NEW APPROACH TO INNOVATIVE TECHNOLOGIES
IN MANUFACTURING

Deliverable 3.4

Demonstrator of new manufacturing technology

Report

Work package No. 3 – Research Project

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1. Executive summary

NEPTUN delivered three demonstrators that can be replicated by partners and manufacturing firms:

1. **Modelling demonstrator for metal lattice structures (additive manufacturing).**
   A validated, imperfection-aware virtual workflow that predicts stiffness, strength and failure initiation for titanium alloy Ti-6Al-4V lattice structures made by laser powder bed fusion. The workflow couples parametric geometry and material calibration with finite-element analysis, and optionally ingests micro-computed-tomography geometry to include as-built imperfections. Output: design rules (e.g., beneficial ranges of nodal fillets versus mass increase), scaling relations and hotspot maps. This is a **method demonstrator**; no physical finishing cell is claimed.
2. **Human–robot collaborative station for hinge disassembly.** A collaborative workstation where a robot supports a human operator in removing a hinge pin and sorting parts. It combines vision-based detection, force-assisted extraction and reliable controller-side motion. Result: a safe, repeatable pattern for delicate disassembly and re-use.
3. **Method pack for digital transformation in manufacturing.** A lightweight decision-support method that maps interactions among technology, organisation and people, producing step-by-step roll-out lists, interaction flow maps and leadership-versus-employee dashboards to accompany adoption of Demonstrators 1 and 2.

Common thread: integration first link existing tools into lean pipelines to reduce trial-and-error, speed up learning and minimise risk.

2. Objectives and scope

- Validate, in realistic settings, three demonstrators that reduce development waste, improve safety and accelerate uptake of advanced manufacturing.
- Provide replication packages: assets, operating procedures, evaluation indicators, safety notes and risks with mitigations.

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3. Demonstrator architecture

3.1. Modelling demonstrator for metal lattice structures (additive manufacturing)

Purpose. Provide an engineering-grade virtual test bench for titanium Ti-6Al-4V lattice specimens made by laser powder bed fusion, so that geometry and process-sensitive choices can be optimised before physical trials.

Scope. Kelvin and Octet unit cells (and compatible families) across selected relative densities; parametric nodal filleting; uniaxial tension as the primary load case, with low-cycle and fatigue extensions planned next.

Workflow.

1. **Geometry.** Parametric unit cells and specimens with fillet radius as a factor; optional import of micro-computed-tomography meshes to reflect as-built imperfections (strut waviness, junction notches).
2. **Material.** Elastic-plastic titanium Ti-6Al-4V with isotropic hardening from inverse calibration against tensile data.
3. **Meshing.** Tetrahedral meshes refined at junctions; scripted studies for convergence.
4. **Analysis.** Implicit finite-element analysis with geometric nonlinearity; boundary conditions mirror the laboratory tensile set-up.
5. **Outputs.** Force–displacement curves; effective stiffness and peak load; maps of von Mises and principal stresses and of strain-energy density; mass penalties for filleting.
6. **Design guide.** Recommended fillet ranges per density band; notes on when image-based meshes are required.

Status. Methods validated and correlated with laboratory tests; consistent hotspot localisation observed; ready for broader parameter sweeps and for fatigue-relevant indicators.

3.2. Human–robot collaborative station for hinge disassembly

Purpose. Turn a delicate manual operation into a safe, repeatable human–robot routine that supports re-use and remanufacturing.

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System. Collaborative robot with an arm-mounted three-dimensional camera and an overhead two-dimensional camera; force–torque sensor; gripper with replaceable rubber-lined fingers; magnetic pick tool; sorting bins. Vision models detect the pin head and classify parts. Open-source middleware acts as a data bus; motion remains on the robot controller for reliability and safety.

Process. Detect → grip and support pin while the human unscrews → force-guided extraction with on-line correction → sort elements → proceed to the next hinge by operator cue or automatic event detection (planned).

Status. Full sequence repeatable in laboratory trials; near-perfect recognition accuracy; no safety-zone violations; step-shortening strategy halves the extraction time when resistance is low.

3.3. Method pack for digital transformation

Purpose. Help companies stage adoption of Demonstrators 1 and 2 with minimal organisational whiplash.

Toolkit. Anonymous survey, semi-structured interviews and a coding guide; flow visualisations that expose cross-domain interactions; roll-out checklists and dashboards that contrast leadership and employee perceptions.

Status. Delivered and used to create case-level action plans and sequencing lists; coverage spans the majority of areas relevant to transformation.

