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Product-Service Systems across Life Cycle

Total Cost of Ownership for Product-Service system: application of a prototypal model to aluminum melting furnaces

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Abstract

The well-established Total Cost of Ownership (TCO) concept can support the development or assessment of Product-Service Systems (PSS), since it adopts a lifecycle perspective, therefore enabling a "whole cost" evaluation, that may lead to eco-efficient choices by customers. This paper explores an application of the TCO concept to aluminum melting furnaces, a specific example of highly energy-intensive equipment.
A TCO model is created, validated and tested through 8 case studies of small- and medium-sized aluminum die casting producers located in Lombardy. Empirical findings of the analyses carried out through the model suggest the main determinants of furnaces TCO and possible levers to reduce costs of such equipment. On average, operating costs of an aluminum melting furnace, such as materials, labor and energy, combine for about 95% of the furnace TCO. Based on current operational modalities, the studied companies incur costs ranging from about 127 to 400 Euros per ton of molten aluminum, due to furnaces ownership and utilization. This evaluation leads to identify actions to reduce such costs (e.g. through energy-efficient furnaces, scale economies by installing centralized, large-sized furnaces) and ideas for the development of use or result-oriented PSS types.

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Keywords: Total Cost of Ownership; Product-Service system; computation model, case studies; melting furnaces; aluminum die casting; cost reduction levers

1. Introduction

Increasing pressures arise to adopt a more sustainable approach to product design, manufacture and usage, at both the business and consumer levels [1]. Among these, a Product-Service System (PSS) approach has been advocated as a way to achieve environmental improvements [2]. However, the quantification of the environmental and economic benefits achievable through PSSs is under-investigated [3], although the adoption of methods such as LCA and LCC has been suggested. This paper adopts a Total Cost of Ownership (TCO) approach to address the eco-efficiency of aluminum melting furnaces, a particular type of highly energy-intensive equipment.

TCO is the sum of all costs associated with the acquisition, use and maintenance of a product or a service [4], and is generally regarded as the "true cost" of buying an item from a particular supplier [5,6]. To compute the TCO of a product, service or PSS, all costs incurred by its end user during the purchasing process and the long-term utilization of the purchased item must be identified and quantified [6,7].

Metal casting is one of the most ancient and versatile techniques to produce semi-finished metal products and components; it consists in pouring liquid metal into a mould and then allowing it to solidify and cool down [8]. Amongst metal casting processes, die casting stands out as a high-rate manufacturing process of non-ferrous components with extremely smooth surfaces and excellent dimensional accuracy [8]. Die casting companies incur large capital costs to purchase appropriate production equipment, which makes die casting process profitable for large-scale production: this, in turn, entails considerable operating costs due to metal melting and casting [8].

Aluminum die casting producers combine for about 59% of worldwide production of non-ferrous metal castings [9], and incur significant energy costs to carry out production

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activities [10]. On average, the melting furnace (i.e. the equipment which liquefies metal in preparation to a casting process) accounts for a remarkable 77% of the overall energy consumption of an aluminum die casting facility [10]. Therefore, melting furnaces can be regarded as crucial equipment to optimize both the operating costs of an aluminum die casting facility and the payback time of investments in die casting equipment.

In this paper, the application of the TCO methodology to aluminum melting furnaces is explored through the creation, test and validation of a TCO-based model of such equipment, then discussed in the light of PSS research.

2. Research setting

This paper describes the first step of an ongoing research project, which aims to apply the TCO methodology and to investigate the application of the PSS concept to aluminum melting furnaces. The first step of this research aims to:

1. create, validate and test a TCO model of aluminum melting furnaces;
2. identify the main determinants of the furnaces TCO and possible cost reduction levers of interest to aluminum die casting producers;
3. discuss the findings in the light of the PSS concept.

At first, a *literature review* of selected applications of the TCO methodology to manufacturing and service contexts is carried out, aimed to analyze cost elements and computation procedure adopted by authors.

Secondly, *case studies* of 8 small- and medium-sized aluminum die casting producers are conducted, in order to:

- structure a TCO model of aluminum melting furnaces and collect input data to the model, in cooperation with the studied companies;
- confirm the validity of both the input data and the results of TCO computation;
- analyze the TCO of the studied furnaces and investigate how it is impacted by the input data to the model.

3. Background

3.1. Product-service systems (PSSs)

A Product-Service System is defined as “a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models” [11]. The PSS research stream emphasizes the objective of reducing the lifecycle impacts of products and services and therefore increasing their sustainability. The definition of PSS reported above, moreover, reflects the view that PSSs have a different business model than “traditional” products.

Figure 1 reports one of the most acknowledged classifications of PSSs [12], where three categories (and eight subcategories) are identified in-between the two extremes of “pure product” and “pure services”.

In *product-oriented PSSs*, the business model is still mainly geared towards sales of products, but some extra services are added. For both customers and suppliers this model appears as the most familiar one as it uses knowledge and experience that has been gained for many years. Therefore, the supplier can use the traditional business model (product/price) and add value by additional services, with the aims of improving or restoring the functionality of the product, such as through maintenance and repair (basic field services and inspection).

In *use-oriented PSSs*, the traditional product still plays a central role, but the product stays in ownership with the provider, and is made available in a different form, and sometimes shared by a number of users. The provider keeps the property rights of the product and may have the responsibility for its utilization conditions (timely installation, maintain, upgrade, etc.). The customer pays a fee (fixed or based on the intensity of usage) to gain access to it.

In *result-oriented PSSs*, the client and provider in principle agree on a result, and there is no pre-determined product involved [12]. The customer pays a fee that depends on the achievement of a contractually set result in terms of product/system performance or outcome of its usage. The value for the customer is generated by the reduction of initial investment, the minimization of operational costs and risks.

3.2. The TCO methodology

Dating back to the first half of the twentieth century for the evaluation of purchases and suppliers, the TCO concept was popularized in 1987 by the Gartner Consulting Group as a cost evaluation method for ICT investments [13]. Between the 1990’s and the early 2000’s, Ellram [4,5], Degraeve and Roodhooft [6,7,14], and Ferrin and Plank [15] contributed to theoretical development of the TCO methodology. In the last 15 years, the TCO methodology has definitely gained recognition as a valid cost evaluation method for products and services.

In particular, the TCO methodology has been applied to main durable goods industries, such as ICT and electronics (e.g. [16,17]), automotive and motor vehicles (e.g. [18,19]), machinery (e.g. [20,21]) and energy equipment (e.g. [22,23]). Despite considering various model objects, TCO models of durable goods are typically based on the following data:

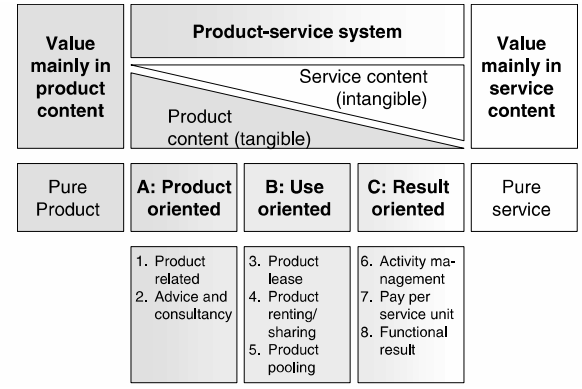

Fig. 1. A taxonomy of product service systems [12]