



Ergonomic Design of a Vacuum Lift Assist End Effector for Handling Automotive Exhaust Systems

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Background / Problem Statement

Tenneco manufactures exhaust systems for the automotive sector. This project focused on improving the manual handling process of an exhaust assembly.

Problems:

- Two musculoskeletal injury reports submitted.
- HSE MAC assessment identified red-category risk.
- Two-person lift increased cycle time from 212 s to 227 s.
- Additional annual labour cost $\approx$ £85k.



Operator manually handling the P6 MHEV exhaust assembly between leak testing and packaging operations.

Project Aim and Objectives

Aim: Design and validate a bespoke vacuum lift-assist end effector for safe single-person handling of an exhaust assembly.

Objectives:

- Eliminate HSE red-category risks.
- Restore single-operator process.
- Integrate with existing vacuum system.
- Meet structural and ergonomic requirements.
- Achieve cost-effective implementation.

Product Definition

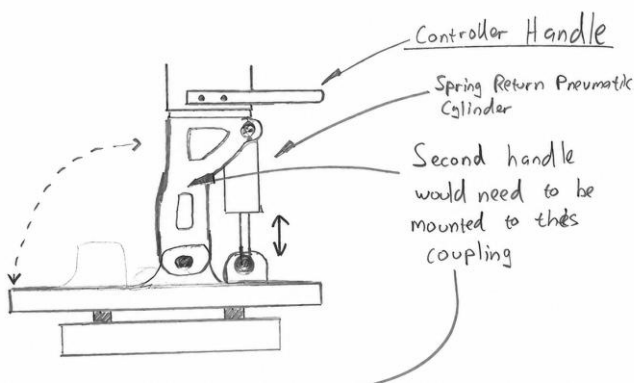
Customer requirements were translated into engineering specifications.



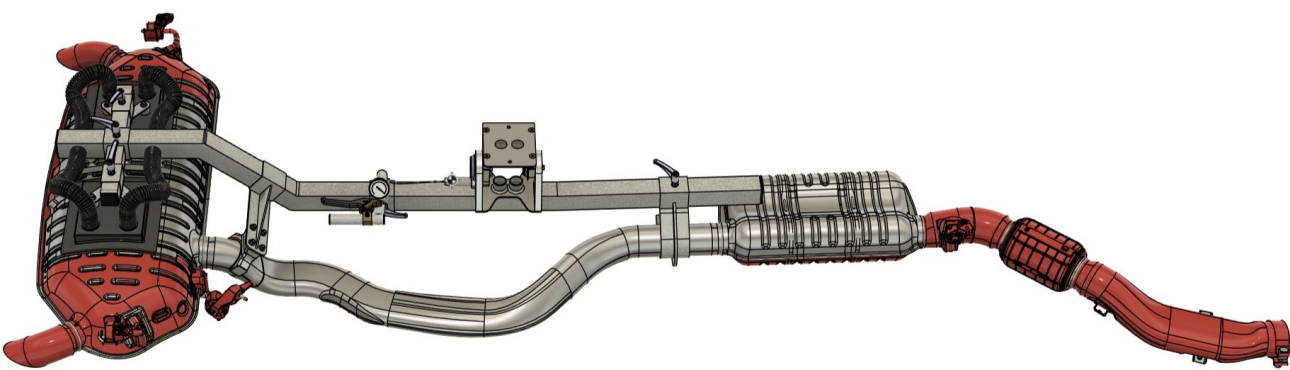
Key stages of the product definition process: Quality Function Deployment, Design & Failure Mode Effects Analysis, and Product Design Specification (Ullman, 2018; AIAG and VDA, 2019)

Design Development

- Design decomposed into 7 functional subsystems
- 3 hand-drawn concepts created for each subsystem
- Appropriate materials and manufacturing processes selected
- Weighted decision matrices used for selection
- 3D-models generated



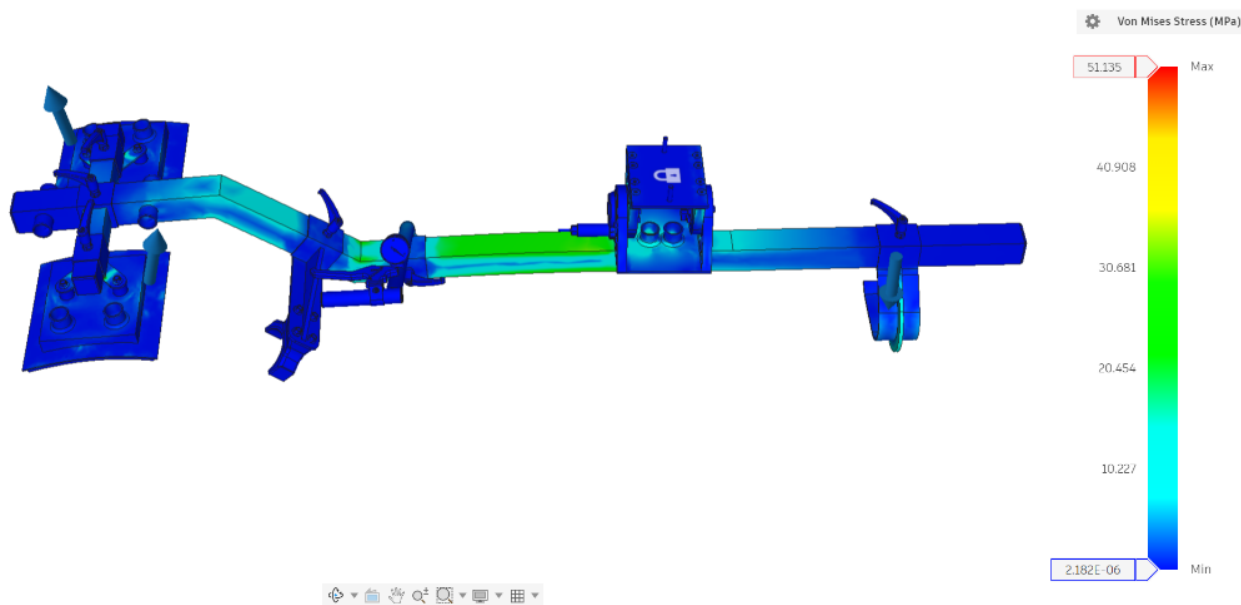
Hand-drawn sketch of a pneumatically operated pivot mechanism concept.