4. Assets and build (what exists and how to replicate)

4.1. Modelling demonstrator (software and data)

- Finite-element input decks and batch scripts for parametric runs.
- Titanium Ti-6Al-4V material cards with calibrated hardening curves.
- Template meshes for Kelvin and Octet geometries; instructions for importing micro-computed-tomography meshes.
- Result notebooks: stiffness/strength scaling, hotspot atlases and mass-benefit tables.

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4.2. Human–robot station (hardware and software)

- Collaborative robot; cameras; force–torque sensor; gripper fingers (CAD available); magnetic pick tool; sorting bins; sample door and hinge sets.
- Trained vision models and middleware plugins for data exchange and robot monitoring.

4.3. Method pack (documents and templates)

- Questionnaire; interview-coding guide; templates for flow maps and sequencing lists; dashboard specification.
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5. Operating procedures (abridged)

5.1. Modelling demonstrator

1. Select geometry set (unit cell, density band, fillet radii).
2. Choose model path: parametric meshes or image-based meshes from micro-computed tomography.
3. Assign material card (batch-specific if available).
4. Run analysis; export force–displacement and field data.
5. Compute stiffness and peak load; extract hotspot maps; record mass penalty.
6. Update the design guide with recommended fillet ranges and caveats.

5.2. Human–robot station

1. Detect the pin head and parts, or guide the robot by hand in a safe mode.
2. Grip and support the pin while the operator unscrews the screw.
3. Extract the pin with force-guided motion and step-shortening when resistance is low.
4. Place and sort parts; proceed to the next hinge by cue or auto-event.

5.3. Method pack

1. Run the survey and interviews; code responses.
2. Generate interaction maps and identify the strongest driver-to-effect links.

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3. Produce a sequencing checklist and an alignment dashboard; review with the company.
4.

6. Validation and indicators

6.1. Modelling demonstrator

- Agreement between model and test for effective stiffness and peak load within predefined error bands across density and fillet sets.
- Hotspot localisation consistent with observed failure initiation in most tests.
- Monotonic property gains with moderate filleting, with a documented inflection when added mass outweighs benefit.

  Indicators: correlation coefficients; mean absolute percentage error for peak force; percentage overlap between predicted hotspots and fracture origins; number of validated geometry settings.

6.2. Human–robot station

- Full sequence repeatable; near-hundred-percent detection in laboratory trials; no safety incidents.
- Force-guided extraction naturally slower, but step-shortening halves that phase when resistance is low.

  Indicators: operation time versus manual baseline; zero incidents; ergonomic metrics (reduced wrist load).

6.3. Method pack

- Coverage of the majority of transformation areas; delivered sequencing lists and alignment dashboards.

  Indicators: percentage of covered areas; number of actionable steps adopted per case; leadership-versus-employee gap reduction over time.

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7. Safety, compliance and human factors

- Human–robot station follows shared-workspace principles with adaptive role allocation; motion control remains in the robot controller. Emergency stops and distance monitoring confirmed in tests.
- Modelling demonstrator poses no physical safety risk; data handling follows institutional policies.
- Any physical trials run under local machine-safety procedures (guards, interlocks, extraction where applicable).

8. Technology readiness, risks and mitigation

- **Modelling demonstrator:** readiness around level five (validated in representative laboratory conditions).

  Risks: computational cost for high-fidelity meshes; sensitivity to as-built imperfections; boundary-condition artefacts.

  Mitigation: sub-modelling near hotspots; homogenised far-fields; micro-computed-tomography geometry for selected cases; alignment fixtures in tests; scripted mesh-convergence studies.

- **Human–robot station:** readiness between levels five and six (robust laboratory demonstrator).

  Risks: large misalignment can exceed collaborative-robot forces.

  Mitigation: assisted mode with the operator or a higher-payload robot; automatic event detection for state switching.

- **Method pack:** ready for consultancy and training.

  Risks: data-access constraints in companies.

  Mitigation: anonymised agreements; minimal, interoperable software stack.

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9. Sustainability and impact

- **Less waste and energy**: modelling replaces portions of physical prototyping and shortens trial cycles; in the human–robot station, safe disassembly enables re-use.
- **Better decisions**: design-for-performance of lightweight lattice parts (informed filleting at nodes) and clearer hand-offs to surface-integrity steps when needed.
- **Regional uptake**: ready-to-use packages for labs, open days and company pilots.

10. Conclusions

The demonstrators confirm that integrating mature tools virtual testing for lattice structures, reliable human–robot routines and a practical transformation method yields practical, safer and less resource-intensive manufacturing workflows. The modelling demonstrator enables data-driven geometry choices before printing; the human–robot station converts delicate disassembly into a predictable team task; the method pack orchestrates people, organisation and technology. The package is ready for dissemination and for industrial pilots aimed at production-level readiness.

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