, Dept. of Mechanical Engineering, SSET

Vision and Mission of the Institute

Vision

To be a centre of excellence in providing technical education in harmony with the changing global order.

Mission

To offer technology related education of exceptional quality to students by developing their total personality with due emphasis on ethical values and preparing them to meet the growing challenges of the industry and human society.

Vision and Mission of the Department

Vision

To be a centre of excellence in Mechanical Engineering recognized for its quality education, innovative research and social outreach programs.

Mission

1. Provide excellent student-centric education generating high calibre graduates to face global challenges.
2. Maintain state-of-art facilities for faculty and students to learn, research and disseminate knowledge.
3. Emphasize on collaborative technology-transfer encouraging innovations for the benefit of society.

FACULTY ARTICLE

Industry 4.0 and the Smart Factory Revolution: What It Actually Means for Mechanical Engineers in India

Beyond the buzzwords — a practical account of the technologies, skills, and mindset shifts that will define manufacturing careers in 2024 and beyond.

Mr. Francis Thomas, Assistant Professor, Department of Mechanical Engineering

The phrase 'Industry 4.0' has been circulating in engineering circles since Klaus Schwab coined it at Davos in 2016. Seven years on, it has become simultaneously more concrete — actual factories are running actual smart systems — and more confusing, as vendors attach the label to everything from a Wi-Fi-connected temperature sensor to a fully autonomous production line. For the mechanical engineer beginning a career in 2024, cutting through this noise to understand what the fourth industrial revolution actually demands is not optional. It is the difference between leading the transformation and being displaced by it.

India's manufacturing sector — contributing 17% of GDP and employing 27 million people — is at an inflection point. The Production Linked Incentive (PLI) scheme has catalysed investment across 14 sectors, from auto components to medical devices. The National Logistics Policy 2022 has begun integrating digital tracking across supply chains. And the DPIIT's Smart Cities and Industrial Corridors initiative is wiring together new greenfield manufacturing zones with industrial IoT infrastructure from day one. The mechanical engineer who understands only materials and mechanisms — and not data and digital systems — will find themselves increasingly peripheral in this environment.

The Five Pillars of Industry 4.0 for Mechanical Engineers

1 Industrial IoT (IIoT) and Sensing

Vibration, temperature, current, and pressure sensors are the nervous system of the smart factory. Mechanical engineers must specify sensor placement, understand signal conditioning, and interpret the data streams their machines generate. Familiarity with OPC-UA, MQTT, and basic time-series data analysis is rapidly becoming a baseline expectation in manufacturing roles.

2 Digital Twins and Simulation-Driven Operations

A digital twin is a live, physics-based model of a physical asset, continuously updated by sensor data. For mechanical engineers, building twins means linking FEA/CFD models with operational measurements — enabling virtual commissioning, predictive maintenance, and process optimisation without stopping the production line.

3 Cyber-Physical Systems and Autonomous Control

CPS integrate computation, networking, and physical processes. In manufacturing, this translates to machine tools that self-correct toolpath errors based on in-process measurement, presses that adjust tonnage in real time to material variability, and assembly robots that detect and adapt to part-to-part dimensional variation.

4

Additive and Hybrid Manufacturing

3D printing is graduating from the prototyping lab to the production floor. Selective laser sintering of production-grade polymers, directed energy deposition of metal tooling repair, and hybrid CNC/AM machines that can add and subtract material in a single setup — these are live capabilities at Indian OEMs in 2023.

5

Data Analytics and AI-Assisted Decision Making

Statistical Process Control gave way to machine learning for quality prediction. A mechanical engineer comfortable with Python, basic supervised learning, and manufacturing data pipelines can contribute directly to quality, yield, and throughput improvement — skills that no purely mechanical curriculum teaches.

"Industry 4.0 does not make mechanical engineering less relevant. It makes the mechanical engineer who understands physical systems and data systems simultaneously the most valuable person in any factory."

