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GEAR UP

RESEARCH DIGEST

EXPLORING IDEAS. ENGINEERING SOLUTIONS.
EMPOWERING TOMORROW.



IDEAS THAT DRIVE PROGRESS



RESEARCH

Advancing knowledge
through inquiry



INNOVATION

Turning ideas into
impactful solutions



SUSTAINABILITY

Engineering for a
better tomorrow



COLLABORATION

Uniting minds.
Creating change.



IMPACT

Driving real-world
transformation



“ WHERE CURIOSITY
MEETS ENGINEERING,
RESEARCH CREATES
REAL-WORLD IMPACT. ”



DEPARTMENT OF MECHANICAL ENGINEERING

SCMS School of Engineering and Technology
Karukutty, Kerala, India

RESEARCH.
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INSTITUTIONAL FRAMEWORK

Vision and Mission

THE INSTITUTION — SCMS SCHOOL OF ENGINEERING AND TECHNOLOGY

VISION

To be a premier institution moulding ethical and socially responsible engineers with emphasis on *Service Learning*.

To be among the top ten institutions in India by 2040, shaping technology innovators and leaders for spearheading research relating to sustainable development goals.

MISSION

Innovative education and research for shaping technoleaders.

QUALITY POLICY

SSET is envisaged as a premier institution offering 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 industry and the diverse societal needs of the institution.

THE DEPARTMENT — MECHANICAL ENGINEERING

VISION

To be a leader in Mechanical Engineering education through sustainable innovation and impactful research.

MISSION

- Integrate service-learning into Mechanical Engineering education to solve local and global challenges.
- Upskill students in emerging technologies to lead design, manufacturing and allied industrial sectors.
- Promote innovative and interdisciplinary research in Mechanical Engineering, emphasising sustainable and ethical practices.

PROGRAMME EDUCATIONAL OBJECTIVES

- **PEO 1** — Graduates will address global challenges by applying technical knowledge and skills.
- **PEO 2** — Graduates will contribute to sustainable development goals through innovative research.
- **PEO 3** — Graduates will engage in lifelong learning and upskilling through industrial projects.

PROGRAMME SPECIFIC OUTCOMES

- **PSO 1** — Apply community-based learning to identify and solve engineering problems.
- **PSO 2** — Analyse and design mechanical systems with emphasis on sustainable development goals through research-based learning.
- **PSO 3** — Apply advanced digital and manufacturing tools in project-based practice.

HOW THIS VOLUME MAPS TO THE DEPARTMENTAL MISSION

Service learning appears wherever a project begins outside the laboratory — the hematology analyzer developed with Agappe Diagnostics, the centering mechanism answering a problem in an HMT workshop, the leaf collector built for the institution's own grounds. Emerging technologies appear in the fuzzy controller, the finite element analysis of a hyper-elastic actuator, and the machine learning framework of the casting study. Sustainability drives the agro-waste reinforcement, the plastic brick machine and the solar desalination work.

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Dr. Rag R L*also Head of Department***ARTICLES 06, 08****Dr. Raghav G R****ARTICLE 01****Mr. Sanju A. C.****ARTICLE 02****Dr. Gibin George****ARTICLE 03****Mr. Rakesh A****ARTICLE 04****Mr. Nikhil Asok****ARTICLE 05****Mr. Anup Kumar T M****ARTICLE 07****Mr. Ajith Kumar R****ARTICLE 10****Mr. Francis Thomas****ARTICLE 11****Dr. Mahesh Rengaraj R****ARTICLE 12****Mr. Eldho Paul***Functional Head (Mechanical), Agappe Diagnostics Ltd.***ARTICLE 06 — EXTERNAL**

INCOMPLETE ATTRIBUTIONS

Article 09 reaches the editorial team without a named project guide, recorded in the source only by institution. It is reproduced as it stands rather than filled in by inference; the Department is invited to supply the attribution for the archival record.

SUBMISSION AND REVIEW

Contributions to Volume 2 are invited from final-year and postgraduate project teams of the Department. Manuscripts are reviewed by the section editor for the relevant domain together with the project guide, against four criteria: soundness of the stated method, sufficiency of the evidence for each claim made, reproducibility of the reported figures and tables, and explicit treatment of limitations.

Framework and design studies are welcome, and are expected to state clearly which of their claims rest on measurement and which on established principle.

FOREWORD

Message from the Editor-in-Chief

It is with great pride that the Department of Mechanical Engineering presents the research digest of the B.Tech graduating batch of 2019–2023. Twelve projects, forty-eight students, and the first attempt to set this Department's final-year work out as a single edited volume rather than as a shelf of separate reports.

The twelve projects exemplify the intellectual curiosity, technical discipline and innovative spirit that define the education at SSET. From pneumatic control systems and nanofibre fabrication to solar desalination, robotic rehabilitation devices and indigenous medical instruments, they address engineering challenges of direct relevance to industry, healthcare and sustainable development.

Each represents months of focused inquiry, hands-on fabrication and systematic validation under the dedicated mentorship of our faculty. The collaborative project with Agappe Diagnostics Ltd. for the Mispa Count X hematology analyzer stands as a testament to the Department's growing industry engagement — a student team working inside a commercial product development cycle, against a specification that had to be manufacturable and serviceable, not merely correct. The contributions to solar desalination, clean energy and sustainable materials demonstrate our students' awareness of global challenges.

Four of the twelve began outside a laboratory: in a diagnostics factory, in an HMT workshop, on the institution's own grounds, and in the data of a steel foundry. That proportion is not accidental. A department that teaches service learning must send students to look at problems where they occur, and the engineering that comes back is different for it — constrained, specific and answerable to somebody.

I would draw attention to one quality in particular. Several of these teams chose the harder framing of their question. The ballistic composite team could have reported that glass fibre performs well; instead they measured it against aramid on four metrics and published the three on which it loses. The centering mechanism team rejected two of their own designs before arriving at the third. That willingness to record what did not work is the beginning of research discipline, and it is more valuable than any single result in these pages.

Gear Up — the title under which this digest first appeared — captures the spirit of this graduating batch: ready, equipped and energised for the challenges ahead. My congratulations to all graduates, and my gratitude to the faculty guides whose dedication made these accomplishments possible.

“A department that teaches service learning must send students to look at problems where they occur — and the engineering that comes back is different for it.”

Dr. Rag R L

*Editor-in-Chief · Professor and Head,
Department of Mechanical Engineering, SCMS School of Engineering and Technology*

VOLUME 1 · MAY 2023

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SYNTHESIS

The Volume at a Glance

Twelve projects, and a departmental research identity visible in outline for the first time.

12 RESEARCH ARTICLES	48 STUDENT AUTHORS	4 RESEARCH DOMAINS	4 EXTERNALLY GROUNDED	1 EXTERNALLY PUBLISHED
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FOUR LINES OF ENQUIRY

Materials and composites. Articles 01–03 each add something to a matrix and measure what changes. The first introduces jackfruit skin ash as a ceramic oxide reinforcement in aluminium — the earliest instance of an agro-waste filler in this series, and a thread the Department has pursued in every volume since. The second tests glass fibre against aramid on four metrics and reports the three where it falls short. The third builds a machine rather than a material, and validates the operating window that machine requires.

Control, robotics and precision systems. The largest group. Articles 04–07 share a preoccupation with systems that resist straightforward control — a compressible gas, a hyper-elastic actuator, a fluidic circuit of forty-four tubes, a worn wheel of unknown radius. In each case the answer is to change the problem rather than strengthen the controller.

Energy, thermal and water systems. Articles 08 and 09 both pursue thermal performance without a power budget: a heat pipe that needs no pump, and a still that needs no fuel. Both became sustained departmental threads.

Sustainable manufacturing and Industry 4.0. Articles 10–12 turn waste into a structural material, sun into mechanical torque, and foundry data into a prediction.

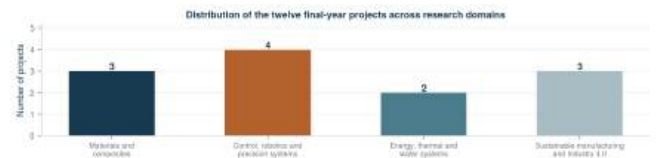


Fig. A. Distribution of the twelve projects across research domains.

WHAT THIS FOUNDING VOLUME ESTABLISHED

Read against the volumes that followed, three commitments visible here proved durable: *agricultural waste as engineering feedstock, passive thermal systems, and solar desalination.*

Article 01's jackfruit ash anticipates the rubberwood ash composites of later cohorts. Article 08's heat pipe anticipates three subsequent oscillating heat pipe studies. Article 09's stepped still anticipates four more. What looks in this volume like twelve independent projects turns out, in retrospect, to be the point at which several research lines began.

Four contributions grounded in an external industrial or field setting

Agappe Diagnostics Ltd. — hematology analyzer	Article 06
HMT workshop — railway wheel reprofiling	Article 07
Institutional grounds — solar leaf collector	Article 11
Steel foundry data — casting defect analysis	Article 12

Fig. B. Four of the twelve contributions took their problem from an external industrial or field setting rather than from the literature.

ARTICLE 01 PART I · MATERIALS AND COMPOSITES

Advancing Thermal and Mechanical Frontiers: the Al-Cu-Gr-AHA Metal Matrix Composite

Althaf K A, Avinash T G, Shabeeb K Nowshad, Yadu R Varma

Project guide: Dr. Raghav G R, Department of Mechanical Engineering
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ABSTRACT — This investigation synthesises and characterises a hybrid metal matrix composite using Al6061 as base matrix, reinforced with copper for thermal flux, graphite for solid lubrication, and a novel agro-waste filler — Artocarpus Heterophyllus Ash derived from jackfruit skin. AHA was produced through a three-stage thermal route: five days of solar drying, primary furnace burning at 750 °C for six hours, and secondary re-burning converting carbon to stable ceramic oxides. Stir casting dispersed all three reinforcements into the melt. The composite achieved a 33.2 % increase in tensile strength to 166.5 MPa and a 15.7 % increase in thermal conductivity to 176 W/m·K, alongside a 44 % reduction in hardness that improves machinability for complex heat-sink geometries.

KEYWORDS aluminium composite · Artocarpus Heterophyllus Ash · graphite · stir casting · thermal conductivity · agro-waste reinforcement

166.5 MPa
TENSILE STRENGTH, +33.2 %

176 W/m·K
THERMAL CONDUCTIVITY, +15.7 %

53.19 HB
HARDNESS, -44 % FOR MACHINABILITY

750 °C
AHA CALCINATION TEMPERATURE

1 · STRATEGIC RATIONALE

Aerospace and automotive sectors have shifted away from monolithic aluminium alloys. Al6061 remains a staple for its versatility but often fails the heat-dissipation requirements of modern high-performance cooling systems. Metal matrix composites allow macro-properties to be tailored through precise integration of dissimilar micro-constituents.

