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DEVELOPMENT OF A REPOSITORY TO SUPPORT DESIGN FOR ADDITIVE MANUFACTURING (DFAM)

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***Abstract**: At present there are few established design support tools to aid industrial designers to design products specifically for additive manufacturing (AM) processes. The aim of this paper is to discuss the development of a design support tool particularly aimed at the laser sintering (LS) system. A taxonomy has been developed that comprises four taxons of reasons for AM utilisation. These are user fit requirements, improved product functionality, parts consolidation and improvement of aesthetics (or form). Each of these requirements has been expanded in a repository that contains various examples of design features that are only possible to manufacture using AM technology. This will be presented as a method to aid designing for AM by enabling industrial designers to visualise and gather design feature information that could be incorporated into their own design work. Finally, the results from a user trial of the repository are presented.*
***Keywords**: Additive Manufacturing, Design Support Tool, Design Feature Taxonomy, Laser Sintering*

1. INTRODUCTION

According to Campbell (Campbell, 2008), a wealth of design knowledge is currently being generated by designers when designing and developing innovative products for manufacture using AM systems. Many of these products have 3D features within them that are only possible to manufacture using AM technology. At present there are few established design support tools to aid industrial designers to design products specifically for AM processes such as laser sintering. Previous work, undertaken by Burton (Burton, 2005), went as far as suggesting the format and structure for a tool but this was never developed into a full working system. Furthermore, most of the AM support tools developed to date have been focusing on AM material and system selection (Munguia, 2009) or part deposition orientation studies (Pandey et al., 2007). Page at el. (2005), demonstrated the generation of 3D CAD data using coded pattern projection and laser triangulation systems. Their research demonstrated the generation of 3D models using these two systems and claimed that imaging-based scanners offer faster and more automated methods of generating CAD models. Kruf et al. (Kruf et al., 2006), published an ongoing research on Design for AM of functional LS parts that focus on materials properties and reproducibility, AM texturing software, coatings for LS parts and design rules for LS. Their research is about the use of Computer Aided Optimization (CAO) software that has been used to remove non-efficient material from an initial 3D CAD model to create a new design optimised for laser sintering.

This paper discusses the development of an AM design feature repository that could be used as a method to aid designing for AM, particularly for laser sintered parts or products. The design feature repository enables industrial designers to visualise and gather design feature information from examples in the repository that could be incorporated into their own design work. Results from a user trial of the repository are discussed in the following sections.

2. REPOSITORY STRUCTURE

The design for additive manufacturing (DfAM) feature repository was developed base on the AM design taxonomy as shown in Figure 1. The taxonomy has been developed as a result of an interview study on reasons for AM utilisation, and it consists of four reasons for AM utilisation (Maidin et al., 2009). These are user fit requirements, improved product functionality, parts consolidation and improvement of aesthetics. These four top levels of the taxonomy were further into sub-categories.

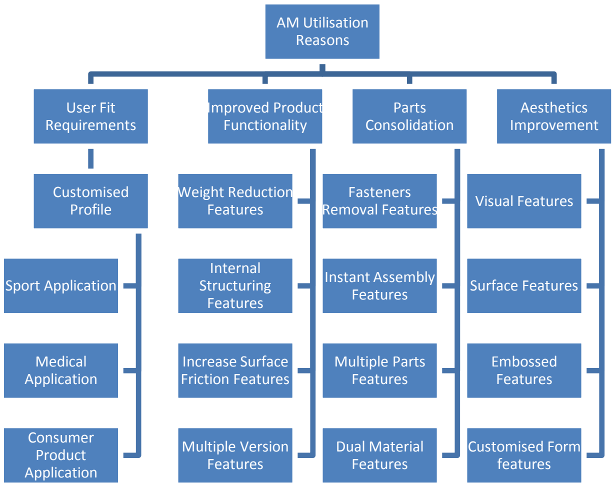
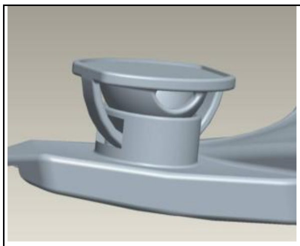