India's Industry 4.0 Adoption Landscape — 2023

Sector	I4.0 Maturity Level	Key Technologies Deployed	Leading Companies
Automotive	Advanced	Digital twin, cobots, AI vision	Tata Motors, Maruti Suzuki
Aerospace / Defence	Intermediate	PLM, MES, precision metrology	HAL, DRDO, BEL
Pharma / FMCG	Intermediate	Track & trace, IoT quality	Sun Pharma, HUL
Auto Components	Developing	OEE monitoring, SCADA	Bosch India, Motherson
General Engineering	Early	ERP integration, basic sensors	SME sector (wide variation)
Process Industries	Advanced	DCS, predictive maintenance	ONGC, HPCL, FACT

Table 1 — Industry 4.0 adoption across Indian manufacturing sectors, 2023.

FACULTY ARTICLE

Advanced Composite Materials: Mechanics, Manufacturing and Applications in Modern Engineering

From ISRO's rocket fairings to Formula One monocoques — how composite materials are rewriting the engineering design rulebook, and what every mechanical engineer must understand about them.

Dr. Raghav G R · Associate Professor, Department of Mechanical Engineering

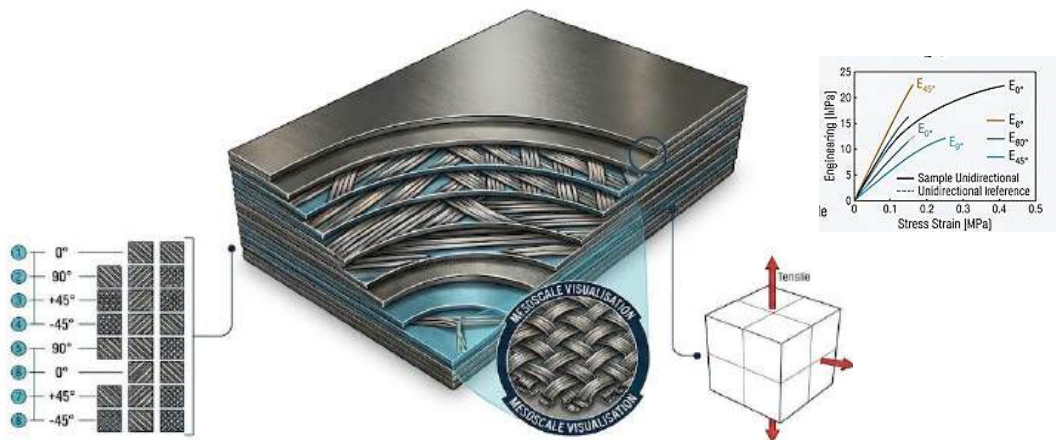


Fig. 2 — Fibre orientation network in a woven CFRP laminate, visualised at the mesoscale. Fibre angle, stacking sequence, and ply count collectively determine the laminate's anisotropic stiffness tensor.

Composite materials — engineered combinations of two or more distinct constituents producing properties superior to either alone — have been known since ancient Egyptians reinforced mud bricks with straw. But the composites revolution of the past half-century is something different: the quantum-mechanical engineering deliberate, between high-performance fibres and polymer matrices to produce structural materials that are simultaneously lighter, stronger, and more fatigue-resistant than any metal they replace. In December 2023, ISRO's LVM3-M3 mission placed One Web satellites into orbit using a composite payload fairing that saved 340 kg over an aluminium equivalent — allowing 18 additional satellites per launch. This is not an exotic research outcome; it is the practical engineering payoff of three decades of composite materials science, and it is being replicated across sectors from automotive to civil infrastructure.

The Four Composite Families

Polymer Matrix Composites (PMC) — the dominant family. CFRP (carbon fibre / epoxy) and GFRP (glass fibre / polyester or epoxy) account for over 80% of structural composite usage. Thermoset matrices (epoxy, bismaleimide) offer high temperature resistance; thermoplastic matrices (PEEK, PPS) offer weldability and recyclability — the growth area of the decade.

Metal Matrix Composites (MMC) — aluminium or titanium reinforced with SiC or B4C particles or fibres. Used where moderate-temperature service, conductivity, or dimensional stability preclude polymers: brake discs, piston crowns, electronic packaging.