This project pairs conventional reinforcement with an organic agricultural residue, pursuing a localised metallurgical innovation aligned with sustainable manufacturing. Each constituent addresses a distinct property axis.

2 · TURNING ORGANIC WASTE INTO A CERAMIC OXIDE

AHA production follows a deliberate three-stage thermal route. Five days of solar drying eliminate moisture. Primary furnace burning at 750 °C for six hours reduces organic matter to carbon. Secondary re-burning at the same temperature converts that carbon into stable ceramic oxides — SiO₂, MgO₂ and Al₂O₃.

The second burn is what distinguishes this from simply adding ash. Residual organic matter in the melt would volatilise and generate porosity; the fully oxidised product is chemically stable and free of organic impurity before it reaches the aluminium.

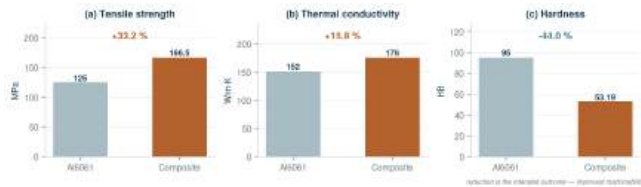


Fig. 1.1. Composite performance against standard Al6061. Tensile strength and thermal conductivity both rise substantially; hardness falls, which in this application is the intended outcome rather than a penalty.

3 · FABRICATION

Synthesis used stir casting, a liquid-state route preferred for scalability and cost. High-shear mechanical agitation creates a vortex ensuring homogeneous distribution of copper, graphite and AHA particles through the molten aluminium and preventing agglomeration. Casting used a split-type die of 50 mm outer diameter and 300 mm length under a double-stage vacuum pump in a stainless steel chamber.

Table 1.2. OES composition of the final specimen

Element	%	Element	%
Aluminium	92.36	Carbon	0.85
Copper	3.57	SiO ₂	0.56
Graphite	1.59	MgO ₂	0.43
Iron	0.35	Chromium	0.19

4 · CHARACTERISATION AND DISCUSSION

Table 1.1. Reinforcement architecture

Constituent	Role	Specific function
Al6061	Matrix	Ductile load-bearing framework, excellent formability
Copper	Thermal catalyst	Transforms the matrix into a heat-management material
Graphite	Solid lubricant	Reduces internal friction; dimensional precision at temperature
AHA (jackfruit skin ash)	Ceramic oxide filler	Nucleating agent reducing porosity; raises interfacial bonding

Morphology. SEM and EDX confirmed successful integration of the hybrid reinforcements, with the processed AHA showing an oxygen weight percentage of 15.51 % — direct confirmation that the desired stable oxides had formed. Polarised optical microscopy revealed significantly refined grain boundaries against monolithic Al6061, indicating that AHA and copper particles acted as heterogeneous nucleation sites during solidification and induced a Hall-Petch strengthening effect.

Table 1.3. Performance against standard Al6061

Property	Al6061	Composite	Change
Tensile strength	125 MPa	166.5 MPa	+33.2 %
Thermal conductivity	152 W/m-K	176 W/m-K	+15.7 %
Hardness	95 HB	53.19 HB	-44 %
Wear rate	3.25 gm/m	4.33 gm/m	increased

Why the hardness reduction is deliberate. Graphite acting as a solid lubricant, together with AHA porosity, disrupts matrix continuity just enough to facilitate chip formation. For a material destined to be machined into complex heat-sink geometries, machinability is a functional requirement rather than a compromise — though the increased wear rate is the price, and the study reports it.

5 · CONCLUSION

The Al-Cu-Gr-AHA composite represents a significant advance in hybrid MMC engineering. The tensile and thermal gains make it a candidate for next-generation aerospace cooling systems and automotive engine components. The work establishes that agro-waste derivatives, properly processed into ceramic oxides, can serve as high-performance and cost-effective reinforcements in advanced metallurgy.

THE TRADE-OFF STATED PLAINLY

Three properties improve and one degrades. Wear rate rises by a third, which the same graphite and porosity that deliver machinability necessarily cause. For a heat sink this matters little; for a sliding or bearing surface it would disqualify the material. The application boundary follows from the data.

A DEPARTMENTAL THREAD BEGINS

This is the earliest of several contributions across the digest series to reinforce an aluminium matrix with an agricultural ash. Later volumes take up rubberwood ash in the same role, which makes this study the origin point of a line of enquiry the Department has since pursued repeatedly.

Metal Matrix Composites

Stir Casting

Agro-Waste Reinforcement

REFERENCES

1. Srinivasan Vishwanath, et al. (2015). Evaluation of mechanical properties of Al-Cu alloy with graphite and fly ash composite. *IJERT*.
2. Rajeshkumar Gangaram Bhandare, et al. (2014). Preparation of aluminium matrix composite by stir casting. *IJCET*.
3. Saravanakumar, K., et al. (2013). Studies on aluminium-graphite by stir casting. *IJSER*.
4. Shridhara, K. T., et al. (2015). Characterisation of Al-Cu alloy with bamboo leaf ash and graphite MMC. *IJERT*.

ARTICLE 02 PART I · MATERIALS AND COMPOSITES

Comparative Analysis and Fabrication of a Glass Fibre Sandwich Composite for Ballistic Protection

Vinay P. Mony, Sanjaykrishna K Menon, Bony Jose, Jishnu Venugopal

Project guide: Mr. Sanju A. C., Assistant Professor

SCMS School of Engineering and Technology, Karukutty · A P J Abdul Kalam Technological University · June 2023

ABSTRACT — This research investigates glass fibre-reinforced polymer as a cost-effective alternative to Kevlar for personal ballistic protection. A glass-fibre sandwich composite in an epoxy matrix, enhanced with silicon carbide particulates and built around a low-density core, was fabricated by hand lay-up and characterised against an aramid benchmark. Tensile performance reached near-parity with Kevlar at 2505.25 N against 2590 N — a shortfall of only 3.3 % — with maximum stroke strain of 4.97 % indicating sufficient ductility. Impact energy absorption showed the largest gap at 168.1 against 248.6 J/mm². The results validate GFRP as a reliable and affordable option for low-velocity ballistic threats across civilian security sectors, where the economic constraint of aramid limits adoption.

KEYWORDS glass fibre composite · ballistic protection · sandwich construction · silicon carbide · hand lay-up · Kevlar comparison

2,505 N

TENSILE FORCE — 3.3 % BELOW KEVLAR

168.1 J/mm²

IMPACT ENERGY ABSORPTION

80 Shore D

MEASURED HARDNESS

4.97 %

MAXIMUM STROKE STRAIN

1 · THE ECONOMIC CONSTRAINT

Ballistic engineering rests on the interplay between a continuous matrix and a dispersed reinforcement phase. In sandwich construction, bonding two high-strength face sheets to a lightweight core optimises strength-to-weight ratio and improves load distribution and energy dissipation during high-strain-rate impact.

The cost of aramid fibre limits its adoption among civilian security, private protection and regional law enforcement. Glass fibre exhibits analogous properties — durability, stiffness, low density — at a significantly lower price, offering a viable pathway to affordable protection where the alternative is often no protection at all.

2 · FABRICATION ROUTE SELECTION

Five methods were compared on tooling cost, production rate and advantage. Resin transfer moulding offers closed-mould precision at high tooling cost; vacuum bagging gives optimal fibre wetting and minimal voids at low rate; filament winding and pultrusion suit cylindrical and constant profiles respectively. Hand lay-up was selected for economic feasibility and geometric adaptability at prototype scale.

The sequence: gel coat for surface quality and demoulding; glass fibre roll stock manually positioned with controlled orientation; epoxy matrix inclusive of SiC applied by pouring and rolling; and FRP rollers for thorough impregnation and air elimination.

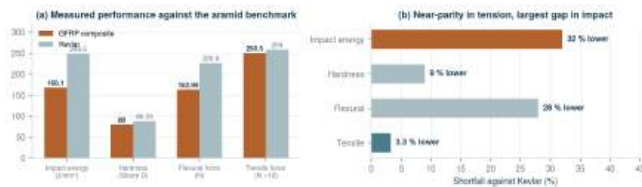


Fig. 2.1. (a) Measured performance across four metrics against the aramid benchmark, with tensile force scaled to share the axis. (b) The shortfall expressed as a percentage — the ordering is the finding, not the individual values.

3 · SANDWICH CONSTRUCTION

To maximise second moment of area and global stiffness without proportionate weight increase, a sandwich construction was employed. Low-density core materials — end-grain balsa, foam or honeycomb — were integrated between GFRP face sheets to provide structural separation and enhance energy dissipation.

4 · LITERATURE THEMES

Three themes framed the design. On fibre architecture, unidirectional composites excel at energy dissipation while woven architectures give superior penetration resistance through interlaced fibre constraint. On interfacial dynamics, load transfer efficacy is governed by the fibre-matrix interface, and moisture absorption and thermal fluctuation degrade the epoxy over service life. On validation, modern ballistic design relies on finite element and multiscale modelling to predict failure before physical prototyping, with all testing adhering to National Institute of Justice protocols.

5 · RESULTS AND DISCUSSION

Table 2.1. Constituents and their roles

Constituent	Contribution
Glass fibre	Primary structural reinforcement — tensile strength and stiffness at low cost
Epoxy resin	Matrix — load transfer between fibres, rigid cross-linked network
Silicon carbide	Particulate additive — global hardness, thermal conductivity, wear resistance

Table 2.2. Mechanical testing against the aramid benchmark

Metric	GFRP	Kevlar	Gap
Impact energy absorption	168.1 J/mm²	248.6 J/mm²	32 % lower
Hardness (Shore D)	80	88.33	9 % lower
Flexural maximum force	162.99 N	226.8 N	28 % lower
Tensile maximum force	2505.25 N	2590 N	3.3 % lower

Reading the pattern. The near-parity in tension and the wide gap in impact are not contradictory; they follow from fracture mechanics. Glass fibre matches aramid in resisting a steadily applied tensile load, but lacks the molecular chain toughness and orientation that lets aramid absorb energy during a high-strain-rate event. Ballistic performance depends on the second property, not the first.

That said, the impact figure remains within acceptable thresholds for low-velocity handgun protection, which defines the application envelope precisely: this material is a credible answer for the civilian and regional security threat profile, and is not a substitute for rifle-rated aramid armour.

6 · CONCLUSION

Kevlar remains the standard for high-velocity rifle protection, but the glass fibre sandwich composite represents a balanced solution — reliable defence against common handgun rounds with significant socio-economic advantage. The cost-effectiveness of hand lay-up combined with glass fibre availability democratises access to personal protection.

STATED FUTURE DIRECTIONS

Hybridisation combining GFRP with thin aramid layers, and optimised core materials, to close the remaining impact performance gap without sacrificing the economic benefit that motivates the work.