Fig. 1. Taxonomy of Reasons for AM Utilisation

Based on findings from published literature and various websites, a total of 120 DfAM features have been identified and clustered as follows:

- user fit requirements – 30 features
- improved product functionality - 28 features
- parts consolidation – 38 features
- improved aesthetics – 32 features

As shown in Figure 2, each of the features in the DfAM feature repository has information associated with it such as the reason for AM utilisation, taxonomy sub category, name of the design feature, area of application, functionality keywords, the AM system used, type of material used and the designer who created the feature. Most of these design features were designed for and manufactured with the laser sintering process. The design features taxonomy is by no means exhaustive and will be expanded by adding more design features in the various sub-categories. The taxonomy has currently been implemented within a Microsoft Access database known as the DfAM feature repository. A series of forms have been created to enable designers to search or browse through the feature categories.



AM Reason: Consolidation
Sub Category : Instant Assembly
Design Feature: Integrated ball & socket
Application: Consumer product
Functionality Keywords:

i. Ball joint
ii. Encapsulation
iii. Spherical movement
iv. Self-levelling
v. Ready assembled

AM System: SLS
Material: Polymer
Designer: Ian Campbell, Loughborough University, UK

Fig. 2. Example of information in the DfAM feature repository

3. PILOT USER TRIAL

To ascertain user perceptions of the DfAM feature repository, verify its overall feasibility and to gather suggestion for its improvement, four MSc students on the Industrial Design Masters Programme at Loughborough University were given a project to re-design a user-interaction product so that it could be produced with a laser sintering AM system. Prior to the study, the students were given an introductory lecture on AM together with a paper version of the feature repository. They were asked to use this as an aid to their designing task by searching for applicable and innovative features that could be included in their product. In addition, each student was required to keep a design diary to record their use of the feature repository and their design decisions in regard to designing specifically for AM. This aided further analysis of the DfAM system with a view to future improvement. On completion of the design task, the students completed a questionnaire to gain feedback on their views of the effectiveness and applicability of the repository.

The findings of the questionnaire showed that the students found the DfAM feature repository to be easy to use and they understood its design aid strategies that provided examples of design features based on the user selection of the reasons for AM utilisation. Furthermore, the students also felt that the DfAM feature repository was helpful in suggesting possible design features to adapt for use within their own design work. Examples of innovative design features in the repository also helped the students to understand the design freedom associated with AM. The students found that the DfAM system would be appropriate for use during the conceptual design stage. They agreed that using the DfAM system, would have a positive influence upon their conceptual product design. However, one student felt that the DfAM tool could be improved generally in terms of the pictorial data and textual content. There were also suggestions to include the explanation of all AM systems available and all other types of suitable materials into the repository but this is beyond the scope of this research at this stage.

4. CONCLUSION

The main objective of the DfAM feature repository is to enable designers to access and reuse design knowledge accumulated over the years, specifically the features designed for laser sintered additive manufactured parts or products. It allows designers to visualize and retrieve AM design feature information and knowledge at the conceptual design stage. By providing four reasons for utilization of AM with various design feature examples that fall under various sub-categories of applications, the DfAM feature repository provides an innovative way to approach AM part or product design. The use of the DfAM feature repository is also likely to enable fast conceptual idea generation and to demonstrate AM design freedom to novice designers.

The AM design features taxonomy is seen as a useful aid for industrial designers to understand the design freedom associated with AM. The classification of four taxons that were further expanded into sub-categories of various design features is anticipated to help designers to visualize and extract design feature information to assist the AM design process.

This research has shown that the DfAM method of providing designers with examples of design features from the repository is a suitable strategy to aid in designing additive manufactured parts or products. The next stages of the research are to improve and validate the repository with responses from professional industrial designers and to create a web based system to gather, present and to exploit the prominence of design for AM.

5. ACKNOWLEDGEMENT

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