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Engineering change management in individual and mass production

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Abstract

The ability to manage engineering changes (ECs) efficiently reflects the agility of an enterprise. A large majority of products become gradually improved and perfected through the developmental-design process, during which the set design requirements are met or even upgraded, thus prolonging the product life cycle. The concept of product improvement was based on the activation and tracking of (ECs) through the developmental-design phase and the manufacturing phase. A special method was used to recognize activities within the process and the degree of involvement of individual participants. The individuals involved in the process were provided with appropriate information and the required communication channels with others were ensured. The EC process was generalized and applied to different types of production. A product's complexity and design level were analyzed first, and key factors such as CE methods, process definition, information system, communication and organization were used as a tool for optimizing the EC process. The method was tested and successfully applied into industrial practice.

Keywords: Engineering change process; Design levels; Product's complexity; Workflow; Product life cycle; Iterative product development

1. Introduction

Once a product is developed and its manufacture begins, its level of excellence immediately starts decreasing due to other competitive products on the market [1]. Its life on the market can be prolonged by continual product improvements. A longer product lifetime also increases its profitability, because the development of a new family of products is associated with considerable costs. A prolonged product life cycle is typical first of all for complex products. Product improvements thus involve both the planning of new variants and the making of minor modifications.

The ability to manage engineering changes efficiently reflects the agility of an enterprise. For the purpose of this paper, an engineering change (EC) is a modification of a product's component after the product has entered production. A number of techniques exist to avoid changes as much as possible, such as quality function deployment, as well as to make changes as early as possible in the design process, such as concurrent engineering [1]. However, after a product has entered production some changes are unavoidable, and this paper is focused on the management of ECs.

In industry, engineering change management (ECM) is recognized as a problem that receives too little attention relative to its importance. Wright's [2] conclusion is that from the manufacturing perspective ECM is a disturbance obstructing smooth product manufacture, but such a perspective ignores ECM's capacity to provide the incentive for product improvement. Wright's conclusion is that a number of coordinated research programs are required to establish the ground rules for maximizing the product design benefits from EC activity.

Many and especially late ECs are very costly for any development project. ECs consume one-third to one half of the total engineering capacity and represent 20–50% of total tool costs [3]. The key contributors to long EC

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lead times are: complex approval process, snowballing changes, scarce capacity and organizational issues. Loch [4] analyzed the process of administering engineering chain orders within a large vehicle development project. Despite the tremendous time pressure in development projects, EC process lead times are in the order of several weeks, months and even over one year [4]. A detailed analysis has shown a low proportion of value-added time in the EC process—less than 8.5%. An EC spends most of its lifetime waiting for further processing. Loch [4] suggests the following improvement strategies in order to reduce EC lead-time: flexible capacity, balanced workloads, merged tasks and sharing resources (pooling).

Huang [5] investigated the current state of ECs in current industrial practice. Huang focused on big manufacturing companies and found that it is necessary to develop methodologies and techniques to improve the ECM practices. There was no evidence that ECM software packages had been used within the surveyed companies. Current ECM practices vary between companies, from formal to ad hoc approaches.

ECM support can be implemented in commercial PDM/PLM or ERP softwares (PDM/PLM—Product Data/Lifecycle Management, ERP—Enterprise Resource Planning). There are web-based ECM systems that provide better information sharing, simultaneous data access and prompt communication [6]. But even a high level of information technology for ECM is very often paper based, especially in smaller companies [2,6,7]. The reasons for this are that computer aids are not well known to EC practitioners and some of existing computer aids do not reflect good EC practice. In some cases, comprehensive functionality of some systems undermines their focus and imposes intensive data requirements [6].

ECs can be avoided during the conceptual design phase. Ho [8] analyzed the probability of EC in a multi-level product structure. ECs of a component part are affected significantly by the number of immediate parent items and the magnitude of ECs. However, the depth of product structure has no significant impact on the EC of any item [8].

Rouibah [9] focused on cases in which complex product development involves more than one company—distributed ECM. The concurrent design process results in a parameter network that tells us how closely different components are interrelated. The knowledge contained in this network helps manage cross-company activities during the ECM process. The use of STEP compatible data models is a step towards easier inter-company data exchange during the EC process [10].

A review of the references emphasizes the problem of ESs in companies and offers quite specific solutions for complex products. This paper establishes a general model of ECM that also includes evaluation. A method is presented which optimizes the EC process in different types of production. It is based on product complexity analysis, design level and key factors such as CE methods, process definition, information system, communication and organization. The reference ECM model helps engineers recognize the main problems and improve the process. This was also confirmed on examples from industrial practice.

2. Characteristic design and product levels

Product development involves four characteristic levels of design. Each of them requires certain very specific activities [1]. The characteristic design levels could therefore ensure very clear definitions of the activities and thus provide the necessary software and other support for all phases of the design process [11,12]. The following four levels of the design process have become established in professional literature: original, innovative, variation and adaptive (Table 1) [13]. On the basis of the above design levels, design tasks can be determined and distributed among them.

Original design means the designing of entirely new products, whereby a new working principle is determined for a new or known function. In the process of designing from scratch, one therefore needs to define the working principle, model of shape, functionality and technical shape.

Innovative design means designing products by varying the working principles, which fulfil the required function to the optimum degree. In innovative design one needs to define the model of shape, functionality and technical shape.

Variational design means designing products by varying loads, therefore comparable models of shape are obtained. In variational design one needs to define the functionality and technical shape.

Adaptive design means designing products by adapting their dimensions to the technical and technological possibilities for their manufacture. In adaptive design one needs to define the technical shape. This shape is conditioned both by optimization of microtechnology (special features of the manufacturing technology) and by the shape design of details (ergonomics, assembly, etc.). Adaptive design is a dominant type of design (Table 1) and typical of the EC process.

The characteristic design phases are: determination of design requirements, conceptual design, embodiment design and preparation of technical documentation [14]. During their work, designers will require different types of support, depending on the phase of design or abstraction of the product they are working on at the time [15,16].

The product's complexity (Fig. 1) has an important influence on the EC process and it was used in the