Remanufacturing of electronic control units for off-road vehicles: process analysis and sustainability assessment

L. Nastasi, S. Fiore

DIATI (Dep. of Engineering for Environment, Land and Infrastructure), Politecnico di Torino, 10129, Italy
Keywords: remanufacturing; electronic control units; agricultural machinery
Presenting author email: livia.nastasi@polito.it

Introduction

In recent years, the amount of electronics installed in vehicles has rapidly raised due to their growing complexity and functionalities, including drivetrain and comfort systems, communication technologies and driving safety equipment (Bosch, 2014). The management of these electronic systems is handled by electronic control units (ECUs) and a single vehicle could host 70 ECUs or more (Kleylein-Feuerstein et al., 2015). In this context, due to the high embedded value of electronics, remanufacturing could represent a key circular strategy to extend their lifespan by restoring a product to its original performance, with a warranty that is equal to or better than that of a newly manufactured (British Standards Institution, 2009). The aim of this study is to analyse the remanufacturing processes of ECUs at full scale within a case study company from the technical, environmental and economic viewpoints.

Methodology

Three different ECUs (Figure 1) commonly adopted in agricultural machinery (CNH Industrial, 2023) were selected: engine control units, joysticks and displays. All the information and data were sourced from CNH Industrial and a case study remanufacturing company located in Italy. The adopted methodology involved several steps: (i) disassembly and mass balance of the ECUs (5 per type); (ii) data collection to assess the remanufacturing process for each ECU type; (iii) environmental and economic assessment of the remanufacturing process.

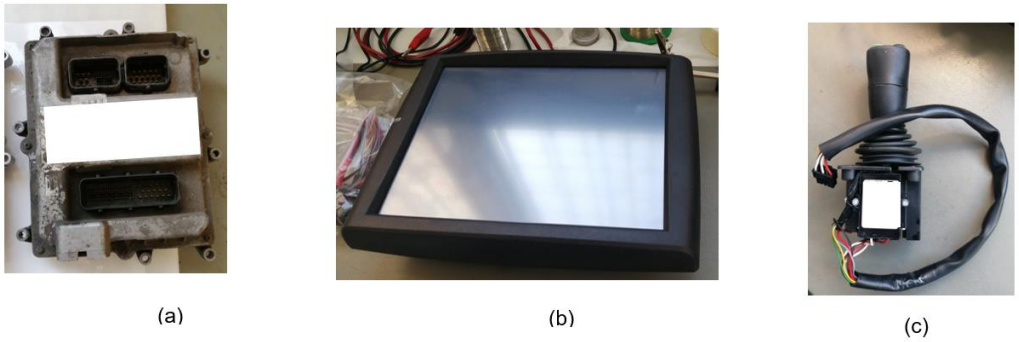

Figure 1. Electronic control units considered in this study: (a) engine control, (b) display, (c) joystick

The environmental assessment was based on ISO 14064 (ISO, 2019) and the GHG Protocol Product Standard (WRI and WBCSD, 2011). The system boundaries were defined gate-to-gate, including transport of the ECU to the remanufacturer, remanufacturing process, and packaging. A single ECU was considered as functional unit. Various remanufacturing scenarios based on the most common failures and involving the replacement of different components were considered. The data inventory was based on primary data acquired from the case study company, and on background data from Ecoinvent 3.9.1 database (Ecoinvent 3.9.1, 2022), Product Environmental Footprint database (European Commission, 2022) and literature. Concerning the economic assessment, prices of remanufactured ECUs and newly manufactured items were provided by CNH Industrial.

Results

ECUs disassembly allowed to identify the main components of the three different ECUs. Engine control units consist of metal plates and electronics (transistors, resistors, and diodes); joysticks are composed of a plastic structure, buttons, electronics (including various cables), and metal parts; displays include electronics (capacitors and inductors), plastic case, a liquid crystal display, and a touch screen. The remanufacturing processes are different for each type of ECU, but they can be generally described as follows: transport, preliminary test,

disassembly, components' replacement, final test, cleaning, reassembly and packaging. The entire process requires in average 3.13 hours for engine control units, 47 minutes for joysticks, and 29 minutes for displays.
The highest average GWP value was obtained for displays (15.3 KgCO2/ECU), followed by engine control units (3.7 KgCO2eq/ECU) and joysticks (340 gCO2eq/ECU). The largest share of GWP is ascribed to the production of electronic components such as cables, liquid crystal displays, and integrated circuits. Remanufacturing allows to retain most of the original mass of ECU components, specifically 96% for engine control units, 98% for joysticks, and 99% for displays. In terms of economic assessment, remanufactured ECUs offer a purchase price for the final customer that is 22-25% lower than newly manufactured items. This discount is achieved through the "core credits" system, where the final customer receives financial incentives for returning end-of-life ECUs to the dealer.

Conclusions

The key outcomes of this study highlighted that remanufacturing ECUs allows to retain most of the original mass of the initial product, avoiding virgin raw materials extraction and the production of new items. Remanufacturing specific process depend on the type of ECU, both in terms of timing and specific operations. Additionally, the total GWP is influenced by the type and amount of replaced components. From an economic point of view, remanufacturing offers several advantages to customers, including a lower price compared to new ECUs and a reduction in machine downtime.

Acknowledgements

This research activity was performed with the support of *PON "Ricerca e Innovazione" 2014-2020, Asse IV "Istruzione e ricerca per il recupero" con riferimento all'Azione IV.4 "Dottorati e contratti di ricerca su tematiche dell'innovazione" e all'Azione IV.5 "Dottorati su tematiche green". DM 1061/2021*.

References

Bosch, R. (2014). Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive, 5th Edition. In *Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive: 5th Edition*. Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-01784-2

British Standards Institution. (2009). *BS 8887-2:2009. Design for manufacture, assembly, disassembly and end-of-life processing (MADE). Part 2: Terms and definitions*.

CNH Industrial. (2023). *CNH Industrial website*. https://www.cnhindustrial.com/

Ecoinvent 3.9.1. (2022). *Ecoinvent, Allocation, cut-off by classification, Ecoinvent database version 3.9.1*. https://ecoinvent.org/

European Commission. (2022). *Product Environmental Footprint database* . https://nexus.openlca.org/database/Environmental%20Footprints

ISO. (2019). *UNI EN ISO 14064-1:2019 - UNI Ente Italiano di Normazione*. https://store.uni.com/uni-en-iso-14064-1-2019

Kleylein-Feuerstein, J., Joas, F., & Steinhilper, R. (2015). Remanufacturing of Electronic Control Units: An RFID Based (Service) Interface. *Procedia CIRP*, *29*, 168–172. https://doi.org/10.1016/J.PROCIR.2015.02.163

WRI and WBCSD. (2011). *Product Standard | GHG Protocol*. https://ghgprotocol.org/product-standard