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Rapid Prototyping for Assembly Training and Validation

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Abstract: Rapid prototyping refers to a group of techniques that are used to fabricate a model of a physical part layer-by layer directly from a computer aided design file. It has been widely used in several domains to accelerate, check and validate product design, and implementation of product. However, little work has been dedicated to the use of rapid prototyping technology in manufacturing assembly validation and training. This paper presents guidelines for using rapid prototyping in manufacturing assembly. A case study is designed to validate the design and implementation of an assembly product made of sub-parts, and to validate the assembly and human operator training processes. Rapid prototyping technology is applied successfully for assembly process planning.

Keywords: Rapid prototyping, 3D printing, Fused Deposition Modeling, Assembly

1. INTRODUCTION

Manufacturing assembly refers to the process of putting manufactured parts together to make a complete product such as a machine or an electronic circuit (Kalpakjian and Schmid, 2001). Globalization of markets places increased emphasis on product and process validation and requires efficient and effective product design changes (Maropoulos and Ceglarek, 2010). Assembly operations are a key component in modern manufacturing systems and assembly processes have a direct influence on product quality, time to market, and cost; thus, they require special validation (Seth et al., 2011). Process of assembly validation includes: 1) a human operator can assemble the part or component or not, 2) a human operator can disassemble the part or component or not for maintenance, 3) the difficulty of the assembly/disassembly process, and 4) the time to complete assembly (Gomez and Zachmann, 1999, Abidi et al., 2013).

Rapid prototyping (RP) is the technology that produces physical models from 3D Computer Aided Design (CAD) data directly (Dheeraj, 2012). Nowadays, RP has been used in many fields (medical, product development, engineering), since it has a capability to produce a physical model for any geometrical complexity in a short time using the additive manufacturing approach (Novakova-Marcincinova and Kuric, 2012). These technologies give the designer the ability to check the shape of a product, validate the fitness of assembly parts, and test the function of the produced model. RP technologies vary in material, building time, model cost and model quality (Series, 2009).

RP has been mainly used to obtain prototypes to check the validity of a design (Dheeraj, 2012; Onuh and Yusuf, 1999; Series, 2009). Little interest has been given to consider RP for assembly training, and to validate feasibility of assembly (not to validate each single part prototype alone).

Existing research focused on using engineering drawings and digital models for assembly training, and validation (Seth et al, 2011). Some of the limitations of using these traditional assembly-training tools include; physical interaction is not present, force feedback is missing, and physical properties such as friction, gravity are not present. These limitations can be overcome by using RP models.

In this work, the RP technology is used for assembly planning and a case study is developed to illustrate the benefits of using RP models in assembly training, and validation.

2. RAPID PROTOTYPING: AN OVERVIEW

Manufacturing technologies can be classified as formative, subtractive, or additive. Existing manufacturing technology either falls into one of these categories, or is a hybrid process that uses more than one. RP is the automatic fabrication of physical models using additive manufacturing technology (Onuh and Yusuf, 1999).

There are many ways for classifying RP technologies. One way to classify RP systems is by the initial form of material used to build the prototype. RP systems can be categorized into liquid-based such as Stereolithography (Stl), solid-based

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such as Fused Deposition Modelling (FDM) and Laminated Object Manufacturing(LOM), and powder based such as Selective Laser Sintering (SLS), Three-Dimensional Printing (3DP), and Electron Beam Melting (EBM; Series, 2009; Pandey, 2010).

RP was initially used to produce physical 3D models. Today, they are used in a wide range of applications, such as Product Design (Mihaiela et al., 2009), Ergonomic Evaluation (Yagnik, 2014), Customized Prostheses (Farias et al., 2013), Medical Training (Abdel-Sayed and von Segesser, 2011), and are even used to produce final product (Novakova-Marcincinova and Kuric, 2012). In product design, RP is employed to discover errors or misfits in the design of a part that can lead to savings in time and cost. The medical field has benefited from using RP to build human implants accurately and quickly, and using RP models to train cardio-vascular surgical procedures.

Mechanical RP scale models enable visualizing complex shapes, which cannot be seen or understood on conventional engineering drawings, and enable the ability to physically interact with them to verify form and function (Dheeraj Nimawat 2012). RP was used in engineering projects to help students produce models of real-world objects (Diegel et al., 2006). RP enabled engineers to identify and resolve problems that could be missed when using digital models. In manufacturing assembly, RP allowed product development teams to understand how the model components need to fit together during manufacturing (Yagnik, 2014). Despite the wide variety of applications of RP, yet another under-explored application is to use RP for assembly training, and to validate assembly operations.

