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Re-engineering the Engineering Change Management process for a drawing-less environment

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ABSTRACT

Currently, 3D models and 2D drawings are the main basic elements that together form and carry the product definition throughout the product lifecycle. With the advent of the Digital Product Definition trend, industries have been interested in adopting a Model-based Definition (MBD) approach that enables the integration of drawing annotations directly onto a 3D model, thereby minimizing the need to generate engineering drawings. This drawing-less environment requires a way to adequately carry the product definition throughout a product's lifecycle while supporting all of the downstream users' specific needs. The objective of this article is to present a solution to carry the Engineering Change Management (ECM) process in a drawing-less environment. Therefore, based on ECM process requirements from two Canadian aerospace companies, we propose an MBD dataset which consists of an MBD model and a distribution file. The proposed MBD dataset is evaluated and the MBD-driven ECM process is outlined.

1. Introduction

The journey towards Digital Product Definition is already underway. Driven by the aerospace and automotive industries, the American Society of Mechanical Engineers (ASME) issued the ASME Y14.41 standard in 2003 [1], thereby setting the stage for 2D drawings to be phased out [2]. With new advances in CAD solutions, such as CATIA [3] and NX [4], it is possible to insert GD&T (Geometric Dimensioning and Tolerancing) data as well as notes directly into the CAD model. Adopting the Model-based Definition (MBD) would be the next step to continue to reduce time-to-market and improve product quality by improving the way the product definition is exploited by its downstream users. Traditionally, engineering drawings have been the means to carry, control and maintain the product definition. The term product definition is defined here as the set of product attributes, features or characteristics that coexists in a specific state of balance in order to meet physical and functional requirements as well as multidisciplinary constraints [5].

Accurate, informative communications and collaboration among all of the stakeholders in product manufacturing represents a critical factor for success [6]. Moving to an MBD environment will change the way the product definition – traditionally carried, controlled and maintained by engineering drawings – is accessed, distributed, annotated, validated, approved, released and stored. To that end, companies are actively searching for a means to carry, control, distribute and maintain the product definition throughout the product lifecycle in the absence of engineering drawings. In addition, specific tools may need to be developed to fulfill all of the downstream users' needs. The ASME Y14.41-2003 standard [1] made a first step by providing standard rules for the display, orientation, and query of annotations when they are stored in a 3D model instead of being part of a drawing [7].

The main objective of this article is to propose a solution that enables the Engineering Change Management (ECM) process to be conducted in a drawing-less environment. It was decided to focus on the ECM process because:

- It is present at the back end of almost all complex new product development projects [8]. It is estimated that more than 35% of today's manufacturing resources are devoted just to managing changes to engineering drawings, manufacturing plans and scheduling requirements [9].
- The ECM process is based on the study, review, annotation, modification, validation, approval and release of engineering drawings.
- It impacts the product data management system.
- It represents a complex and trans-functional process (involving a variety of requirements and constraints from multidisciplinary participants). From this perspective, the proposed MBD dataset

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would likely suit the requirements of other product lifecycle processes.
- The ECM process is a mini, highly constrained design process [10].

This article is arranged in four parts. First, the role that engineering drawings play throughout the ECM process is identified and detailed, and the ECM technical requirements are outlined. Next, the solution that was adopted to conduct the ECM process in the absence of engineering drawings is developed and presented (Sections 3 and 4). The proposed solution is then evaluated against the previously identified technical requirements. Finally, the ECM process is re-engineered to support its execution when using the proposed solution.

2. ECM process requirements

An engineering change is an alteration made to any parts, drawings or software that have already been released during the product design process. The change can be of any size or type; the change can involve any number of people and take any length of time [11]. The ECM process is designed to maintain the integrity of the product being modified and to ensure the traceability of engineering changes.

Before a solution to conduct the ECM process in the absence of drawings can be envisioned, we must first identify the role engineering drawings play throughout the ECM process and understand the specific requirements from all of the ECM process participants to determine what specific tools need to be put in place. This information was assembled after summarizing a focused consultation of 25 documents (manuals, work instructions and procedures) and based on the results of having conducted 28 interviews within the Engineering, Configuration Management, Manufacturing, Inspection, Certification and Airworthiness departments of two Canadian aerospace companies.