Mechanical Properties Comparison

Material	E (GPa)	UTS (MPa)	Density
Mild steel (Fe360)	200	400	7.85
Al 2024-T3	73	480	2.78
Ti-6Al-4V	114	1000	4.43
GFRP (UD, 0°)	45	1200	2.0
CFRP (UD, 0°)	135	1800	1.55
CFRP (quasi-iso)	70	600	1.55

Failure Modes (CFRP)

Matrix cracking (first failure, low strain) → delamination propagation → fibre failure (ultimate). In fatigue, stiffness degradation precedes strength loss, enabling non-destructive life monitoring.

Manufacturing Processes: From Autoclave to Out-of-Autoclave

Autoclave curing remains the gold standard for aerospace-grade CFRP laminates: pressures of 5-7 bar and temperatures of 120-180°C produce void contents below 0.5% and fibre volume fractions of 60-65%. But autoclaves are capital-intensive and slow. The industry trend is strongly toward Out-of-Autoclave (OOA) processes: vacuum-bag-only (VBO) curing of prepregs, resin transfer moulding (RTM), and vacuum-assisted RTM (VARTM) — which can produce aerospace-quality parts at significantly lower tooling and energy cost.

Process	Void Content	FVF (%)	Cycle Time	Capital Cost	Typical Use
Autoclave (prepreg)	< 0.5%	60–65	4–8 hrs	Very High	Aerospace primary structure
VBO (prepreg)	0.5–2%	55–62	4–8 hrs	Medium	Aerospace secondary, motorsport
RTM	0.5–2%	55–60	0.5–2 hrs	High	Automotive, wind blades
VARTM	1–3%	45–55	2–6 hrs	Low	Marine, civil, wind blades
Filament winding	0.5–2%	60–75	2–6 hrs	Medium	Pressure vessels, pipes, shafts
AFP/ATL	< 1%	58–65	Variable	Very High	Large aerospace structures

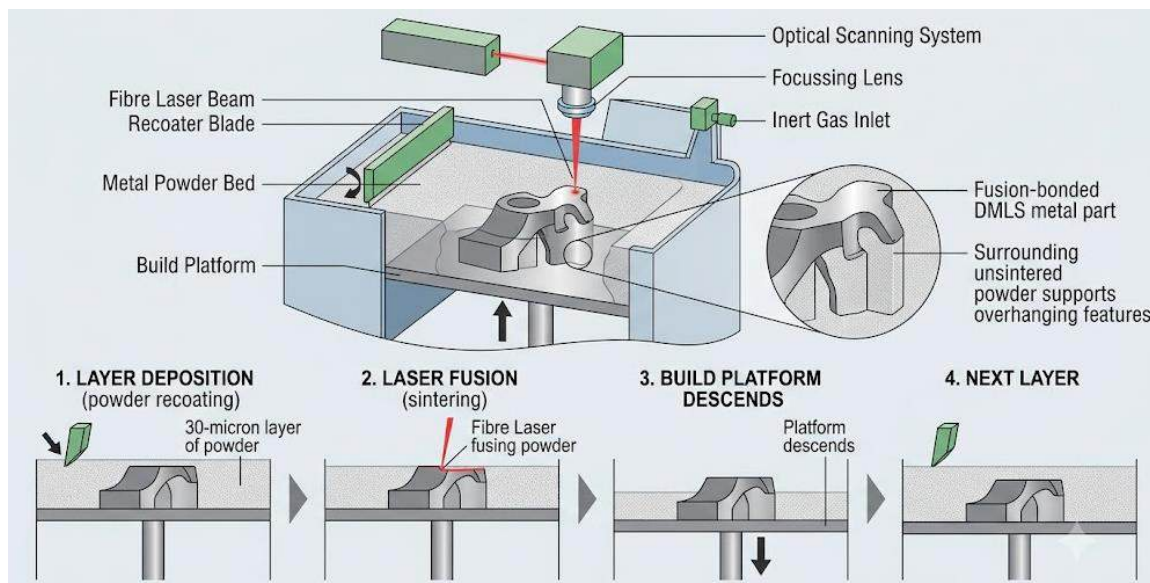


Fig. 3 — Layer-by-layer deposition in a DMLS metal AM build: each 30-micron layer is fusion-bonded by a fibre laser before the build platform descends. The surrounding unsintered powder supports overhanging features.

