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An Automated Maintainability Prediction Tool Integrated with Computer Aided Design

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Abstract

Design for maintainability is an important aspect of aircraft design, with maintenance representing 10 – 25% of the direct operating cost of an aircraft [1]. Design for Maintainability incorporates many aspects including assembly/ disassembly time, accessibility, visibility and ergonomics and it can be challenging for design engineers to consider at the design stage due to the time taken and specialist knowledge required.

There are a number of existing tools that can be used to assess individual aspects of maintainability but these were mostly developed as paper based tools that require the designer to visualise the maintenance task while studying the engineering drawings or observing an operator performing the task. This paper presents an automated maintainability prediction tool that is integrated with the CATIA v5 Computer Aided Design software. The tool allows the designer to rapidly estimate the maintenance corrective time for a maintenance task utilising a CATIA product model as its input. It uses elemental maintenance action standard times from MIL-HDBK-472 Procedure V to estimate maintenance task times, and RULA, OWAS and LBA ergonomics methods to apply a time penalty based on the operator ergonomics during the task.

In this paper the maintainability prediction tool will be tested on a range of simple aircraft maintenance tasks to assess how accurately it can predict maintenance corrective times. The results from the tool are compared to experimental data from physical trials for each maintenance task and the results discussed.

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Keywords: Aircraft Design; Maintainability Prediction; Computer Aided Design; Ergonomics; MIL-HDBK-472

1. Introduction

Design for Maintainability is an important part of the product development process that has attracted more attention in recent decades. In the aerospace industry, it is estimated that maintenance represents 10 – 25% of the direct operating cost of an aircraft [1] and due to the highly competitive global market, great effort is given to consider maintainability as early as possible in the development stage of an aircraft. A product in which maintainability aspects have been taken into consideration would produce multiple benefits and great cost savings in the overall lifecycle of the product.

Maintainability is defined by MIL-STD-721 [8], as "the measure of the ability of an item to be retained in or restored to specific conditions when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources at each prescribed level of maintenance and repair."

One of the challenges of improving maintainability is to accurately predict maintenance times early in the design process. Design engineers are required to consider many different down-stream aspects during the design process and they need simple tools that can rapidly allow them to compare different design alternatives. An interesting approach that satisfies the overall goals of improved maintainability is the development of a software tool that is integrated with the existing design toolset to allow designers to predict maintenance times early in the design process. With that in mind, the use of 3D design software CATIA in connection with Visual Basic for Applications (VBA) is proposed in order develop an application for automated maintenance task time

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prediction. Inputs from a CATIA product model combined with elemental maintenance action standard times from MIL-HDBK-472 will provide an initial time estimate. The use of ergonomics methods, Rapid Upper Limb Assessment (RULA), Ovako Working posture Assessment (OWAS) and the Lower Back Analysis (LBA) combined using the Posture Evaluation Index (PEI) will be used to calculate a time penalty index to incorporate the working posture into the time estimate. To evaluate the accuracy and efficiency of the developed tool, a series of physical experiments have been conducted regarding simple maintenance tasks on an aircraft.

2. Literature Review

2.1 Maintainability Prediction Methods

The most notable literature regarding maintainability prediction is MIL-HDBK-472, which was first published in 1966 containing four approaches. A revision was published in 1984 with the Procedure V being the most recent and therefore the most accurate maintainability prediction method [4] and later incorporated into MIL-HDBK-470A [2]. All of the procedures depend upon reliability and maintainability data and experience [4] and are based on two key parameters: failure rate and repair time.

In MIL-HDBK-472 Procedure V, two methods can be used in order to predict maintainability. Method A is to be applied early in the design phase and method B, in which a detailed design is needed, is used more often at a later stage in the design process. Overall, method B is more easily implemented in a design tool because elemental activities are combined for time estimation, which could then be simulated in a virtual environment. All the elemental activities should be established at the beginning of the process either by experiment or using the provided time standards. Then the elemental activities are summed to provide the total time.

In this research only the tabulated elemental maintenance action times from MIL-HDBK-472 Procedure V are used and not the full maintainability prediction method. Tabulated data is provided for common maintenance tasks including removal and replacement of fasteners, electrical components and other common components. The simplicity and ease of access to tabulated data makes procedure V the most convenient one to integrate in a CAD system, like CATIA, however accessibility and visibility aspects are not covered by this method. Also, whilst the elemental maintenance times used in MIL-HDBK-472 Procedure V are more recent than other maintainability prediction methods, the underlying data is still quite dated as they were published in 1984.

2.2 Accessibility and Ergonomics

Accessibility is defined as a design feature that affects the ease of access to an area for the performance of visual and manipulative maintenance [8]. According to the DOD-HDBK-791 [8], accessibility does not simply mean that the items could be reached. If the items can only be reached by special tools or in an awkward body position, the accessibility score should be lower.

Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and it applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance [9]. Various methodologies have been developed through the years in order to evaluate and predict ergonomic aspects. RULA (Rapid Upper Lib Assessment) is a postural targeting method for estimating the risks of work-related upper limb disorders [5]. A RULA assessment gives a quick and systematic assessment of the postural risks to a worker. It makes use of qualitative scores and the analysis can be conducted before and after an intervention to demonstrate that the intervention has reduced the risk of injury. The RULA action levels define the level of urgency to change how a person is working as a function of the degree of injury risk. In Table 1, the classification of RULA score can be seen, along with an interpretation

Table 1: RULA action levels [5]

Action level	RULA score	Interpretation
1	1-2	The person is working in the best posture with no risk of injury from their work posture.
2	3-4	The person is working in a posture that could present some risk of injury from their work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position, so this should be investigated and corrected.
3	5-6	The person is working in a poor posture with a risk of injury from their work posture, and the reasons for this need to be investigated and changed in the near future to prevent an injury.
4	7+	The person is working in the worst posture with an immediate risk of injury from their work posture, and the reasons for this need to be investigated and changed immediately to prevent an injury.

RULA, as a method, evaluates and focuses only on the upper body and, as a result, the lower body is not taken into account. Therefore, another methodology was developed, called Rapid Entire Body Assessment (REBA), which, extends the RULA method to evaluates the whole body postural musculoskeletal disorder (MSD) risk [10]. RULA has been used in this research in order to link to the available functions in CATIA.

The National Institute for Occupational Safety and Health (NIOSH) published a lifting equation for the assessment of low-back disorder risk in jobs with repeated lifting [11]. Based on the NIOSH method the lower back analysis (LBA) score was defined as the compression on the L4 and L5