EDITORIAL NOTE ON SCOPE

The study characterises mechanical properties against an aramid benchmark; it does not report live-fire ballistic testing to the NIJ protocols it cites. The conclusion that the material suits low-velocity threats is therefore an inference from material properties, appropriately framed as such by the authors, and would require certified ballistic testing before any protective claim could be made.

WHY THE TENSILE RESULT MATTERS MOST

A 3.3 % shortfall on the metric where the two materials are closest is what makes hybridisation plausible: a thin aramid layer need only supply the impact toughness, because the glass fibre already supplies the tension.

Ballistic Composites

Sandwich Construction

Affordable Protection

REFERENCES

1. Bhat, A., Naveen, J., Jawaid, M., et al. Recent advancements in glass fibre reinforced epoxy composites for ballistic protection.
2. Ribeiro, M. P., et al. Mechanical and ballistic properties of epoxy composites reinforced with glass fibres: a comprehensive review.
3. Nurazzi, N. M., et al. Enhancing the energy absorption of glass fibre epoxy composites for bulletproof applications.
4. Soden, P. D., Kaddour, A. S., & Hinton, M. J. Failure criteria in fibre reinforced polymer composites.

ARTICLE 03 PART I · MATERIALS AND COMPOSITES

Fabrication of Nanofibres via Centrifugal Spinning: Design, Optimisation and Morphological Analysis

Shiva Suresh, Mohammed Fahim, Nawjyoth Madhav, P Sashank

Project guide: Dr. Gibin George, Assistant Professor
SCMS School of Engineering and Technology, Karukutty, Kerala

ABSTRACT — This research demonstrates the design and experimental validation of the 'Cyclone' centrifugal spinning machine, establishing forcespinning as a viable high-throughput alternative to electrospinning for nanofibre fabrication. Centrifugal spinning uses mechanical acceleration rather than high-voltage electric fields, bypassing any requirement for solution conductivity and removing the discharge hazard. Polyvinyl alcohol was prepared at 8, 12 and 16 wt% in deionised water by magnetic stirring at 85 °C for two hours. A 12 wt% solution spun above 2400 rpm onto a 320 mm collector produced continuous fine fibres with minimal defects; 8 wt% formed beads and 16 wt% produced short discontinuous chains. The framework provides a foundation for biomedicine, filtration, energy storage and functional textile applications.

KEYWORDS centrifugal spinning · forcespinning · nanofibres · polyvinyl alcohol · Rayleigh-Taylor instability · collector distance

12 wt%
OPTIMAL PVA CONCENTRATION

2,400 rpm
MINIMUM JETTING SPEED AT OPTIMUM

320 mm
REQUIRED COLLECTOR DIAMETER

0.847 N
CALCULATED CENTRIFUGAL FORCE AT 7000 RPM

1 · WHY THE NANOSCALE CHANGES THE RULES

Between 1 and 100 nm, materials transition from Newtonian bulk behaviour to surface-dominated phenomena. The exponential increase in surface-area-to-volume ratio means the atoms at the surface dictate chemical reactivity, catalytic efficiency and mechanical performance. Nanofibres exploit this across biomedicine, where they mimic the extracellular matrix for cellular attachment; filtration, where small pore size and high surface area capture sub-micron contaminants; energy storage, where ion transport is enhanced; and functional textiles.

2 · CENTRIFUGAL SPINNING AGAINST ELECTROSPINNING

Material independence is the substantive economic advantage: bypassing solvent-based dielectric adjustment allows a broader spectrum of polymer emulsions and electrically insulating polymers to be processed without reformulation.

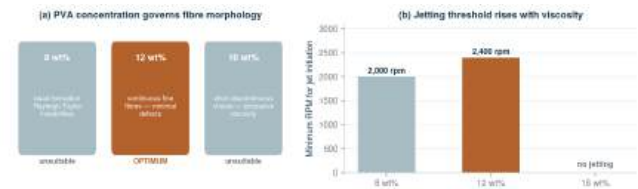


Fig. 3.1. (a) Fibre morphology across the three concentrations tested — the optimum is a narrow window between insufficient chain entanglement and excessive viscosity. (b) Minimum rotational speed for jet initiation; at 16 wt% no continuous jet formed at any speed tested.

3 · MACHINE ARCHITECTURE

Table 3.2. The 'Cyclone' design

Component	Specification
Spinneret	18-gauge syringe, 0.84 mm ID, 12 ml
Drive system	RS 775 DC motor, 12–24 V, 10 A regulator
Collector	Pole design, 0.5 mm bolts, 120 mm spacing, 320 mm diameter

Force validation. With solution density 1240 kg/m³, derived mass 0.0165 kg, rotation radius 0.07 m and angular velocity 733.04 rad/s at 7000 rpm, the centrifugal force $F = m \cdot r \cdot \omega^2 = 0.8466 \text{ N}$ — validated as sufficient to overcome polymer surface tension and internal viscous dissipation.

4 · PARAMETRIC RESULTS

Table 3.1. Comparison of the two routes

Feature	Electrospinning	Centrifugal spinning
Driving force	High-voltage electric field	Mechanical centrifugal force
Production rate	Low — limited by jet stability	High — scalable by RPM and nozzles
Safety profile	High-voltage discharge hazard	Enhanced mechanical safety
Material limitations	Requires dielectric or conductive solutions	Material independent
Morphological quality	Prone to Rayleigh-Taylor instabilities	Reduced bead tendency

Solution preparation. PVA of molecular weight 85,000–124,000 and 96 % hydrolysis was dissolved by magnetic stirring at 85 °C and 600 rpm for 120 minutes in a sealed vial, followed by 60 minutes of ambient stirring to stabilise viscosity before spinning.

Table 3.3. Effect of concentration

Parameter	8 wt%	12 wt%	16 wt%
Fibre quality	Bead formation	Continuous fine fibres	Short discontinuous chains
Minimum RPM for jetting	2000	2400	no jetting
Result	Unsuitable	Optimal	Unsuitable

Two failure modes at opposite ends. At 8 wt% the polymer chains are insufficiently entangled to sustain a continuous jet, so surface tension breaks it into droplets through Rayleigh-Taylor instability and beads form. At 16 wt% viscosity is so high that viscous dissipation exceeds the available centrifugal force and no jet forms at all. The optimum at 12 wt% is the narrow band where chain entanglement is sufficient and viscosity still tractable.

Collector distance. Initial trials at 200 mm failed: flight time was insufficient for solvent evaporation, so the polymer arrived wet. Increasing to 320 mm extended flight time enough for solidification before impact. For water-based solvents the study identifies this distance as a non-negotiable requirement rather than a tunable parameter.

REFERENCES

1. Wang, L., et al. (2017). Multi-compartment centrifugal electrospinning based composite fibres. *Chemical Engineering Journal*.
2. McEachin, Z., & Lozano, K. (2012). Production and characterisation of polycaprolactone nanofibers via forcespinning. *Journal of Applied Polymer Science*.
3. Marjuban, S. M. H., et al. (2023). Recent advances in centrifugal spinning and applications in tissue engineering. *Polymers*.

5 · CONCLUSION

The 'Cyclone' system validates centrifugal spinning as a high-throughput and safer alternative to electrospinning. Three findings define the operating envelope: 12 wt% PVA balances surface tension against chain entanglement; rotational speed must be tuned to solution viscosity rather than set globally; and a 320 mm collection distance is essential for water-based solvents.

STATED FUTURE DIRECTIONS

Antimicrobial wound dressings and bone tissue engineering scaffolds. The high porosity of centrifugally spun mats makes them well suited to mimicking the human extracellular matrix, with potential to accelerate development of biocompatible regenerative materials.

WHAT WAS BUILT, AND WHAT FOLLOWS

The deliverable here is a machine and a validated parameter window rather than a material. That is the correct order: the apparatus and its operating envelope must exist before any specific fibre chemistry can be pursued, and the departmental capability created by this project outlasts the specific PVA result that demonstrates it.

Nanofibres

Forcespinning

Machine Design

Fuzzy Controlled Pneumatic System: Compensating Stiction, Hysteresis and Dead Band

Akhil P Saji, Ashwin T S, Govind V Menon, Jerrin Jordan

Project guide: Mr. Rakesh A, Assistant Professor
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ABSTRACT — This research addresses the non-linearities inherent in pneumatic control systems — specifically hysteresis, stiction and dead band. Equal percentage pneumatic control valves introduce non-linear characteristics that limit the effectiveness of classical PID control. The study evaluates classical PI and PID controllers against a Takagi-Sugeno fuzzy logic model in a MATLAB/Simulink and Arduino environment, driving a 45 mm bore double-acting cylinder through a 5/2 solenoid valve at set-points from 1.5 to 8.0 bar. The fuzzy controller provided superior set-point tracking and a marked reduction in overshoot at every pressure tested, where PID exhibited steady-state error, sustained jitter and a significant overshoot spike at the highest set-point.

KEYWORDS fuzzy logic control · Takagi-Sugeno · pneumatic actuation · stiction · hysteresis · PID comparison · Arduino

4
SET-POINTS EVALUATED

8.0 bar
HIGHEST PRESSURE TESTED

45 mm
CYLINDER BORE DIAMETER

0
OVERSHOOT UNDER FUZZY CONTROL

1 · WHY AIR RESISTS PRECISE CONTROL

Pneumatic power transmission is strategically important in mechatronics for its high power-to-weight ratio and cost-effective safety profile. But the compressibility of air makes precise positioning nearly impossible without a control layer capable of mitigating the stochastic behaviour of a compressed gas.

Effective control also minimises atmospheric leakage and optimises cycle times, directly influencing industrial throughput. The classical PID controller, though well understood, relies on linear assumptions and struggles against the non-linear friction profiles and pressure fluctuations of a real pneumatic circuit.

2 · THE FUZZY ARCHITECTURE

The Takagi-Sugeno scheme operates in three stages. The **fuzzifier** converts crisp input signals into fuzzy sets through membership functions, categorising variables into linguistic terms — low, medium, high. The **rule base** executes if-then logic, integrating expert knowledge directly into the control loop. The **defuzzifier** processes the aggregated result back into a crisp PWM signal to actuate the hardware.

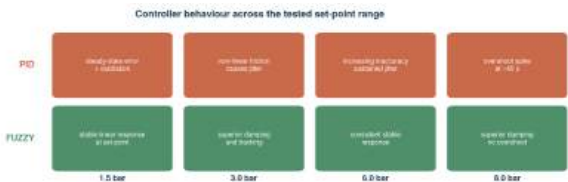


Fig. 4.1. Observed controller behaviour at each tested set-point. PID degrades progressively with rising pressure; the fuzzy controller holds a consistent response across the full range.

