DESIGN GUIDELINES FOR REMANUFACTURING

A proof-of-concept project demonstrates how products can be designed to be remanufacturable

Any future circular economy will involve remanufacturing, a process that restores end-of-life parts and products so that they can go back into service. By giving products a new life rather than treating them as waste, remanufacturing reduces the need for raw natural resources to make new products from scratch.

Today, sectors as diverse as aerospace, automotive, medical devices, industrial printing, restaurant and food service, and office furniture remanufacture products and components. Yet, despite its potential to reduce energy and carbon emissions and conserve valuable materials, remanufacturing accounts for a mere 2% of total sales of all products.[1]

To expand the use of remanufacturing, products must be designed to be remanufacturable. But today, a product designer's toolkit does not typically include the necessary knowledge or design rules. Much of the information required to design a product suitable for remanufacture is accumulated through years of experience by a few seasoned practitioners.

A project led by the Rochester Institute of Technology set out to identify and document a clear path for integrating remanufacturing principles into computer-aided design (CAD) tools and design practices. In partnership with the equipment company Caterpillar and the Remanufacturing Industries Council, the researchers developed a set of design rules for a heavy-duty off-road (HDOR) techno-economic case study, validated the impact of design on remanufacturing, and outlined next steps.

PROJECT DESCRIPTION

The 12-month project began in December 2019. The team conducted an extensive literature review, compiling over 1,500 guidelines from 116 documents. The literature review addressed these questions:

- How can product design be used to maximize the value recovered from products during remanufacturing?
- How is the concept of designing a product for remanufacturing currently conveyed to the designer?
- How is design for remanufacturing related to recycling and other sustainability topics, and can remanufacturing guidelines be gleaned from these other topic areas?

The researchers then combined the guidelines from scientific publications with a set of remanufacturing best practices they collected by surveying experienced large original equipment manufacturers. The result was a framework of 30 core design practices—for example, commonizing parts so that they can be reused across product families. The framework also encompassed topics such as modular design, durability, features to enable quick assembly or disassembly, and others.

To validate the design rules, the team reviewed them with a panel of remanufacturing industry experts. They then demonstrated the application of these rules through an HDOR product case study that focused on valve rocker arm assembly. Caterpillar provided the case study, and the company's engineers helped vet and refine the rules.

The case study results showed that even though application of design for remanufacturing added cost to the new design, the total life cycle benefit to the company was significant, saving several tons of steel the and reducing labor costs by several hundred thousand dollars.

For the final project task, the team defined a set of broadly applicable steps for integrating design for remanufacturing guidelines into commercially available CAD tools. The detailed process steps, outlined in the final project report, include data collection and aggregation, rule and algorithm creation, and software development.

[1] U.S. International Trade Commission (ITC), Remanufactured Goods: An Overview of the U.S. and Global Industries, Markets, and Trade, p. xviii. October 2012. https://www.usitc.gov/publications/332/pub4356.pdf. Accessed January 4, 2023.

[2] Caterpillar. 2021 Sustainability Report. https://s7d2.scene7.com/is/content/Caterpillar/CM20220511-3628c-87ee2. Accessed January 4, 2023.

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PROJECT IMPACT

This project successfully developed and demonstrated a proof-of-concept process for developing comprehensive design for remanufacturing guidelines that currently are distributed across varying sources and experts.

When remanufacturing principles are integrated into various engineering tools and commercially available CAD platforms, designers will have the insight necessary to develop products that eventually can be rebuilt or reused. This will significantly reduce the energy, carbon emissions, and material volume embedded in a product's life cycle. For example, remanufacturing enabled Caterpillar, to recover 127 million pounds of material in 2021 alone.

The current HDOR sector remanufacturing intensity is 3.8%.[3] Assuming a conservative 25% increase in HDOR remanufacturing intensity through the integration of these design rules, the resulting environmental benefits would save an additional 0.54 million metric tons of primary material, save more than 13,000 gigawatt-hours of energy, and prevent 3.6 million metric tons of carbon dioxide emissions each year. Implementing these design rules across all industry sectors would reap even greater benefits.

NEXT STEPS

The project team plans to develop the design for remanufacturing design process further and integrate the resulting design guidelines into commercially available CAD platform(s).

Remanufacturing is not the optimum end-of-life option for every part or product. To help make this determination, this software needs to enable the design team to also evaluate a part's financial and environmental viability and decide whether a product is a candidate for remanufacturing. While this assessment tool was not part of the exploratory project, the team plans to include this capability in a second-generation CAD-integrated tool.

The project team plans to extend this methodology to determine whether it can support design for other circular economy processes, such as recycling.

The Remanufacturing Industries Council will distribute portions of the project findings to the remanufacturing industry.

[3] U.S. ITC.

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