FACULTY ARTICLE

Additive Manufacturing: Pushing the Boundaries of Design Freedom and Industrial Production

Mr. Nikhil Asok N• Assistant Professor, Department of Mechanical Engineering

In September 2023, ISRO successfully test-fired a PS4 engine in which the thrust chamber and injector head — components that previously required 19 individual parts and hundreds of assembly hours — were printed as a single monolithic piece using Laser Powder Bed Fusion (LPBF). The print took 72 hours. The result was a 97% reduction in parts count, a 19% weight saving, and a propellant mass fraction improvement that translates directly to additional payload capacity. This is what additive manufacturing looks like when it is used not to make existing designs faster, but to make designs that were previously impossible.

LAYER BY LAYER

Powder Bed Fusion & Extrusion

DMLS/SLM fuses metal powder with a laser; FDM extrudes thermoplastic filament. Both build geometry layer by layer, enabling internal channels, lattices, and organic forms impossible with subtractive machining.

DIRECTED ENERGY

Wire Arc & Laser Cladding

WAAM (Wire Arc AM) and DED (Directed Energy Deposition) feed wire or powder directly into a high-energy heat source. Ideal for large near-net-shape billets and repair of high-value components such as turbine blades.

VOXEL DESIGN

Topology & Generative Design

AM's freedom is only realised through design tools that optimise a material distribution at the voxel level. Topology optimisation (SIMP, BESO) and generative design algorithms produce structures 30-70% lighter than conventional equivalents.

Key AM Milestones in India — 2023

Organisation	Achievement	Technology	Impact
ISRO	PS4 rocket engine — single-piece	LPBF (Inconel)	97% parts reduction
HAL	Aircraft structural brackets	DMLS (Ti-6Al-4V)	Airworthy qualification
GE Aviation India	Fuel nozzle production	LPBF	100,000 units/year
DRDO	Guided munition components	SLM (steel)	Confidential
IIT Bombay / IITB-Mona	Biomedical implants	EBM (Ti)	Regulatory trial
MSME sector (Pune)	Conformal cooling moulds	DMLS (tool steel)	30% cycle time saving

Table 3 — Notable AM applications in India, 2023.

The Topology Optimisation Connection

Additive manufacturing's design freedom is only fully exploited through topology optimisation — the computational method of distributing material within a design space to satisfy structural requirements at minimum mass. The process starts with a solid design space, applies finite element analysis under the specified load cases, and iteratively removes material from regions of low stress until a specified mass fraction (typically 20-40% of the original solid) remains.

The results — organic, bone-like structures with intricate internal geometries — cannot be manufactured by any conventional process. DMLS or EBM can build them directly from a CAD file. At SCMS SET, our current research involves topology-optimised satellite brackets in Ti-6Al-4V: preliminary FEA shows a 44% mass reduction versus the baseline machined design, with natural frequency shifted 23% away from the launch vehicle excitation band.

"When ISRO prints an entire rocket engine as one part, the question is not 'can additive manufacturing replace machining?' The question is: 'what can we now design that we could never design before?'"

What Students Must Know About AM

Core AM Competencies for Mechanical Engineers
1. Design for AM (DfAM): overhang rules, support minimisation, lattice design, build orientation selection — fundamentally different from Design for Machining
2. Post-processing: hot isostatic pressing (HIP) for density, heat treatment for microstructure, CNC finish machining of critical surfaces — AM is rarely a complete process in isolation
3. Material properties: AM microstructures differ from wrought equivalents: anisotropy, surface roughness effects on fatigue, porosity — all require characterisation before structural application
4. Quality assurance: X-ray CT scanning, acoustic emission, and in-situ melt pool monitoring are the quality tools of metal AM — not coordinate measuring machines

STUDENT ARTICLE

Designing a Two-Stage Helical Gear Reduction Unit from Scratch: Our DME Project

A step-by-step account of how S6 students turned a Machine Design problem set into a fully detailed, manufacturing-ready gear unit design — and what twelve weeks of iteration taught us about the gap between theory and practice.