2.1. Role of engineering drawings within the ECM process

Different authors have proposed distinct engineering change processes consisting of two [12], five [13] or six [11] phases. However, within the two aerospace companies studied here, we observed that the ECM process could clearly be split into the four stages proposed by Maurino [14]: (1) request – the need to make a modification has been identified; (2) instruction – the details regarding the modification are thoroughly described and documented; (3) execution – the impacted documents (drawings, specifications, reports, standards, etc.) are updated; and (4) application – the modifications are communicated and carried out at the company level. Normally, a Change Review Board must give its approval to move the process from one stage to the next [14].

Fig. 1 shows the role engineering drawings play at each stage of the process. As noted within this figure, throughout the execution of the four ECM process stages, drawings are identified, analyzed, annotated, modified, approved and then released.

At the request stage, the need to address a problem is identified and is formally documented within the Engineering Change Request document. Detail and assembly drawings[1] are reviewed and studied by the Engineering group to support the change proposal activity in which different alternatives to solve the problem are posed and discussed [15]. One solution is selected and

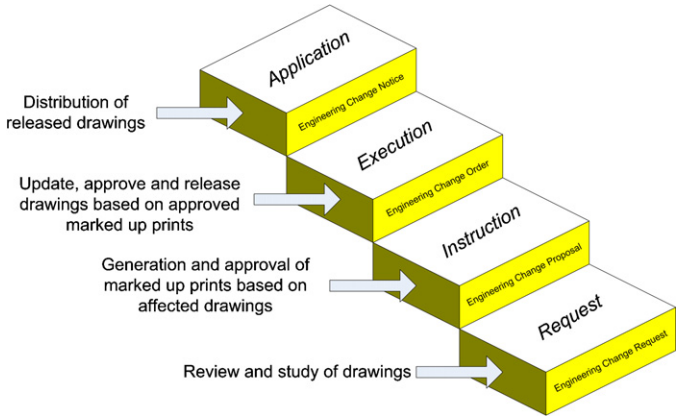

Fig. 1. Role of engineering drawings within the ECM process.

then documented within the Engineering Change Proposal document. At the instruction stage, the details of the proposed change are determined and documented within the Engineering Change Order (ECO) document. These required modifications are normally indicated on the impacted drawings (either manually or electronically). These annotated drawings are commonly referred to in the industry as "marked-up prints". A marked-up print is the document that represents the change design intent from the Engineering Group. Marked-up prints ensure a clear understanding of the required modifications. The marked-up prints, along with a list of all of the affected engineering documents, are part of the ECO document. Generally, the proposed change is approved by a Change Review Board, composed of a group of stakeholders (Engineering, Manufacturing, Quality, Airworthiness, Configuration Management, Inspection, etc.) that discusses and assesses the applicability of the change (ex. cost, time, implementation concerns). During the approval cycle, marked-up prints are reviewed, validated and approved. At the execution stage, the affected drawings are updated.[2] The Engineering group then validates, approves and releases these drawings. The approved change is documented in the Engineering Change Notice (ECN) document. Finally, at the application stage, the ECN is used as the means to communicate and propagate the change throughout the company. For example, the Manufacturing group will use the released drawings to modify their manufacturing operations sheets.

It is important to note that one of the main roles played by engineering drawings is found at the instruction stage, where they provide the basis for the creation of the marked-up prints which are then reviewed, validated and approved (since they convey the change design intent information) before moving into the execution stage.

Within the ECM process context, drawings are traditionally considered as the official and legal documents that carry the history of a product's evolution through time. This is usually supported by the use of a revision history block that provides the part's revision, a description or identification of the change authorization document, the date and the approver's names [16]. The amount and type of change information contained within this block varies from organization to organization. Each time a revision is made to a drawing, the change information is recorded within this block. The ASME Y14.35M-1997 [17] standard defines the practices for revising drawings and establishes methods for identifying and recording revisions.

[1] Other types of drawings, such as layouts, can be impacted by an engineering change. However, based on the collected engineering change scenarios within the two companies, it was noticed that most of the time only detail and assembly drawings are affected.

[2] Drawings are not always updated or revised. If the change has an impact on the form, fit or function of a part, the definition of a new part (and a new part number) may be required. In that case, a new drawing will have to be generated based on the supplied marked-up prints.