3 · HARDWARE

Table 4.2. System specification

Component	Specification
Air compressor	3 hp / 2 kW, max 12 bar, 500 L
Double acting cylinder	45 mm bore diameter
Solenoid valve	12 V DC, 5 W, 5/2 way
FRL unit	Max pressure 10 bar
Pneumatic tubing	PVC, 8 mm diameter

Flow originates at the two-stage compressor, passes through the FRL unit for conditioning, and enters the 5/2 solenoid valve via a T-joint with a monitoring pressure gauge. The Arduino-driven valve directs air to either the extension or retraction port of the cylinder.

4 · RESULTS AND DISCUSSION

Table 4.1. Theoretical comparison

Parameter	Classical PID	Fuzzy logic
System linearity	Assumes linearity	Compensates for non-linearity
Adaptability	Manual re-tuning per pressure	Reasons with imprecise information
Expert knowledge	Mathematical tuning of gains	Incorporates linguistic rules directly
Noise robustness	Susceptible; needs filtering	Robust to noise and uncertainty

Table 4.3. Controller response by set-point

Set-point	PID behaviour	Fuzzy behaviour
1.5 bar	Steady-state error and oscillation	Stable linear response at set-point
3.0 bar	Non-linear friction causes jitter	Superior damping and tracking
6.0 bar	Increasing inaccuracy, sustained jitter	Consistent stable response
8.0 bar	Overshoot spike at ≈40 s	Superior damping, no overshoot

Why PID fails here. The failure is attributed to saturation, noise and stiction. PID cannot compensate for the stick-slip phenomenon or the hysteresis of an equal percentage control valve, because both are discontinuous behaviours that no fixed set of linear gains can anticipate. The controller responds to error it has already accumulated, by which point the valve has broken free and overshoot.

The fuzzy controller mitigates this through a wider operating range and adaptive gain, tuning its response instantaneously to compensate for mechanical resistance rather than reacting to the consequences of it.

5 · CONCLUSION AND OUTLOOK

Classical PID controllers, while suitable under linear conditions, are insufficient for high-performance non-linear pneumatic systems. The fuzzy logic controller effectively compensated for the stiction, hysteresis and dead band associated with equal percentage valves. The broader implication is that fuzzy systems suit industrial automation because they integrate human-like reasoning without requiring exhaustive mathematical modelling of a plant that resists being modelled.

STATED FUTURE OUTLOOK

High-resolution real-time sensors for closed-loop feedback, refining fuzzy customisability for complex multi-variable industrial environments.

EDITORIAL NOTE

Results are reported as observed behaviour at four set-points rather than as quantified overshoot, settling time or steady-state error. The qualitative comparison is consistent and clearly favours the fuzzy controller, but numerical performance indices would allow the improvement to be stated as a magnitude rather than a direction.

THE PRACTICAL ARGUMENT

A PID loop requires re-tuning whenever supply pressure changes. A fuzzy rule base written in linguistic terms does not. In a workshop where the compressor is shared and line pressure drifts through the day, that difference decides whether a control scheme survives contact with the plant.

Fuzzy Control

Pneumatics

Mechatronics

REFERENCES

- Mishra, P., Kumar, V., & Rana, K. P. S. A novel intelligent controller for combating stiction in pneumatic control valves.
- Situm, Z., Pavkovic, D., & Novakovic, B. Servo pneumatic position control using fuzzy PID gain scheduling.
- Armstrong-Helouvry, B., et al. A survey of models, analysis tools and compensation methods for control of machines with friction.
- Ali, H. I., et al. A review of pneumatic actuators — modeling and control.
- Rahmat, M. F., et al. Non-linear modeling and cascade control of an industrial pneumatic actuator system.

ARTICLE 05 PART II · CONTROL, ROBOTICS AND PRECISION SYSTEMS

Design and Implementation of a 3D-Printed Soft Robotic Digit with Split-Bellow Actuators for Neurological Rehabilitation

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Project guide: Mr. Nikhil Asok, Assistant Professor
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ABSTRACT — This research presents the design, fabrication and characterisation of a 3D-printed soft robotic digit using split-bellow fluidic actuators for neurological hand rehabilitation. Fused deposition modelling in thermoplastic elastomer TPE 83A produced a compliant architecture leveraging hyper-elastic constitutive behaviour for motion generation. Unlike continuous bellows, the split-bellow design places active deformation elements only at the anatomical joints, with rigid segments between them acting as phalanges so that fluidic energy concentrates where flexion is required. Finite element analysis in ANSYS using the Yeoh third-order model guided the geometry, and the prototype achieved joint-specific flexion consistent with activities of daily living at 30 kPa, mitigating the ballooning failure mode that afflicts continuous-bellow designs.

KEYWORDS soft robotics · split-bellow actuator · TPE 83A · fused deposition modelling · Yeoh model · neuroplasticity · rehabilitation

30 kPa

OPERATING PRESSURE
ACHIEVED

3

ANATOMICAL JOINTS ACTUATED
INDEPENDENTLY

420 %

ELONGATION AT BREAK, TPE
83A

0.15 mm

PRINT LAYER HEIGHT

1 · REHABILITATION THROUGH REPETITION

Post-stroke hand paralysis creates a substantial socio-economic burden, often producing long-term hemiparesis that severely restricts activities of daily living. Clinical recovery relies on neuroplasticity — the central nervous system's capacity for structural and functional reorganisation — and current therapeutic paradigms such as mirror therapy emphasise high-repetition movement to reinforce neural pathways. They are hampered by cost and by the requirement for professional supervision.

Soft robotic orthoses represent a shift: compliant, biocompatible materials offer a safer human-machine interface and the mechanical intelligence to assist natural motion at a fraction of the cost of rigid counterparts. This project addresses single-digit rehabilitation as the foundation for a complete five-finger glove.

2 · THE SPLIT-BELLOW PRINCIPLE

Active deformation elements are placed only at the metacarpophalangeal, proximal interphalangeal and distal interphalangeal joints. Rigid segments between them act as phalangeal bones, concentrating all fluidic energy at the joints to maximise mechanical efficiency.

The bending moment at each joint is dictated by the leverage arm created by r_1 and wall thickness. Increasing r_1 relative to r_2 lengthens the moment arm, producing greater flexion at lower pressure. The base thickness creates a passive tension layer resisting expansion, forcing the actuator into bending rather than simple elongation — the strain-limiting backbone principle.

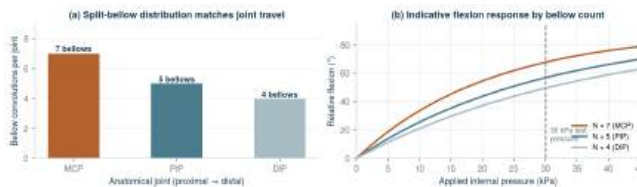


Fig. 5.1. (a) Bellow convolutions allocated per joint, decreasing from proximal to distal in line with required travel. (b) Indicative flexion response by bellow count, with the 30 kPa test pressure marked.

3 · ADDITIVE MANUFACTURING OVER CASTING

Table 5.2. Manufacturing route comparison

Feature	3D printing (FDM)	Traditional casting
Design flexibility	Complex internal geometry, tailored anisotropy	Limited by mould geometry
Prototyping	CAD to prototype; patient-specific	New mould per iteration
Material selection	Tailored elastomers across Shore hardness	Restricted to castable silicones
Motion tuning	Wall thickness and layer adhesion control	Uniform properties limit tuning

4 · COMPUTATIONAL ANALYSIS

FEA in ANSYS used the Yeoh third-order model, which accurately characterises the stress-strain relationship of elastomers under large deformation. Geometry was meshed with high-order elements, one end designated fixed support and outer walls frictionless, with a 30 kPa internal pressure load applied to the inner chambers. Results confirmed that increased bellow count and larger r_1 both significantly reduce the pressure required to reach a target bending angle.

5 · MATERIAL, FABRICATION AND TESTING

Table 5.1. Geometric parameters

Parameter	Definition	Value
b	Base thickness	3 mm
t	Wall thickness	1 mm
r ₁	Large chamber internal radius	7 mm
r ₂	Small chamber internal radius	3 mm
N	Bellow counts — MCP, PIP, DIP	7, 5, 4
a ₁	Length of one convolution	5 mm

Table 5.3. TPE 83A properties

Property	Value
Density	1.14 g/cm ³
Tensile strength	32 MPa
Elongation at break	420 %
Modulus of elasticity	0.345 GPa

Material choice. TPE 83A was selected over TPU-95A for superior viscoelastic properties and Shore hardness, giving a more delicate hand feel for medical application while maintaining high inter-layer adhesion — the property that determines whether a printed pneumatic chamber holds pressure at all.

Print parameters. Fabrication on a Make3d Pratham Series 3.0 FDM printer at 0.15 mm layer height, 30 % infill, 240 °C extruder temperature and 40 mm/s, with four to five adjacent perimeters specified expressly to prevent leakage through the printed wall.

Pneumatic circuit. A 3/2 direction control valve governs fluidic power. De-energised, the inlet is blocked and the actuator port connects to exhaust, venting the chamber and allowing digit extension. Energised, compressed air enters the internal chambers, inducing expansion and flexion.

6 · CONCLUSION

The split-bellow soft robotic digit achieved joint-specific flexion at 30 kPa using TPE 83A, effectively mitigating the ballooning failure mode. The design demonstrates affordable rehabilitation engineering at a fraction of clinical-grade device cost, and the validated single digit serves as the foundation for a complete five-finger rehabilitation glove.

STATED FUTURE WORK

Integration of soft curvature sensors for real-time kinematic feedback; variable stiffness through hybrid multi-material printing; and addressing residual air leakage through increased wall perimeters or post-printing vapour smoothing.

WHY LEAKAGE DOMINATES THE DESIGN

Almost every fabrication decision in this project — perimeter count, layer height, extruder temperature, material selection — is ultimately about inter-layer adhesion. A printed pneumatic actuator fails at its layer boundaries long before it fails in the bulk material, which is why the print parameters carry as much design weight here as the geometry does.

EDITORIAL NOTE

Flexion is reported as achieved and consistent with daily-living requirements; measured joint angles against applied pressure are not tabulated. The curvature sensors named in the future work would supply exactly that data.

Soft Robotics

Additive Manufacturing

Rehabilitation Engineering

REFERENCES

- Zhao, S., et al. (2022). 3D-printed soft pneumatic robotic digit based on a parametric kinematic model.
- Gonzalez, D., et al. (2022). Characterisation of 3D printed pneumatic soft actuators.
- Gariya, N., et al. (2023). Experimental study on a bending type soft pneumatic actuator.
- Stano, G., et al. (2020). Additive manufacturing for soft robotics: airtight monolithic PneuNets.

ARTICLE 06

PART II · CONTROL, ROBOTICS AND PRECISION SYSTEMS

Optimisation of 3-Part Hematological Analyzers via Integrated Microfluidic Manifolds

Aswin Surendran, Athul M, Sandeep Biju, Sanjay T J

Project guide: Dr. Rag R L, Professor and Head of Department · External supervisor: Eldho Paul, Functional Head (Mechanical), Agappe Diagnostics Ltd. SCMS School of Engineering and Technology, Karukutty — in collaboration with Agappe Diagnostics Ltd.

