Optimizing Workflow with Reduction of Reworks to Models and Drawings

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Abstract *— This study delves into aerospace design rework challenges, focusing on Collins Aerospace. Analyzing 280 change notices, it pinpoints notes and Geometric Dimensioning and Tolerancing (GD&T) as key rework origins. Structured communication via pre- and post-task meetings, combined with training and checklists, mitigate confusion and improves attention to detail. Additionally, investing in training programs covering redlines creation and the ASME Y14.5 GD&T standard, along with providing comprehensive checklists, proved instrumental in enhancing the accuracy and completeness of design submissions, ultimately resulting for the reduction of reworks instances.*

Key Terms *— Change Notice, Product Lifecycle Management, Redlines, Geometric Dimensioning and Tolerancing.*

INTRODUCTION

In the aerospace industry, the design phase of a project tends to be a long process due to different factors that can impact the timely completion of deliverables. A typical design process workflow at Collins Aerospace involves collaborating with stakeholders from other disciplines to incorporate changes in model requirements, review standardization procedures, acquire checker verification and feedback, complete a verification review board process to ensure quality and submit change management validations. After completing the review board process, the design will be presented to the client for feedback, and they will inform if the design meets their requirements. If not, the project may be sent back to the designer for rework and pass through the same process as before.

Problem Statement

Reworks are part of the design process and are expected as part of the project. Nevertheless, too many reworks consume additional time, which could impact project deadlines for the design phase and increase costs.

One reason for which a design is sent back for rework is if the manufacturing personnel finds that the drawing does not comply with their requirements. For example, a drawing could be requested if the Geometric Tolerance and Dimensioning (GD&T) used for the model is a previous version or if the drawing is over-defined and this must have less and simpler GD&T due to available resources, such as lack of technical knowledge or machinery limitations.

Effective communication and clear instructions are key factors when working in the design area. When these factors fail, it can be another cause for reworks. For instance, if instructions are not clearly stated in writing, it increases the probability that the designer could have doubts or confusion regarding requirements. Redlines marked to specify the exact location of instructions for a drawing are often created to avoid miscommunications. Outdated or incorrect redlines can also be a cause for additional reworks.

Objectives

The purpose of the project was to determine the causes of reworks occurring during the design phase of a project. The objectives were to:

- Minimize the number of reworks that occur for a project.
- Decrease costs due to excessive reworks by minimizing the risk of not complying with established deadlines.

Contribution

Being able to identify the different root causes of reworks for a project will grant project engineers, change management, checkers, and design engineers the awareness of risk factors to consider when planning. These determine which best practices were most beneficial to implement.

BACKGROUND

This paper delves into important topics for designers in the aerospace industry, including PTC Windchill Product Lifecycle Management, redlines, Geometric Dimensioning and Tolerancing, Export Control Classification Number, Bill of Materials, and PLM Part Structure. A comprehensive understanding of these subjects is vital for effective performance within the aerospace sector.

PTC Windchill Product Lifecycle Management

Product Lifecycle Management (PLM) is a strategic process that controls a product lifecycle from the initiation, development, and release of the product. PLM software provides a digital thread for delivering the work requested while also making it easier to track and share data throughout the process. This data shows the continuity in which a model and/or drawing went through. PTC Windchill is a specific type of PLM software where work requests, also known as change notices, are acquire and managed. For the design phase of PTC Windchill PLM, a change notice will be created before any new models or changes to existing released designs. A change notice provides important information such as:

- Date Requested
- Work Breakdown Structure (WBS) number
- Deadlines for change
- Change instruction
- Status of change
- Priority of change

After completing the change notice, it will go through the process of change management for the release and completion of the change notice. If the change management team notices that the change is not correctly updated or additional adjustments are needed, then the change will become a rework, having the word rework in the title.

Redlines

Designers often receive instructions to perform certain tasks, and many times, these instructions arrive as redlines. A redline is a document in which existing models and/or drawings are updated with new instructions in the form of a red line, crossing out the change that needs to be made. This document is given to the designer, and if, during the process, new changes need to be made, the redline is updated, providing the new update using another color to differentiate the original redline from the new instructions.

Geometric Dimensioning and Tolerancing

Geometric Dimensioning and Tolerancing (GD&T) is a necessary tool for design and manufacturing. The ASME Y14.5 GD&T is an industry-standard practice that provides guidelines on definitions, requirements, and recommended practices for design models and drawings. This provides the best practices for standardization, improved quality, reduced costs, and deliverables.