3D CAD model of the end effector design interfacing with the P6 MHEV exhaust assembly.

Summary of key design verification results against the Product Design Specification (PDS).

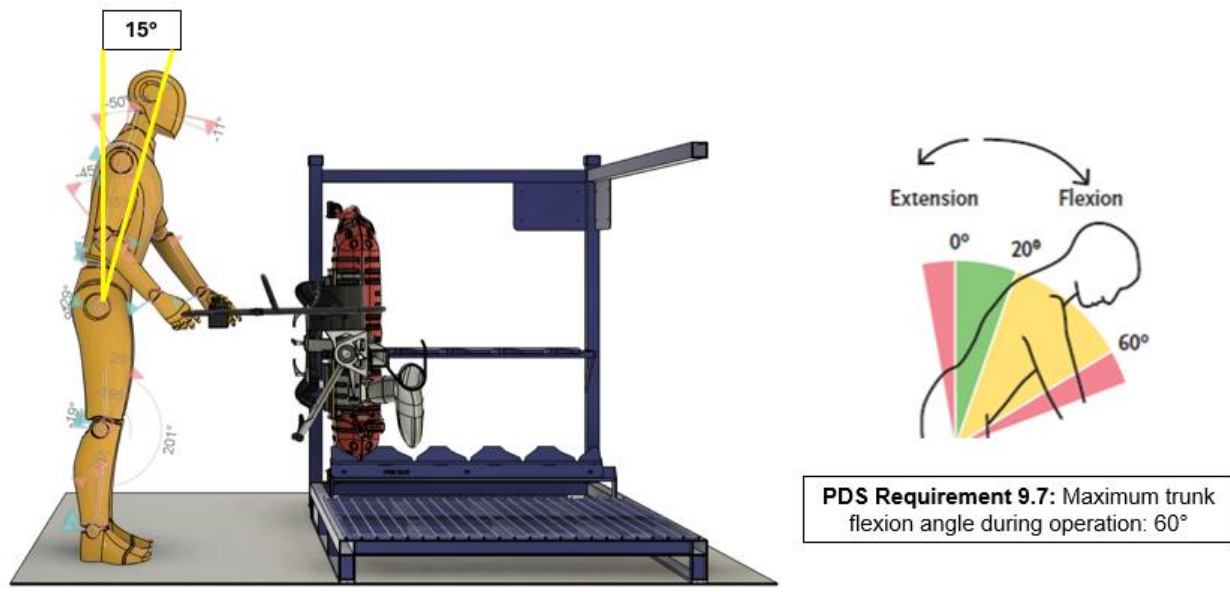
Requirement	Result
Weight <18 kg	17.89 kg
Total suction cup area >631 cm ²	654 cm ²
Stress in framework <124 Mpa	83.2 Mpa
Deflection between exhaust interfaces <10 mm	2.9 mm
Equilibrium angle <15°	14°



Finite element stress analysis of the final end-effector assembly under maximum design loading.

Ergonomics

Digital human modelling was used to assess operator postures and verify compliance with anthropometric and biomechanical requirements.



Digital human modelling assessment of maximum trunk flexion during exhaust loading into the stillage (Design Neta, 2017).

Supplier Selection

Weighted supplier selection matrix used to evaluate manufacturing quotations and identify the preferred supplier.

Criteria	Weighting	Potential Manufacturing Suppliers		
		1 - Cruz	2 - CES	3 - JG
Cost	0.40	2	1.6	2
Manufacturing Capability	0.20	0.45	0.6	0.45
Lead Time	0.15	0.8	1	0.8
Experience	0.15	0.45	0.45	0.6
Support / Communication	0.10	0.3	0.5	0.1
Total Weighted Ratings		4	4.15	3.95

Business Case

- £8,325 Capital Cost
- £85,000 Annual Saving
- 1.25 Months Payback Period
- Approved By Tenneco Management

Conclusions

- ✓ Bespoke end effector successfully designed.
- ✓ Eliminated HSE red-category manual handling risks.
- ✓ Restored single-operator handling process.
- ✓ Approved for manufacture by Tenneco.

References

- Design Neta (2017) Human Body Model. Available at: <https://grabcad.com/library/human-body-model-joints-for-fusion360-1> (Accessed: 23 April 2026).
- Ullman, D.G. (2018) The mechanical design process. David G. Ullman.
- AIAG and VDA (2019) FMEA Handbook. Available at: <https://www.aiag.org/training-and-resources/manuals/details/FMEA-1> (Accessed: 27 February 2026).