ABSTRACT — This research optimises the Mispa Count X — the first indigenous three-part hematology analyzer in India — by replacing high-complexity rotary valves and intertwined tubing with a passive shear block mechanism and a PMMA-based microfluidic manifold fabricated by stereolithography. The integrated manifold reduces 44 separate tubes to a single component, cutting total fluid path length from 2,280 to 1,313 mm and removing 3,790.64 mm³ of internal volume, with a finished prototype mass of 956.49 g. Darcy-Weisbach and Hagen-Poiseuille analysis confirmed the shorter integrated channels introduce no excessive resistance that would compromise aspiration accuracy. The work shifts hematological analysis toward a compact, low-maintenance indigenous solution for the Indian diagnostic market.

KEYWORDS hematology analyzer · microfluidic manifold · PMMA · stereolithography · Coulter principle · indigenous diagnostics · Agappe

44 → 1

TUBING LINES CONSOLIDATED

3,790 mm³

INTERNAL FLUID VOLUME
REMOVED

42 %

REDUCTION IN TOTAL PATH
LENGTH

< 1 min

DIAGNOSTIC RESULT TIME

1 · INDIGENOUS DIAGNOSTICS

The global in-vitro diagnostics landscape is defined by a drive toward indigenous manufacture and technological self-reliance. This project, a collaboration between the Department and Agappe Diagnostics Ltd., targets the Mispa Count X, aiming to rival international benchmarks such as the Coulter DxH 800 and Sysmex XN 1000 while providing a locally manufactured alternative.

Three-part analyzers work on the Coulter principle: particles suspended in a conductive fluid pass through a small aperture, each cell displacing its own volume and causing a momentary impedance spike whose magnitude is proportional to cell volume. It remains the cost-effective benchmark for three-part analysis in resource-limited clinical settings.

2 · THE DESIGN BOTTLENECK

Traditional three-part analyzers carry over forty individual tubing lines that reduce flow efficiency; conventional rotary shear valves are prohibitively expensive; and pressure variation between the RBC and WBC baths requires extra angled valve tubes that clutter the internal architecture further.

The shear block mechanism resolves this: a passive abrasion device for sample dilution that simplifies the mechanical requirement and reduces the need for complex control equipment. Replacing an active rotary valve with a passive component removes a cost centre and a failure mode at once.

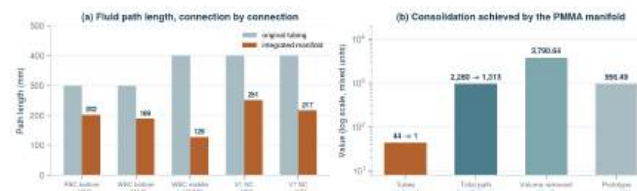


Fig. 6.1. (a) Fluid path length before and after integration, connection by connection. (b) The consolidation achieved, on a logarithmic axis since the four quantities span three orders of magnitude.

3 · MANUFACTURING ROUTE

Stereolithography was used to fabricate the manifold from a SolidWorks model. SLA is decisively superior to subtractive machining or injection moulding in an R&D context: it creates internal serpentine channels and interconnected chambers that cannot be machined by any conventional route, and its resolution holds the geometric fidelity that microchannels require to avoid reliability failure.

4 · FLUIDIC ARCHITECTURE

The operating sequence runs from sample aspiration through dilution in the WBC and RBC baths, photometry for haemoglobin, and waste removal. Key subcomponents are the impedance counting chambers, a syringe bath acting as precision pump for aspiration and dispensing, two-way and three-way solenoid valves regulating flow, and a vacuum chamber at −3.3 psi for waste transport.

Darcy-Weisbach and Hagen-Poiseuille relations were applied to calculate potential head loss due to friction, confirming mathematically that the shorter integrated PMMA channels do not introduce resistance sufficient to cause pump failure or inaccurate aspiration relative to the original 44-tube system.

5 · QUANTITATIVE RESULTS

Table 6.1. PMMA in biomedical service

Property	Benefit
Optical clarity	Immediate visual troubleshooting of fluid flow
Biocompatibility	Chemically inert; safe with samples, lyse and diluent
Physical robustness	Impact resistant and far lighter than glass
Weathering resistance	No yellowing under UV exposure

Table 6.2. Fluid pathway optimisation

Connection	Old (mm)	New (mm)	Volume removed (mm ³)
RBC bottom – V2 C	300	202.41	434.16
WBC bottom – V1 C	300	189.26	492.66
WBC middle – V7 NO	400	127.86	540.35
V1 NC – VC5	400	251.42	661.01
V7 NC – VC4	400	217.30	812.80
Total	2,280	1,313.34	3,790.64

The finished prototype has a total mass of 956.49 g, overall volume of 181,184.17 mm³ and surface area of 50,516.66 mm². A colour-coding system — red for waste, green for diluent, orange for lyse, blue for air — facilitates rapid maintenance by a technician who has never seen the unit before, which matters more in field service than any single dimension in the table above.

Shortened pathways and optimised fluidic resistance together enable diagnostic results in under one minute.

6 · CONCLUSION

Microfluidic manifold integration represents a significant advance in analyzer design. Eliminating heavy metal housing and replacing complex mechanical rotary valves with a passive abrasion mechanism yields a cost-efficient and highly maintainable instrument. External attachment of the primary working components — pistons, valves, baths — ensures serviceability with minimal technical overhead.

The collaboration demonstrates the potential for producing affordable diagnostic equipment within India, offering a model for indigenous medical technology.

THE INDUSTRIAL COLLABORATION

This is the only contribution in the volume developed jointly with a commercial partner against a product already in the market. The constraint that follows — that any change must be manufacturable, serviceable and cheaper than what it replaces — shapes the engineering more than any academic specification could.

EDITORIAL NOTE

Geometric and mass reductions are quantified precisely. Analytical validation of flow resistance is reported as confirmed rather than tabulated, and clinical correlation of counts against the original fluidics is not reported — the step that would be required before the redesigned manifold could enter production.

Medical Devices

Microfluidics

Industry Collaboration

REFERENCES

1. Rhyner, M. N. The Coulter principle for analysis of subvisible particles.
2. Verpoorte, E. M. J., et al. Three-dimensional micro flow manifolds for miniaturised chemical analysis systems.
3. Vijayan, D. K., et al. Mispac Count X. *International Journal of Clinical Biochemistry and Research*.
4. Schulte, T. H., et al. Microfluidic technologies in clinical diagnostics. *Clinica Chimica Acta*.

ARTICLE 07 PART II · CONTROL, ROBOTICS AND PRECISION SYSTEMS

Advanced Mechanical Self-Centering Mechanisms for Railway Wheel Reprofilng in Industrial Lathes

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Project guide: Mr. Anup Kumar T M, Assistant Professor
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ABSTRACT — This research develops a low-cost, high-reliability mechanical centering mechanism for railway wheel reprofiling lathes as an alternative to failure-prone laser displacement sensors. Leveraging the geometric chord theorem, a V-shaped centering handle with roller tips achieves precise wheel-axis alignment without electronic sensitivity: the wheel is lifted until its circumference contacts both rollers, at which point its centre necessarily lies on the angular bisector of the handle, regardless of wheel diameter. A magnetoresistive angle sensor detects when that bisector coincides with the lathe axis and halts the hydraulic lift. Total estimated industrial-grade cost is ₹18,740, against proprietary laser systems that fail under the vibration, thermal instability and metallic dust contamination of a working reprofiling shop.

KEYWORDS railway wheel reprofiling · chord theorem · self-centering · laser displacement sensor · CNC lathe · mechatronics

₹18,740

TOTAL ESTIMATED COST

3

DESIGN ITERATIONS EVALUATED

8–10 mm

DEPTH OF CUT THE MECHANISM MUST SURVIVE

2

ROLLER CONTACT POINTS DEFINING THE CHORD

1 · WHY LASERS FAIL IN THIS ENVIRONMENT

CNC surface wheel lathes reprofile both wheels of an axle simultaneously, taking deep cuts of 8 to 10 mm. Centering is conventionally achieved with laser displacement sensors, and the working environment defeats them.

Critical geometric parameters for successful reprofiling include flange height and width, flange thickness, tread contour, wheel diameter and width, and back-to-back distance across the axle. All depend on the wheel being correctly centred before the first cut.

2 · THREE DESIGN ITERATIONS

- **Design 1, rejected.** Touch-sense probe with hydraulic lift — relied on an assumed wheel radius, and worn wheels have variable radii, so true axial alignment could not be guaranteed.
- **Design 2, rejected.** Mechanical probe measuring axis deviation — calibration became overly complex across the range of wheel diameters encountered.
- **Design 3, selected.** V-shaped centering handle with roller tips — the wheel is lifted until its circumference contacts both rollers, naturally aligning its centre with the angular bisector.



Fig. 7.1. (a) Component cost breakdown for the industrial-grade mechanism. (b) The three laser sensor failure modes that a purely mechanical approach removes rather than mitigates.

3 · THE GEOMETRIC PROOF

The mechanism is governed by the chord theorem and its converse. The two roller contact points serve as endpoints of a chord AB across the wheel; the angular bisector OD of the handle necessarily passes through the wheel centre O.

In triangles AOD and BOD, angle ADO equals angle BDO at 90° since OD is the bisector; OA equals OB as radii of the wheel; and OD is common. By the RHS axiom the triangles are congruent. Alternatively, given AD = DB and OA = OB, the SSS axiom confirms congruency.

The consequence is the whole design: the wheel centre always lies on the bisector, and when the bisector aligns with the lathe axis, centering is achieved *regardless of wheel diameter*. A worn wheel and a new one are handled identically, with no measurement, no calibration and no assumption about radius.

4 · CONSTRUCTION AND VALIDATION

Table 7.1. Laser displacement sensor failure modes

Failure mode	Mechanism	Impact
Thermal interference	Continuous operation drives electronic drift	Skewed data, inaccuracy
Signal attenuation	Metallic dust, humidity and lubricant mist disrupt the beam	Inconsistent centering
Vibration sensitivity	Shock from deep cuts misaligns the optics	Frequent recalibration, lost productivity

Table 7.2. Component specification

Component	Qty	Material	Function
Column	1	Cast iron	Rigid support and vibration damping
Horizontal spindle	1	Stainless steel	Withstands axial force; horizontal travel
Centering arm	1	HCHCR steel	V-shaped structure carrying the rollers
Roller	2	Babbitt metal	Smooth circumferential contact
Helical spring	1	Stainless steel	Constant contact and spindle repositioning
Roller pins	3	HCHCR steel	High-strength pivots

Mechatronic synergy. An SCA60C magnetoresistive angle sensor measures the relative movement of the centering handle against the spindle. When the angular bisector coincides with the lathe axis, the sensor triggers the hydraulic lift to stop, positioning the wheel for the magnetic chucks to engage. The electronics here read a mechanical condition rather than measuring a distance — which is why dust and vibration do not defeat them.