During the creation of a drawing, it is important to use industry best practices while using the different standards. In some cases, models and drawings need to be adjusted due to specific reasons. Instead of providing an angle dimension, it can be presented in its vertical and horizontal dimensions. When a drawing has more than ten sheets, datum feature letters can be missed, placed incorrectly, or repeated. Another observed occurrence is when having a section view created, the drawing must provide the location of which view the section was made from to give traceability, but the zone callouts are not made correctly.

Export Control Classification Number

U.S. Export Control laws establish that any commodities, software, and technology exported must have an Export Control Classification Number (ECCN), which is an example of reworks. The classification number will depend on the item for which the ECCN is being created, which category it will be assigned, and the product group. The aerospace industry falls under a specific category, it may have a different product group. These ECCNs for technical data must be presented in any drawings which are created for any product that is in development and created.

Bill of Materials

The Bill of Materials (BOM) is a list that should provide information regarding which sub-assemblies and parts are being used for a specific model. It should include the quantities for each part and associate any note which is used for the creation of an assembly model.

PLM Part Structure

The PLM can provide logistic information for an assembly model and send this to another software such as SAP. For example, in an assembly that is composed of 20 parts, every part number and quantity that compose this assembly should be documented as a BOM, but within the PLM software.

LITERATURE REVIEW

The aerospace industry has a complex lifecycle, and striving for efficiency is challenging because of the direct impact it has on the bottom line and product quality. The aerospace industry heavily involves human input, which inevitably causes human errors [1]. To identify and eliminate human errors can provide information for risk analysis to mitigate or avoid some of these errors [1].

Reworks commonly range from 30% to 70% [2]. Rework can be avoided in the aerospace industry by leveraging on different design practices such as cross-functional integration, good communication, collocation, strong leadership, and team tenure [3].

Design practices have been proven to decrease work and cost, saving millions for companies [4]. Efficient workflow and reworks reduction avoids most of the budget to be consumed in the design phase [5]. After a design freeze, during which the design is not altered, any reworks presented afterward, if not critical, are minimal compared to those made before the design freeze [5]. Reworks before the design freeze are often ten times more likely to occur due to missed requirements or miscommunication between different disciplines [2]- [5]. Because of this, best practices for the reduction of rework can include the implementation of additional meetings prior to and after implementation of a change notice.

METHODOLOGY

The necessary data for this project was requested from Collins Aerospace. This process required a meeting with managers to ensure access to the data. The same managers were consulted in the process of selecting the project used as a case study for this paper. The selected project needed to have an adequate number of reworks which normally is less than 20% of total change notice.

After the project for the case study was selected, the reworks were tabulated and summarized for analysis. Once tabulated, reworks were categorized by the cause that triggered them. Categorizing the data made it possible to observe any tendencies or patterns in the timing and causes of reworks. This analysis was crucial to identify which practices caused the greatest number of reworks and possible delays in project timelines.

After categorizing and demonstrating the tendency of reworks, the different categories were analyzed to prepare a mitigation for these. For future mitigation of reworks, best practices were identified through a literary review of actual and previous research on the engineering design process. The review was focused on the aerospace engineering industry but was expanded into other disciplines looking to acquire insights in their design process.

RESULTS

The case study provided had a total of 280 change notices, of which 63 were reworks. Some reworks had multiple causes. These were counted as multiple, being the case if these reworks applied for two categories or more. A total of 96 causes were identified under the following categories:

- Note
- Geometric Dimensioning & Tolerancing
- Export Control Classification Number
- Model
- Drawings
- Bill of Material
- PLM Part Structure.

Figure 1 provides the distribution of the reworks based on category and quantity. The visualization provides a better understanding of the best practices with a potential bigger impact on project efficiency. Figure 1 serves as a critical tool for discerning the predominant causes of rework, pinpointing the specific areas where 80% of these occurrences are concentrated. Consequently, this delineates the focal point of the article analysis.

