An Automated Maintainability Prediction Tool Integrated with Computer Aided Design

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1. Introduction

Design for Maintainability (DFM) 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]. Design for Maintainability incorporates many aspects including assembly/disassembly time, accessibility, visibility and ergonomics. One of the challenges of improving maintainability in the aerospace industry is to accurately 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 to develop an application for automated maintenance task time prediction procedures and resources at each prescribed level of maintenance and repair.”

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.

Keywords: Aircraft Design; Maintainability Prediction; Computer Aided Design; Ergonomics; MIL-HDBK-472
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 Limb 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>
<thead>
<tr>
<th>Action level</th>
<th>RULA score</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-2</td>
<td>The person is working in the best posture with no risk of injury from their work posture.</td>
</tr>
<tr>
<td>2</td>
<td>3-4</td>
<td>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.</td>
</tr>
<tr>
<td>3</td>
<td>5-6</td>
<td>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.</td>
</tr>
<tr>
<td>4</td>
<td>7+</td>
<td>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.</td>
</tr>
</tbody>
</table>

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
Based on the NIOSH method the lower back analysis (LBA)
score was defined as compression on the L4 and L5
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