The design was validated by FDM PLA 3D printing before committing to full-scale manufacture, following an eight-stage mechatronics design process from problem identification through to documentation.

5 · ECONOMIC AND OPERATIONAL IMPACT

Table 7.3. Cost breakdown

Component	Cost (₹)
Column and base	10,000
Horizontal spindle	3,200
Centering handle	2,500
Sensor unit SCA60C	2,200
Rollers and pivot pins	840
Total	18,740

By eliminating laser optics the system substantially reduces maintenance frequency and calibration time. Unlike sensor units prone to obsolescence and requiring stable power, these mechanical components can be repaired or replaced on site, ensuring a longer operational lifespan in a workshop setting.

CONCLUSION

Leveraging the chord theorem and integrating magnetoresistive angle sensing delivers a solution that is durable, versatile and cost-effective. The mechanism maintains precision without the liability of electronic sensitivity in demanding workshop environments.

A GEOMETRIC ANSWER TO AN INSTRUMENTATION PROBLEM

The elegance here is that a two-thousand-year-old theorem removes the need for a sensor that costs more and fails more often. The design does not measure the wheel; it constrains it so that measurement becomes unnecessary.

Industrial Automation

Railway Engineering

Precision Mechanisms

REFERENCES

1. Parmar, P. N., et al. (2014). Investigation on automation of lathe machine. *IJETAE*, 4(5).
2. Jhala, S., et al. (2015). Design and development of automation of loading and unloading to DX-100 CNC turning center. *IJSTE*, 1(11).
3. Sun, J., et al. (2013). A vision measurement model of laser displacement sensor and its calibration method. Elsevier.
4. Koleva, S., et al. (2015). Influence of mechanical deformations on machining accuracy of complex profiles on CNC lathes. *MESIC* 132.

Thermal Management Optimisation: Electric Vehicle Battery Cooling Systems Using Heat Pipes

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Project guide: Dr. Rag R L, Professor and Head of Department
SCMS School of Engineering and Technology, Karukutty · A P J Abdul Kalam Technological University · June 2023

ABSTRACT — This research investigates heat pipe integration as an advanced thermal management solution for electric vehicle lithium-ion battery packs. As the automotive industry moves toward high-performance electric propulsion, managing extreme local heat flux concentration has become a safety and performance mandate rather than a design refinement. Heat pipes use the latent heat of vaporisation within a vacuum-sealed envelope to transport significant thermal loads across minimal temperature gradients, ensuring isothermal operation of the battery module without parasitic power consumption. The work proceeded through analytical modelling of heat generation rates, CFD validation of phase-change cycles and capillary limits in ANSYS Fluent, and experimental prototyping into a simulated battery environment.

KEYWORDS heat pipe · latent heat transport · lithium-ion battery · isothermal operation · capillary wick · passive cooling

20–40 °c OPTIMAL CELL OPERATING WINDOW	0 w PARASITIC POWER CONSUMED	3 VALIDATION STAGES — ANALYTICAL, CFD, PHYSICAL	0 MOVING PARTS IN THE COOLING LOOP
--	--	--	--

1 · THERMAL STABILITY AS A SAFETY MANDATE

The evolution of sustainable transport is intrinsically linked to the thermal stability of high-capacity lithium-ion packs. Without advanced cooling, the scope of battery management research is constrained: inefficient thermal regulation prevents safe simulation of ultra-fast charging protocols and high-discharge testing.

2 · WHY PHASE CHANGE BEATS CONVECTION HERE

A heat pipe transports heat as latent rather than sensible energy: working fluid evaporates at the hot end, travels as vapour, condenses at the cold end and returns by capillary action through an internal wick. Because the phase change occurs at essentially constant temperature, the device transports large thermal loads across a very small temperature difference — which is precisely what a battery pack requires.

The capillary return is what makes the system passive and orientation-tolerant. A pumped loop needs power and fails if the pump fails; a wick needs neither, and continues to function as the vehicle climbs, corners or brakes.

STANDARD COOLING	HEAT PIPE INTEGRATION
Heat transfer mechanism Sensible heat — convection/conduction	Latent heat — phase change
Operational energy High — parasitic pump and fan loads	Passive — zero auxiliary power
Temperature uniformity Moderate — prone to local hot spots	Exceptional — isothermal
Reliability Low — moving parts and leak points	High MTBF — sealed, no moving parts

Fig. 8.1. The comparison that motivates the work. Every row favours the passive device; the row not shown is absolute heat transfer capacity, where a pumped loop retains the advantage.

3 · METHODOLOGY

- **Thermal modelling.** Analytical calculation of heat generation rates within the Department.
- **CFD validation.** Simulation of phase-change cycles and capillary limits within the heat pipe framework using ANSYS Fluent.
- **Experimental prototyping.** Physical integration of heat pipe assemblies into a simulated battery environment at the Karukutty facility.
- **Submission and defence.** Formal certification of the research as a verified body of work, June 2023.

The research was conducted under the direct supervision of the Head of Department acting also as project guide, which the authors note as ensuring both the integrity of the thermal data and the safety of high-voltage testing protocols.

4 · STRATEGIC CONCLUSIONS

Table 8.1. Thermal challenges and consequences

Challenge	Description	Consequence
Heat accumulation	Rapid internal rise during aggressive drive cycles and fast charging	Capacity fade, electrolyte decomposition
Efficiency loss	Deviation from the narrow 20–40 °C window	Degraded electrochemical efficiency, reduced cycle life
Safety risk	Local hot spots triggering exothermic reactions	Thermal runaway — fire or explosion

Phase-change cooling is identified as the most viable path for next-generation high-performance electric vehicles. By decoupling cooling performance from parasitic energy loss, the system enhances both safety and operational lifespan.

Superior heat flux management. Heat pipes mitigate the intense local heat flux concentrations characteristic of modern high-density cells — the specific failure geometry that air cooling handles worst, because a hot spot inside a pack is not reachable by bulk airflow.

Passive reliability. The absence of moving parts gives high mean time between failures and reduces long-term maintenance. In a sealed pack that will not be opened during the vehicle's service life, this is not a convenience but a requirement.

Inherent safety. Isothermal operation is the most effective defence against the temperature gradients that precede thermal instability. A pack that is uniformly warm ages uniformly; a pack with a 5 °C spread ages differentially, and the weakest cell governs the whole.

The reduction in cooling system volume and weight translates directly into increased vehicle range and efficiency — a compounding benefit, since a lighter thermal system requires less cooling in turn.

EDITORIAL NOTE ON EVIDENCE

This contribution reports its methodology and strategic conclusions but does not tabulate measured thermal resistance, temperature or heat flux figures. The comparative case for heat pipes is argued from established principles and from the CFD and prototyping work described, rather than from a dataset presented here. Readers seeking quantified performance for this device class will find it in the oscillating heat pipe studies of later volumes, which take up the same question with numbers.

WHERE THIS LEADS

This is the earliest passive battery cooling study in the digest series, and the Department returned to it repeatedly in subsequent years — three further projects across later volumes optimise filling ratio, tube geometry and working fluid for oscillating heat pipes serving the same application. Read in sequence, the four form a sustained line of enquiry that begins here.

THE UNRESOLVED QUESTION

A passive device has a ceiling: beyond some heat flux, the capillary limit is exceeded, the wick dries out and transport collapses. Establishing where that ceiling sits for a realistic pack geometry is the measurement this line of work most needs, and none of the four studies has yet reported it.

Passive Cooling

Electric Vehicles

Phase-Change Heat Transfer

REFERENCES

1. Certified as an original and bonafide work of academic research at SCMS School of Engineering and Technology, Karukutty, June 2023. No external reference list was supplied with this contribution.

Advancements in Stepped Solar Still Desalination: Continuous Water Circulation and Performance Optimisation

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Published: ISSN 2321-9653 · DOI 10.22214/ijraset.2023.53641

ABSTRACT — This study evaluates a modified stepped solar still integrated with a storage tank and continuous water circulation. A cotton black absorber enhances water distribution by capillary action and an external galvanised absorber plate maximises thermal capture, while metal fins create localised hot spots and weirs force water into a helical path that increases residence time against the absorber. Freshwater productivity rose 43–53 % against conventional basin stills, with peak daily efficiency of 61 % against a 42 % conventional benchmark. Total dissolved solids fell from 57,100 to 41 mg/L for seawater, a 99.93 % reduction. Storage tank integration extended the production window by 150 minutes past sunset on residual thermal energy.

KEYWORDS solar desalination · stepped solar still · cotton black absorber · continuous circulation · TDS reduction · flow rate optimisation

61 %

PEAK DAILY EFFICIENCY

53 %

BEST PRODUCTIVITY GAIN

41 mg/L

FINAL TDS FROM SEAWATER

150 min

EXTENSION PAST SUNSET

1 · WHY DISTILLATION

Water scarcity is driven by climate-altered rainfall, demand outstripping natural replenishment, and pollution — over 80 % of global wastewater is discharged untreated, and water pollution claims more lives annually than war. Against filtration and chemical treatment, distillation offers low complexity with no moving parts, negligible maintenance, broad-spectrum water quality and a zero-cost energy source, making it the only one of the three viable as a standalone system.

2 · THREE STRUCTURAL INNOVATIONS

Conventional basin stills are limited by minimal evaporation surface area and poor heat distribution. The stepped design maximises the solar solid angle and increases the water surface exposed to incident radiation. Three further features distinguish this build.

- **Metal fins** placed on the steps create localised hot spots, accelerating evaporation beyond what a uniform surface can achieve.
- **Weirs and helical paths** force water into a longer flow route, increasing residence time in contact with the absorber plate for maximum thermal transfer.
- **A cotton black absorber** uses capillary action to maintain a continuous thin film across the entire absorber surface, preventing dry spots and sustaining evaporation potential through constant circulation.

The third is the most consequential. A dry spot on an absorber is worse than useless: it heats without evaporating, and the energy is lost to the cover as sensible heat.

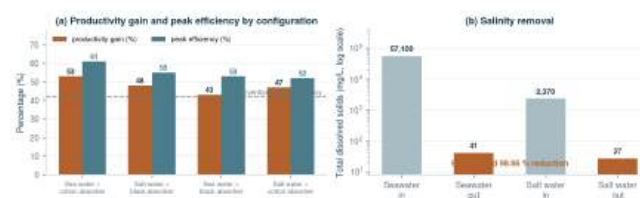


Fig. 9.1. (a) Productivity gain and peak efficiency across the four water and absorber combinations tested, against the 42 % conventional benchmark. (b) Total dissolved solids before and after distillation, on a logarithmic axis.