In this work, RP models were fabricated using Fused Deposition Modelling (FDM; Novakova-Marcincinova and Kuric, 2012). The principle of the FDM is based on surface chemistry, thermal energy, and layer manufacturing technology. The FDM uses Acrylonitrile butadiene styrene (ABS) plastic in filament form, which is melted using a specially designed nozzle head and extruded to build the physical model. As it is extruded, it is cooled and thus solidifies to form the model. The model is built layer by layer, like the other RP systems (Bagsik and Schöppner, 2011), (John Michael Brock, 2000) see Figure 1.

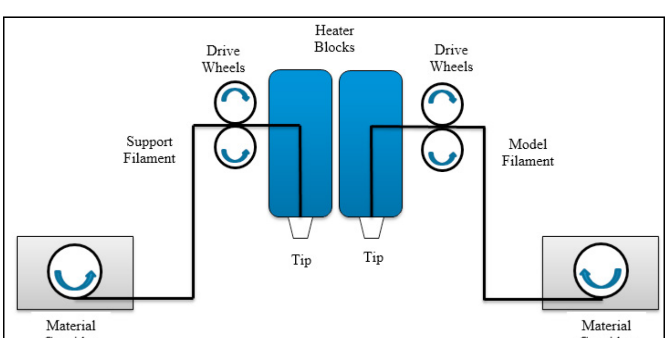

Fig. 1. Schematic of Fused Deposition Modelling (adapted from Yagnik, 2014)

3. CASE STUDY

In this work, a Reciprocating gizmo mechanism assembly is considered as a case study. It is used for converting the input (the lowest gear wheel pair) rotary motion to output linear motion. This assembly model was selected because of its complexity due to number of parts and the similarity between the parts increases the difficulty of assembly furthermore. Figure (2) shows the assembly model.

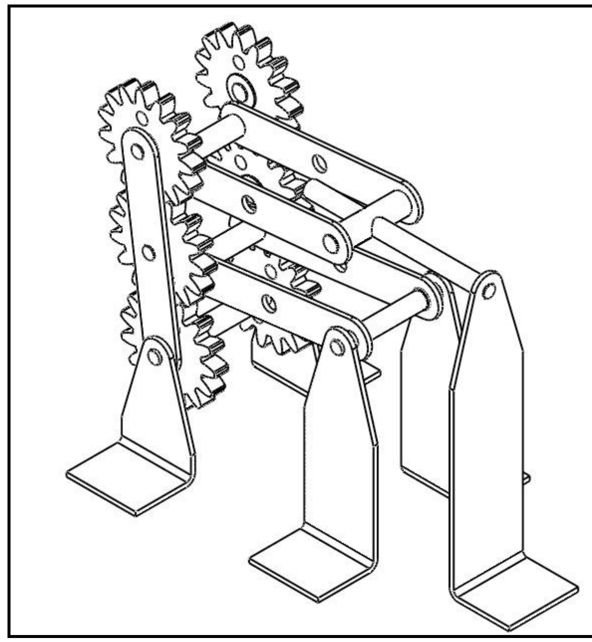

Fig. 2. Reciprocating Gizmo Mechanism

3.1 Design and Fabrication of Reciprocating Gizmo Model

The basic steps for design and fabrication of the model are described as follows:

- **CAD model:** The various components of the reciprocating mechanism are designed and modelled using CAD software i.e. SolidWorks® (SolidWorks, 2014). Figure 3 shows the CAD model of one of the component of the assembly.

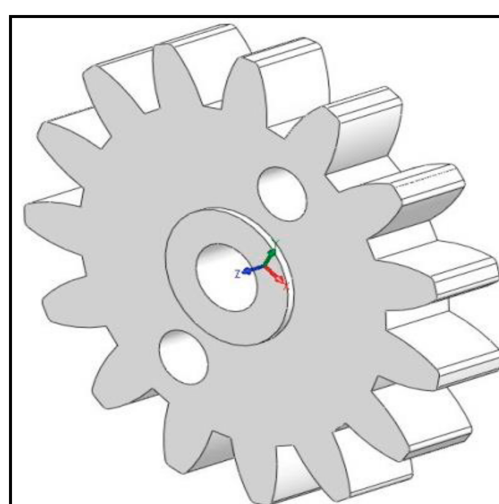

Fig. 3. CAD Model of a Component of Assembly