Abin Pauly · S7 Mechanical Engineering

Our S6 Design project brief read: 'Design a two-stage helical gear reduction unit for an input power of 15 kW at 1440 rpm, output speed 36 rpm, service factor 1.5, 10-year design life at 8 hours/day.' Twelve words of specification, twelve weeks of work. The first thing we discovered is that gear design is not a single calculation — it is a nested system of decisions, each of which constrains all the others.

TWO-STAGE HELICAL GEAR UNIT — DESIGN SPECIFICATION	
Input power	15 kW at 1,440 rpm
Output speed	36 rpm (total reduction ratio $i = 40$)
Stage 1 ratio	$i = 8$ (pinion: 20T, gear: 160T)
Stage 2 ratio	$i = 5$ (pinion: 18T, gear: 90T)
Module (both stages)	$m = 3$ mm
Helix angle	$\psi = 20^\circ$
Material — pinions	20MnCr5, case-hardened, 58 HRC
Material — gears	C45 steel, normalised, 230 HB
Gear face width	$b = 50$ mm (Stage 1), 45 mm (Stage 2)
Lubrication	ISO VG 220 gear oil, splash lubrication
Housing	Cast iron CI 20, split horizontally
Bearing life (L10)	20,000 hrs (both stages)
Efficiency (calculated)	96.2% (Stage 1: 98.1%, Stage 2: 98.1%)
Total design life	29,200 hrs (10 years $\times$ 8 hrs/day)

STUDENT ARTICLE · CONTINUED

The Lewis Equation and Its Many Corrections

Gear tooth bending stress is classically computed using the Lewis equation: $\sigma = W^t / (b \cdot m \cdot Y)$, where W^t is the tangential load, b the face width, m the module, and Y the Lewis form factor. But real gear design requires the AGMA 2101 or ISO 6336 approach — which applies overload, dynamic, size, load-distribution, and rim thickness factors to arrive at the actual bending stress, then checks against the allowable stress modified for material, life, temperature, and reliability. Our Stage 1 calculation spreadsheet ran to 47 rows before we had a single bending safety factor.

The contact (Hertzian) stress check was equally sobering: $\sigma_H = Z_E Z_H Z_\varepsilon Z_\beta \sqrt{\frac{W_t K_o K_v K_s K_m}{b d_i I}}$

Z_E is the elastic coefficient (191 $\sqrt{\text{MPa}}$ for steel-steel), and the K-factors account for application, dynamics, and load distribution. Our final contact safety factor was $S_H = 1.28$ — just above the minimum 1.2 for 99% reliability. Three iterations of face width and module adjustment were needed to get there.

"The Lewis equation fits on one line. The AGMA 2101 check takes forty-seven. That difference is not bureaucracy — it is everything that real gears experience that an ideal gear does not."

Three Things We Learned That No Lecture Covered

1

Gear ratio allocation is a design variable

We initially split the ratio equally (6.32×6.32). Our guide pointed out that this gives equal shaft speeds and similar gear sizes throughout — simple, but not optimal. Allocating more reduction to Stage 1 (8:1) reduces the Stage 2 input torque significantly, allowing smaller and lighter Stage 2 gears. The textbooks mention this briefly; design practice hinges on it.

2

Housing design drives everything downstream

Our initial housing was undersized at the bearing bores, resulting in excessive shaft deflection that violated AGMA alignment requirements. Redesigning the housing added 300 g of cast iron and saved us from a catastrophic contact stress failure mode that would not have been visible until disassembly.

3

Lubrication is not an afterthought

Splash lubrication works only if the oil level intersects the lowest gear's pitch circle to a specific depth — too shallow and gears run dry, too deep and oil churning losses exceed 3% of input power. We added an oil level sight glass to our design after calculating the churning power loss.