3 · CONTINUOUS AGAINST BATCH FLOW

Batch flow uses intermittent fixed volumes: labour-intensive, lower in productivity, and with thermal mass that is not continuously matched to fluctuating irradiation. Continuous flow maintains a steady stream over the inclined steps, giving consistent yield and a maintenance benefit that batch operation cannot — constant water movement makes the system markedly less susceptible to scaling and fouling than a stagnant basin.

Optimal flow rates were identified as 1 LPM for seawater and 3 LPM for salt water, with lower flow rates correlating with higher temperature output. The storage tank extends production 150 minutes past sunset on stored thermal energy.

4 · EMPIRICAL RESULTS

Table 9.1. Productivity and efficiency by configuration

Configuration	Productivity gain	Peak efficiency
Sea water + cotton absorber	53 %	61 %
Salt water + black absorber	48 %	55 %
Salt water + cotton absorber	47 %	52 %
Sea water + black absorber	43 %	53 %

Table 9.2. Salinity removal

Source	Initial TDS	Final TDS	Reduction
Seawater	57,100 mg/L	41 mg/L	99.93 %
Salt water	2,370 mg/L	27 mg/L	98.86 %

The salinity result is the one that determines whether the output is drinkable rather than merely abundant. At 41 mg/L the distillate is well within potable limits, from a feed at nearly sixty thousand — and the same apparatus achieves it from both a seawater and a brackish source without reconfiguration.

5 · CONCLUSION

The combination of stepped geometry, material innovation through the cotton absorber and metal fins, and continuous flow optimisation delivers a robust solar desalination solution. The system met its performance benchmark of producing a minimum of two gallons of potable water per day from seawater with no fossil fuel input, and daily efficiency remained consistently 20 % above the conventional baseline.

The recommendation is an inclined still with open water loop integration for community-scale deployment.

STATED FUTURE WORK

Phase change material integration for overnight production, and solar tracking to maximise daily radiation interception.

PUBLISHED EXTERNALLY

This is the only contribution in the volume to appear in an indexed external journal during the project year, with an ISSN and DOI recorded. The digest reproduces it here as a departmental record; the published version is the citable source.

A THREAD THE DEPARTMENT RETURNED TO

Stepped solar stills recur in later volumes of this digest, where subsequent teams optimise water depth and sensible heat storage on comparable apparatus. This study established the geometry and the continuous circulation principle that those later projects took as their starting point.

Solar Desalination

Continuous Circulation

Potable Water

REFERENCES

1. El-Sebaei, A. A., et al. (2014). Experimental investigation of a stepped solar still with continuous water circulation. *Energy Conversion and Management*, 86, 186–193.

2. Velmurugan, V., et al. (2008). Productivity enhancement of stepped solar still — performance analysis. *Thermal Science*, 12, 153–163.

3. Omara, Z. M., et al. (2014). Enhancing the stepped solar still performance using reflectors. *Energy Conversion and Management*, 78, 876–881.

ARTICLE 10 PART IV · SUSTAINABLE MANUFACTURING AND INDUSTRY 4.0

Design and Fabrication of a Sustainable Plastic Brick-Manufacturing Machine

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Project guide: Mr. Ajith Kumar R, Assistant Professor
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ABSTRACT — This research presents the design and fabrication of a prototype manufacturing plant using a chemically powered heating system and a specialised screw extruder to transform post-consumer plastic into building materials. A multi-stage gear drive achieves a total reduction of 96:1, delivering the torque required to process polymer-matrix composites at approximately 15 rpm. Polypropylene–rubber composite bricks sustained compressive loads of 17.05 tons and LDPE–rubber bricks 16.55 tons, against 9.03 tons for traditional clay — improvements of 89 and 83 % respectively. Transmission efficiency was established at 81.10 %. The work validates a scalable solution addressing affordable housing demand while providing a high-volume sink for plastic waste.

KEYWORDS plastic waste valorisation · screw extrusion · polymer matrix brick · worm gear reduction · circular economy · affordable housing

17.05 tons

PP/RUBBER COMPRESSIVE
LOAD

89 %

STRONGER THAN CLAY
MASONRY

96:1

TOTAL GEAR REDUCTION

81.10 %

TRANSMISSION EFFICIENCY

1 · TWO PROBLEMS, ONE MACHINE

Plastics are versatile and a primary driver of landfill overcrowding and marine pollution through their resistance to biological degradation. Meanwhile traditional clay brick production is increasingly unsustainable — topsoil depletion, high-intensity kiln firing and escalating extraction cost set rapid urbanisation against ecosystem preservation.

The central engineering challenge is processing heterogeneous plastic waste while maintaining material integrity, to produce durable bricks with complete waste utilisation and better waterproofing than clay masonry.

2 · THE DIFFERENTIATOR

All four treat plastic as a binder holding aggregate together, which caps the proportion of waste that can be absorbed. This study inverts the relationship: the polymer becomes the primary structural matrix, enabling far higher waste sequestration and inherently superior waterproofing, since the load path runs through the plastic rather than around it.



Fig. 10.1. (a) Compressive load sustained by each brick type against traditional clay masonry. (b) The multi-stage transmission converting a 1440 rpm motor into the low-speed, high-torque rotation extrusion requires.

3 · MACHINE ARCHITECTURE

Table 10.2. Component specification

Component	Specification
AC motor	0.5 hp / 0.376 kW, base speed 1440 rpm
Transmission	Pulley-belt drive + worm gear 30:1 — total ≈96:1
Final screw speed	≈15 rpm, maximum torque configuration
Heating chamber	M.S. sheet, 3000 W coils with copper plates
Screw conveyor	100 mm screw in 25 mm hollow passage
Frame	700 mm height, 2.5 mm M.S. L-angles

Fabrication proceeded through structural frame assembly by carbon arc welding; gas-cutting of a 140 mm pipe to accommodate hopper and inner flange, with the screw conveyor precision-turned on a lathe; brazing of three 1 mm copper plates around the chamber to house the heating filament; and a truncated-pyramid hopper welded from 1.5 mm sheet.

4 · OPERATION AND RESULTS

Table 10.1. Comparison with prior research

Study	Method	Key result
Chauhan et al. (2019)	PET + river sand, 1:3	High strength; absorption below 5 %
Singhal & Netula (2018)	Plastic + stone dust, 3:7	5.6 N/mm ² ; zero absorption
Shah et al. (2017)	PVC dust at 220 °C	6.66 N/mm ² , superior to clay
Dinesh et al.	Plastic + fly ash / quarry dust	Variable, 3.17–5.12 N/mm ²

Process sequence. The 3000 W heater brings the chamber to between 160 and 230 °C depending on the plastic blend. A composite mix of plastic waste, rubber powder and calcium carbonate enters through the hopper. The motor engages at the design speed of 15 rpm for maximum torque, with trial runs conducted at 80 rpm. Molten composite is extruded into a mould box and submerged in a water bath for one hour of controlled cooling.

Table 10.3. Compressive load results

Brick type	Compressive load	Against clay
Polypropylene / rubber	17.05 tons	+88.8 %
LDPE / rubber	16.55 tons	+83.3 %
Traditional clay	9.03 tons	baseline

Three engineering differentiators follow from the extrusion route. Precision extrusion enables interlocking brick geometry, eliminating mortar and reducing construction cost. The absence of kiln firing removes CO₂ and particulate emission from production entirely. And the plastic matrix is inherently non-porous, solving the water absorption problem that afflicts clay masonry in a monsoon climate.

5 · CONCLUSION

The polymer-matrix bricks effectively double the load-bearing capacity of traditional clay, confirming that the technology transforms a low-value environmental pollutant into a high-performance structural asset. Complete waste utilisation, superior compressive strength and zero kiln firing together present a compelling circular economy solution for affordable housing in developing nations.

WHERE THE DESIGN EFFORT ACTUALLY WENT

The headline result is the brick strength, but the engineering content is in the transmission. Extruding a filled polymer melt demands torque, not speed, and a 96:1 reduction reaching 81.10 % efficiency is an exceptionally well-matched drive train for a machine built from workshop stock.

EDITORIAL NOTE

Compressive load is reported in tons as measured rather than converted to stress in N/mm², so the results are not directly comparable with the prior studies tabulated in Table 10.1, which report strength. Specimen dimensions would allow that conversion and would place this work precisely against the literature.

THE UNADDRESSED QUESTION

Long-term behaviour — UV exposure, creep under sustained load, and fire performance of a polymer structural element — is not examined. For a building material these are the properties that ultimately govern adoption, and they are the natural subject of any continuation.

Plastic Valorisation

Circular Economy

Affordable Housing

REFERENCES

1. Rajput, R. K. *Heat and Mass Transfer*.
2. Khurmi, R. S. *Machine Design*.
3. Hajra Choudhry. *Workshop Technology*.
4. Faculty of Mechanical Engineering, PSG Tech (1998). *Design Data*. DPV Printers, Coimbatore.

Solar Operated Waste Leaf Collector: a Sustainable Mechanical Engineering Approach

Nihal Abdul Rasheed, Aswin Girish, Athul Subhash, Kalidas M

Project guide: Mr. Francis Thomas, Assistant Professor · Coordinator: Dr. Vidya Chandran
SCMS School of Engineering and Technology, Karukutty · A P J Abdul Kalam Technological University · June 2023

ABSTRACT — This research documents the design and validation of a solar operated waste leaf collector, transitioning from fuel-dependent prototypes to a system defined by photovoltaic autonomy. By combining high-efficiency solar harvesting with a mechanical intake mechanism, the project demonstrates transduction of solar irradiance into the mechanical torque required for debris collection. MPPT and PWM charge controllers regulate harvest into storage, and brushless DC motors drive the intake at high efficiency and low noise. The system replaces carbon-intensive manual labour and internal combustion machinery with a zero-emission, near-silent alternative operating below 45 dB against more than 85 dB for a gasoline blower, reducing institutional carbon footprint while optimising energy consumption.

KEYWORDS solar machinery · photovoltaic transduction · MPPT · BLDC motor · energy-waste nexus · zero-emission maintenance

< 45 dB OPERATING NOISE AGAINST 85+ DB	0 FUEL COST AND EMISSIONS AT POINT OF USE	4 CORE ENGINEERING PRINCIPLES APPLIED	BLDC MOTOR TYPE SELECTED FOR EFFICIENCY
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1 · THE ENERGY-WASTE NEXUS

The transition to solar-operated machinery is a cornerstone of sustainable mechanical engineering. In waste management it removes dependency on fossil fuel supply chains and reduces local greenhouse emission. The energy-waste nexus describes the intersection where the energy expended on sanitation meets the environmental cost of the waste itself.

Traditional leaf collection — high-decibel gasoline blowers or labour-intensive manual sweeping — is inefficient through that lens. Solar integration addresses the nexus by using the operational environment as the energy source, transducing irradiance into regulated electrical power and then into mechanical torque, without the thermodynamic losses and emissions of a small-displacement engine.