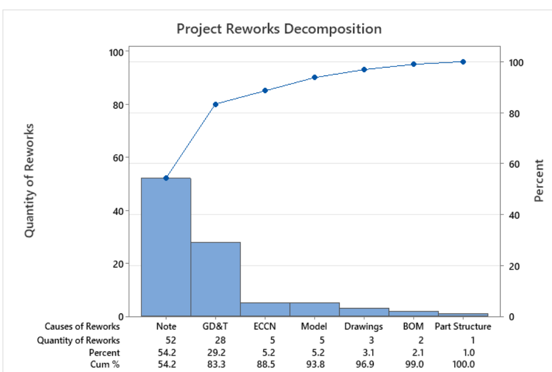

Figure 1

Pareto chart for Project Reworks most occurrence

Note

The Note section referred to information regarding the models that cannot necessarily be inserted, such as material, compliance numbers, test data points, vendor information, lubricants, and others. Many of these notes were standard notes, from an official document provided with the required formatting.

Note, was the category with the most reworks, a total of 52 of them. The different reasons for which the reworks fell under this category were the following: (1) missing notes, (2) incorrect test data points, (3) incorrect standard notes, (4) missing vendor information, and (5) redlines not correctly created.

Geometric Dimensioning & Tolerancing

The second category with the most reworks was GD&T, having a total of 28 reworks. These consist of the standard guide ASME Y14.5 2009 and 2018. In an engineering drawing and model, GD&T will always be present; the reasons to be redone were due to the following factors: (1) repeated datum features letters, (2) incorrect/missing datum features letters, (3) tolerance adjustment for dimensions, (4) incorrect zone callout traceability, and (5) dimension adjustment.

Export Control Classification Number

For ECCN, a total of five reworks were found. These five reworks were caused by: (1) the ECCN for the drawings was not inserted and was left blank, and (2) the ECCN that the drawing had was not the correct one.

Model

In the Model category five reworks were caused. These were due to assemblies involved in replacing an existing screw with a longer one to surpass the nut and comply with the best practice of having a minimum of three threads after the nut.

Drawings

Three reworks fell under this category. Each caused by different reasons: (1) format was not the latest version, (2) the placement of the zone callout was not near the section view letter, and (3) the indication of the last letter used in the drawing was not the correct letter.

Bill of Material

The BOM category had two reworks. These were created because, in the BOM, some notes were not associated with the part number needed. For example, if one note indicated the maximum torque for a screw, the part number in the BOM should have had the note number aside to indicate that the note applied to this specific part.

PLM Part Structure

The part structure was the least observed cause with just one rework and could have possibly been ignored and proceeded with the change as it is. This rework was created because the quantity of some materials was not correct and needed to be fixed.

Discussion

Seeing as how approximately 83.3% of reworks fell under two categories (Note and GD&T) and analyzing reasons for occurrences, some of the best practices identified were:

- Add a step to the process lifecycle in which the designer and creator of redline met and discussed the changes to implement them before working on the task given. This helped ensure that instructions were clear, doubts were clarified, and if, during the discussion, additional changes arise, then the redline may have been updated to include this.
- Add a step to the process lifecycle in which the designer, checker, and creator of redline met after completing the change to discuss these before sending them to change management for revision. This provided the opportunity to confirm that no additional changes needed to be made and that no details of the task given were missing.
- Provide training in redline creation and ASME Y14.5 GD&T standard to identify best practices when implementing the creation of change notice.
- Create a checklist for the designer and checker to use as a guide when completing a task. This allowed for small details, such as the ECCN, to be verified.

CONCLUSION

This study delved into the intricate challenges faced during the design phase in the aerospace industry, focusing particularly on the rework processes at Collins Aerospace. After the examination of 280 change notices, it was evident that a significant percentage of reworks stemmed from issues related to Notes and Geometric Dimensioning and Tolerancing.

The findings have not only pinpointed the primary culprits but have also proposed practical solutions to mitigate these challenges. Establishing clear lines of communication through structured meetings among designers, checkers, and creators of redlines have emerged as a pivotal strategy. These interactions, both prior to and after task execution, ensured clarity, eliminated doubts, and facilitated thorough discussions, minimizing the likelihood of miscommunication or missed details. Furthermore, investing in training initiatives encompassing redline creation and the ASME Y14.5 GD&T standard, and providing comprehensive checklists for designers and checkers, emerged as valuable tools. These resources serve as guides, ensuring meticulous attention to details such as ECCN verification, ultimately enhancing the accuracy and completeness of the design submissions.

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