STUDENT ARTICLE

Refrigeration Cycle Analysis and Heat Pump Systems: From the T-s Diagram to a Real Machine

Shaun Antony · S5 Mechanical Engineering

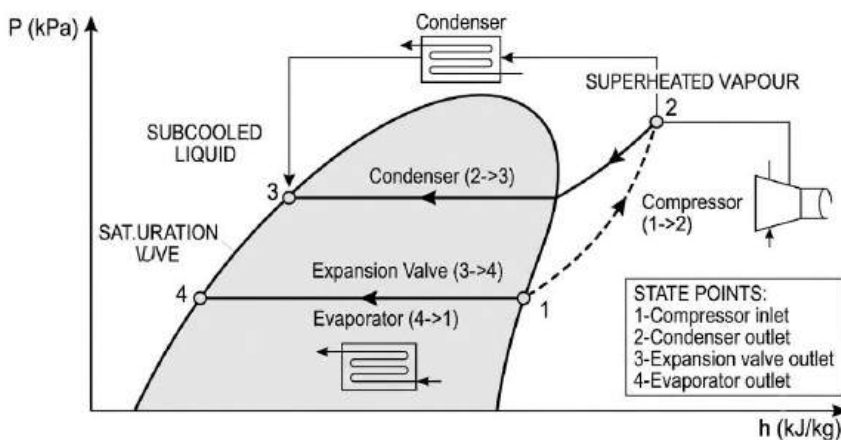


Fig. 5 — Vapour compression refrigeration/heat pump cycle on a P-h diagram. State points 1-4 mark compressor inlet, condenser outlet, expansion valve outlet, and evaporator outlet respectively.

At COP28 in Dubai in December 2023, the Global Cooling Pledge committed 65 countries to phase out hydrofluorocarbon refrigerants and double heat pump deployment by 2030. For the mechanical engineering student just completing a Refrigeration and Air Conditioning module, the timing felt fortuitous — and the subject suddenly felt less theoretical.

My project was to analyse the complete vapour-compression cycle of a split air-source heat pump (ASHP) rated at 5 kW heating capacity, using refrigerant R-32 (a lower-GWP HFO increasingly replacing R-410A). The analysis used both classical T-s/P-h diagram methods and a CoolProp-Python implementation to model the cycle at multiple ambient temperatures — the critical variable for ASHPs in tropical climates like Kerala.

Performance Summary

Parameter	Ideal Cycle	Actual (R-32)	Notes
COP (heating)	5.67	3.42	Actual 39.7% below ideal
COP (cooling)	4.67	2.42	Compressor: 72% isentropic
Compressor work	0.88 kW	1.46 kW	Irreversibilities dominant
Condenser load	5.0 kW	5.0 kW	Fixed (rated output)
Evaporator load	4.12 kW	3.54 kW	Superheat penalty

The Ambient Temperature Effect

Kerala's annual ambient range (18-38°C) creates a 2.1× swing in ASHP heating COP. At 18°C ambient: COP_h = 4.8 (excellent). At 38°C ambient: COP_h = 2.3 (merely adequate). This variability — invisible in a single design-point analysis — is why ASHP systems in tropical climates require variable-speed compressors for seasonal efficiency.

Cycle State Point Analysis — R-32 at 35°C Ambient

State	Point	T (°C)	P (bar)	h (kJ/kg)	
1	Compressor inlet	15	9.38	464.5	Superheated vapour
2	Compressor outlet	82	28.3	508.2	Superheated vapour
3	Condenser outlet	40	28.3	279.8	Subcooled liquid
4	Evaporator inlet	5	9.38	279.8	Two-phase mixture

Where the 39.7% COP Gap Comes From

The ideal (Carnot) COP for heating between 5°C evaporator and 45°C condenser temperatures is $COP_{carnot} = (45+273)/((45+273)-(5+273)) = 7.95$. My actual cycle achieves 3.42 — a gap of 4.53 units of COP, representing thermal and mechanical irreversibilities. Decomposing this gap was the most educational part of the project.

Irreversibility Source	COP Penalty	% of Gap	Mitigation
Compressor inefficiency (72% isen.)	2.24	49.4%	Variable-speed (inverter) compressor
Condenser superheat rejection	0.68	15.0%	Desuperheater / suction-cooled compressor
Evaporator superheat requirement	0.54	11.9%	Electronic expansion valve (EEV)
Pressure drops (pipework & HEX)	0.48	10.6%	Optimise pipe sizing, reduce bends
Refrigerant maldistribution	0.38	8.4%	Distributor nozzle optimisation
Heat losses to ambient	0.21	4.6%	Better insulation of pipework

Table 4 — COP gap decomposition for R-32 ASHP at 35°C ambient.