2 · FOUR ENGINEERING PRINCIPLES

The design philosophy is stated explicitly and is the substantive engineering claim: *design the machine around the energy source rather than electrifying an old design*. An internal combustion machine has energy to waste; a solar machine does not, so every component must maximise mechanical output per unit of energy input.

	MANUAL / ICE	SOLAR-OPERATED COLLECTION
Energy cost	High — fluctuating fossil fuel	Zero — in situ photovoltaic
Noise pollution	> 85 dB — disruptive	< 45 dB — near-silent
Maintenance	High — lubricants, filters, plugs	Low — solid-state electronics
Emissions	Carbon and particulates	Zero at point of use

Fig. 11.1. The operational comparison across four categories. The noise reduction is the effect most immediately apparent to anyone sharing the space with the machine, and follows directly from the choice of a brushless motor over a two-stroke engine.

3 · DESIGNING WITHIN A CONSTRAINED ENERGY BUDGET

High-efficiency MPPT and PWM charge controllers ensure power harvested from the array is stored and delivered with minimal heat dissipation. Brushless DC motors were selected for their efficiency-to-power ratio and silent operation, with drive shafts or direct-drive arrangements optimised so that maximum torque reaches the collection mechanism — whether vacuum-based suction or a mechanical rotary brush.

Table 11.2. Operational comparison

Category	Manual / ICE	Solar-operated
Energy cost	High — fluctuating fossil fuel	Zero — in situ photovoltaic
Noise pollution	> 85 dB — disruptive	< 45 dB — near-silent
Labour efficiency	High man-hours per hectare	Low — mechanically optimised
Maintenance	High — lubricants, filters, plugs	Low — solid-state electronics
Environmental impact	Carbon and particulate emission	Zero at point of use

4 · CONCLUSION AND DIRECTIONS

Table 11.1. Core principles and enabling technology

Principle	Technology employed
Photovoltaic energy transduction	High-efficiency arrays with MPPT/PWM charge controllers
Energy storage optimisation	Battery management for consistent delivery under fluctuating sun
Torque-to-intake transmission	BLDC motors driving suction turbine or rotary brush
Structural integrity	Lightweight frame supporting array and payload without losing manoeuvrability

The collector demonstrates that localised waste management can operate independently of both the power grid and fossil fuel supply chains. Maximum efficiency is achieved through integrated design of energy harvesting and high-torque mechanical transmission, and the prototype provides a measurable route to reducing the carbon footprint of institutional landscaping.

The noise result deserves particular note. A reduction from above 85 dB to below 45 dB is not incremental; it is the difference between machinery that must be scheduled around occupied hours and machinery that can run at any time. On a campus or in a residential setting that changes when the work can be done, not merely how pleasantly.

STATED FUTURE DIRECTIONS

Computer vision for autonomous row-following and obstacle avoidance enabling fully unmanned operation, and LiFePO₄ battery storage for greater energy density and extended operation into low-light conditions.

EDITORIAL NOTE ON EVIDENCE

This contribution presents its engineering framework, design philosophy and comparative analysis, but does not report measured collection rate, area covered per charge, battery capacity or runtime. The comparison table draws on established characteristics of the two technology classes rather than on side-by-side field trial. A measured collection rate in square metres per hour, and runtime on a single charge, would convert a well-argued case into a quantified one.

THE DESIGN PRINCIPLE WORTH CARRYING FORWARD

The distinction between designing around an energy source and electrifying an existing design applies well beyond leaf collection. It is the same principle that separates a purpose-built electric vehicle from a converted one, and it is stated more clearly in this student project than in much of the literature on the subject.

SERVICE LEARNING IN PRACTICE

The machine addresses a maintenance task performed on the institution's own grounds. The problem was observed rather than researched, which is the departmental mission operating as intended.

Solar Machinery

Sustainable Maintenance

Service Learning

REFERENCES

1. No external reference list was supplied with this contribution; the study is presented as an original design and comparative analysis.

ARTICLE 12

PART IV · SUSTAINABLE MANUFACTURING AND INDUSTRY 4.0

Data Analysis for Casting Defect Pattern Recognition in Steel Castings

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ABSTRACT — This research delineates a computational framework applying systematic data analysis to recognise recurring defect patterns in steel casting. Moving beyond reactive post-solidification identification, the study proposes a proactive pattern recognition methodology to reduce scrap and optimise production efficiency. By synthesising manufacturing datasets — thermal gradient evolution, melt chemistry, acoustic emission, strain response — the work identifies which process variables manifest as quality deviations and maps each defect class to its characteristic data signature. Feature extraction transforms raw cooling rates and pouring velocities into mathematical descriptors, with K-means clustering for defect grouping and supervised learning for classification, enabling a shift toward predictive process control and Industry 4.0 readiness.

KEYWORDS casting defects · pattern recognition · feature extraction · K-means clustering · predictive quality assurance · Industry 4.0

4

DEFECT CLASSES MAPPED TO SIGNATURES

2

MACHINE LEARNING METHODS APPLIED

0

POST-SOLIDIFICATION INSPECTION REQUIRED

4.0

INDUSTRY READINESS TARGETED

1 · SYMPTOM AGAINST SOURCE

Steel castings underpin heavy industry, energy and transportation infrastructure. The inherent stochasticity of the casting process produces quality deviations that compromise structural integrity, and reliance on post-solidification manual inspection is increasingly obsolete in an Industry 4.0 context.

The limitation of traditional detection is that it is symptomatic: it examines the defect after formation, which offers little insight into systemic root cause. What is required is a framework that interrogates multi-dimensional process data to identify the non-linear correlations between manufacturing parameters and defect formation — a shift of attention from the casting to the process that produced it.

2 · THE METHODOLOGICAL CORE

Pattern recognition prioritises source over symptom. The research focuses on feature extraction: transforming raw data such as cooling rates and pouring velocities into mathematical descriptors. K-means clustering groups defects and supervised learning classifies them, allowing the system to recognise the sequences that recur before a quality deviation appears.

The practical consequence is direct. If a particular thermal gradient pattern is consistently correlated with shrinkage, then recognising that pattern in real time permits autonomous process adjustment before the shrinkage occurs. Historical data becomes a forward-looking instrument.



Fig. 12.1. The central mapping of the study: each defect class, the data signature that betrays it, and the root process variable that produces it. The middle row is what makes prediction possible.

Table 12.1. Defect taxonomy and data signatures

Defect	Data signature	Primary variable
Interdendritic porosity	High-frequency peaks in acoustic emission during solidification	Gas evolution / mould atmosphere
Non-metallic inclusions	Outlier detection in spectral analysis of melt chemistry logs	Melt purity / deoxidation
Shrinkage cavities	Non-linear decay constants in thermocouple time series	Thermal gradient evolution
Hot tears and cracks	Strain-gauge anomalies and abnormal mould expansion during cooling	Mechanical / structural stress

3 · FINDINGS AND IMPLICATIONS

Transition to predictive quality assurance. Data-driven prediction reduces late-stage scrap by identifying process deviation in real time rather than after solidification. The economic argument is straightforward: a casting rejected at inspection has already consumed its full material and energy cost, whereas a process corrected mid-pour has not.

Algorithmic correlation of process variables. Pattern recognition clarifies relationships that are hidden to inspection — the correlation between humidity-induced gas evolution and interdendritic porosity being the example the study gives. No amount of examining the finished casting reveals the humidity in the foundry three hours earlier; only correlating the two datasets does.

Benchmarking for engineering pedagogy. The authors present the work explicitly as setting a standard for final-year research by integrating data science with core mechanical engineering, moving beyond design-and-fabricate toward computational metallurgy.

4 · CONCLUSION AND PATHWAYS

Data-driven pattern recognition is an essential evolution for quality assurance in steel casting, and the work underscores that the future of mechanical engineering lies at the intersection of material science and data analytics.

Two future pathways are named: deep learning integration, using neural networks over multi-modal visual and sensor data to recognise complex defect clusters automatically; and universal pattern frameworks, evaluating whether data signatures transfer to non-ferrous alloys such as high-strength aluminium and magnesium.

EDITORIAL NOTE ON EVIDENCE

This contribution presents a framework and a taxonomy rather than results from an implemented system. No dataset size, classification accuracy or measured scrap reduction is reported. The defect-to-signature mapping is well constructed and the methodology sound, but the value of the approach can only be demonstrated by applying it to foundry data and reporting how often it predicts correctly.

THE OUTLIER IN THIS COHORT

Eleven of the twelve projects in this volume build or characterise something physical. This one does not. Its subject is a way of thinking about manufacturing data, and its inclusion in a mechanical engineering digest reflects a judgement — correct, in the editors' view — that computational metallurgy is now part of the discipline rather than adjacent to it.

WHAT IMPLEMENTATION WOULD REQUIRE

Instrumented moulds, synchronised logging across thermal, acoustic, chemical and strain channels, and a labelled defect record spanning enough pours to train on. The framework is the easy half.

Computational Metallurgy

Data Analytics

Industry 4.0

REFERENCES

1. Harikrishnan T P, et al. (2020). Data analysis for casting defect pattern recognition. Project report, SSET.
2. Rengaraj R, M. (2020). Methodological frameworks for pattern recognition in computational metallurgy. SSET.

CONCLUDING MATTER

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ALSO LISTED IN THE FACULTY REGISTER

Mr. Suraj R. (gas turbine cooling, CFD) and Mr. Vishnu H (sustainable packaging) appear in the guide register without a matched contribution, and Article 09 carries no named guide. Both records are left open rather than filled by inference.

CALL FOR VOLUME 2

Contributions are invited from final-year and postgraduate project teams of the Department of Mechanical Engineering for Volume 2.

Manuscripts should carry:

- A structured abstract of 200–300 words.
- Four to eight keywords.
- An explicit statement of the research gap addressed.
- A stated method and, for hardware, a stated test protocol.
- Numbered figures and tables with units.
- Measured values wherever a measurement was made.
- A limitations section written by the authors.
- Complete author and guide attribution.

REVIEW CRITERIA

1. Soundness of the stated method.
2. Sufficiency of evidence for each claim made.
3. Reproducibility of the reported figures and tables.
4. Explicit treatment of limitations.

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The Department thanks Dr. Anitha G Pillai, Principal; the workshop and laboratory staff; Agappe Diagnostics Ltd. for opening a live product programme to a student team; and the HMT workshop whose reprofiling problem gave Article 07 its subject.

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GEAR UP

RESEARCH DIGEST

EXPLORING IDEAS.
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EMPOWERING TOMORROW.

“

WHERE CURIOSITY
MEETS ENGINEERING,
RESEARCH CREATES
REAL-WORLD IMPACT.

”



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through inquiry



INNOVATE

Turning ideas into
impactful solutions



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better tomorrow



COLLABORATE

Uniting minds.
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