15th Global Conference on Sustainable Manufacturing

The Sustainable Co-Design of Products and Production Systems

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Abstract

The challenges in designing products and production systems are becoming increasingly complex due to more changeable customer demands, frequent product updates, and the requirements for resource efficiency. Established design processes are often unable to readily accommodate these rapid changes. In addition, incremental benefits are often achieved through existing sustainable design approaches due to inability to fully assess the impacts of product design improvements and their associated implications within production facilities. This highlights the need for more integrated design processes that enable seamless co-development of products and production systems. This paper examines the current interrelation and interaction of these design processes from the resource efficiency viewpoint, proposes a novel sustainable ‘Co-Design’ model, and discusses the ecological benefits of co-designing future products and production systems.

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Keywords: Integrated co-design processes; Sustainable design; Resource-Efficient Manufacturing.

1. Introduction

Customisation, changing demand, shorter product life and frequent product updates, as well as the requirements for improving resource efficiency all necessitate a closer integration of design processes for products and their associated production systems [1,2]. At present, this is usually accomplished through integrating concepts such as ‘concurrent engineering’ which are often supported by information sharing technologies [3]. Nevertheless, these

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approaches have often been reported as insufficient for responding to the dynamic requirements of contemporary product development processes [4], which highlight a need for novel approaches where a single methodology is used for both design processes [1]. This paper proposes a ‘co-design model’ to support a closer integration design processes used for Products and Production System (P&PS), as depicted in Fig.1. With this aim, the literature related to integrated design concepts is reviewed, the interrelation and interaction of existing integrated design are analysed, and a co-design methodology for P&PS is presented.

2. The State-of-Art in Integrated Design of Product and Production Systems

Production system design is normally driven by the specific requirements of an existing and/or redesigned product. This is referred to as the ‘throw over the wall’ concept, which often causes long lead time, increased development costs, low product quality, and a frequent need for redesign of products and/or production systems [5]. To mitigate these difficulties, concurrent engineering was proposed with the aim “of having integrated, concurrent design of products and their related processes, including manufacture and support.” [6]. From the literature, several key characteristics that lead to the success of integrated design can be identified (See Fig.2). These includes: encouraging parallel activities, considering critical issues early in design, exchanging information, and maintaining collaboration between teams. To address these core characteristics, following four corresponding research themes have emerged in relevant publications:

Firstly, the ‘Integrated design process’ such as Integrated Product Development (IPD) and the development process of Ulrich and Eppinger are generally represented in a context of an integration of parallel activities from different processes e.g. marketing, product design, and production development. These generally suggested how an integrated design can be managed through step-by-step activities performed by different stakeholders and present the information flow during integrated design. However, these processes are not widely adopted in industries because they typically provide simple instructions and could not deal with practical complexities [3].

For ‘Specific improvement of design process performance’ theme, the proposed methods commonly utilise one or two integrated design characteristics for enhancing the specific performances of a product, a production system and/or a development process without a guidance for collaboration among design teams. For example, the Design for Manufacture (DFM) has been proposed to improve manufacturability of products by embedding manufacturing information and knowledge into product design process [7]. Likewise, traditional Quality Function Deployment (QFD) has been applied to present product and production system specification to negotiate design and production preference by product designers instead of collaborative consideration from both parties [8].

Thirdly, ‘Technological tools to support integration’ are introduced for sharing design information. Examples of these analytical software packages are DFMA and SEER DFM which offer faster manufacturability using essential information [5]. Moreover, the information and knowledge management tools have traditionally been used via computer aid design and manufacture (CAD-CAM) by product designers to obtain relevant knowledge and data on production processes [8,9]. The STandard for the Exchange of Product (STEP) data has been developed for standardising and facilitating product-related data exchange among different information and knowledge based systems in a product life cycle. It has been highlighted that most of the developments in this area were regarded the
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