"The gap between Carnot and reality is not a failure of engineering. It is the engineering problem — and every entry in that table is a doctoral thesis waiting to be written."

STUDENT ARTICLE

Six Weeks at Tata Motors, Pune: What Industry Really Taught Me

An honest account of an S3 internship at one of India's largest automotive manufacturers — the moments of revelation, the culture shock, the mistakes, and the single conversation that changed how I think about engineering.

Rajat Yadav · S3 Mechanical Engineering

I submitted my internship application to Tata Motors in February 2023, mostly because my senior Akin had done his there and came back changed — quieter, more purposeful, using words like 'cycle time' and 'OEE' in casual conversation. I wanted to know what he knew. I got my offer letter in April and spent the next six weeks wondering if I was actually prepared for it.

The honest answer was: partly. My mechanics and thermodynamics were solid. My CAD was competent. But my first morning on the vehicle assembly line — watching a Nexon body travel at 7.2 metres per minute through 214 stations, each executing its operation in exactly the same 53-second window, every single one — I understood something that no lecture had conveyed: that industrial manufacturing is a system, and the system is far more demanding than any of its individual parts.

My Assignment: Assembly Line Ergonomics Study

I was placed in the Industrial Engineering (IE) group under Mr. Ramesh Patil, a senior IE officer who had spent 18 years optimising assembly operations. My project was to conduct a RULA (Rapid Upper Limb Assessment) ergonomics study for three workstations on the trim line where musculoskeletal strain reports had been elevated over the previous quarter.

RULA quantifies posture risk by assigning scores to upper arm, lower arm, wrist, neck, trunk, and leg positions. Scores above 6 indicate a high-risk posture requiring immediate action. My baseline assessment found scores of 7, 6, and 8 at the three target stations — the 8 was a windshield insertion task requiring operators to work with arms raised above shoulder height for 38 seconds of each 53-second takt time. I recommended a height-adjustable lifting fixture. It was approved and fabricated during my internship period.

The Conversation That Changed Everything

On my last day, Mr. Ramesh asked me what I had learned. I gave him a neat answer about RULA and ergonomics. He nodded and said: 'That is the smallest thing you learned. The real thing you learned is that a 53-second cycle time means that every improvement you make — every millimetre you move a part bin, every second you save in a reach — happens 900 times a day, 300 days a year. You have to think at that scale. Not per operation. Per year.' I have not forgotten that.

DEPARTMENT NEWS & HIGHLIGHTS

05–11 Oct 2023	Dr. Raghav G R received acceptance of his book chapter titled "Fabrication Techniques for Printed and Wearable Electronics" for publication in IOP Publication.
09–15 Nov 2023	Dr. Raghav G R delivered a lecture on "Synthesis and Characterization of Nano Materials" for faculty members of SRM Madurai College of Engineering and Technology on 3rd November 2023.
23–29 Nov 2023	Dr. Raghav G R successfully completed the NPTEL certification course on "Advanced Machining Processes" with Elite Silver Certification.
23–29 Nov 2023	Dr. Vidya Chandran successfully completed the NPTEL certification course on "Accreditation and Outcome Based Education" with Elite Silver Certification.
23–29 Nov 2023	Mr. Suraj R won the Best Teacher Coordinator Award for Yi YUVA 2023.
14–20 Dec 2023	Dr. Rag R L was assigned as reviewer of the BME textbook of AICTE by KTU, and was also assigned by CRC Press as reviewer of a new textbook on "Nanorefrigeration – based Vapor Compression Cycle".
21 Dec 2023 – 10 Jan 2024	Dr. Raghav G R published a book chapter entitled "Fabrication Techniques for Printed and Wearable Electronics" in the book "Advances in Flexible and Printed Electronics Materials, Fabrication, and Applications", IOP Publication, December 2023.
21 Dec 2023 – 10 Jan 2024	Dr. Mahesa Rengaraj and Mr. Noel Joseph Gomez successfully completed the AICTE-ATAL Academy FDP on Precision Manufacturing at Mar Athanasius College of Engineering, Kothamangalam (04–09 December 2023).



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