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Framework for The Development of a New Reconfigurable Guillotine Shear and Bending Press Machine

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Abstract

In today's manufacturing world, consumer satisfaction is difficult to achieve owing to the dynamic and continuous changes in their requirements and the rapid change in product designs. Research has been carried out on several innovations addressing this problem with various machine designs having been produced to deal effectively with the dynamic customer needs. Reconfigurable manufacturing systems (RMSs) and machines (RMTs), having superseded the dedicated manufacturing lines (DMLs) with dedicated machine tools (DMTs); and flexible manufacturing systems (FMSs) with their machines (FMTs), have led to a new era that takes the best aspects of both DMLs, FMSs and machines to conceive a new manufacturing system, RMS and RMTs that satisfy the dynamic nature of customer requirements. The aim of this paper is to present a structured framework that will optimise the development process of a new reconfigurable guillotine shear and bending press machine to be used in sheet metal work. The framework provides a guide for designers and manufactures of sheet metal machines in developing the new machine. To develop the framework, research used various tools such as reviewing existing literature on RMSs & RMTs, DMLs & DMTs, FMSs & FMTs and expected product change responsiveness. Research also explored literature on the development of machine modules for reconfigurable machines and reconfigurable technology systems. The framework seeks to provide a structured approach towards the machine development by highlighting important steps to be taken and various aspects to be considered. The results give a framework that will guide the development of a reconfigurable guillotine shear and bending press machine tool that can be configured and reconfigured to enable cutting and bending of varying sheet metal products by a single machine with dual functionality.

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1. Introduction

Many manufacturing companies are facing increasing unpredictable market changes that are driven by rapid introduction of new products and continuous changes in product demand. Sheet metal working is one of the most versatile processes in industry today, producing a variety of industrial and domestic products, such as motor vehicle body parts, vehicle trailers, scorch carts, door frames incubator housings, stoves, etc. In manufacturing, production patterns are changing, with large scale and mass production having declined significantly, and the pace at which one product is replaced by another has increased, [4]. Most machines used in production are failing to meet the changing product and production requirements due to the nature of their design. Current production machines are dedicated machine tools (DMTs) and computer numerically controlled (CNC) flexible machine tools (FMTs). This paper presents work in progress for the development of a reconfigurable guillotine shear and bending press machine (RGS&BPM). The machine has a specific target market of Small and Medium Enterprises (SMEs). Using DMTs and FMTs in production lines implies that two machine tools are required, a guillotine shear machine tool for producing blanks and a bending press for bending the blanks into required configurations. The development of a RGS&BPM will consolidate the best aspects of the DMTs and FMTs into a new machine that will perfume both functions as a single unit. The design concepts however, are based on RMSs

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and RMTs, using the basic designs of the two machines. The aim of this paper is to develop and propose a framework that can be used by designers from the proposal stage to the concept evaluation stage. Research work review on different design frameworks such as the theoretical framework, conceptual framework, design recovery framework, agent based framework and modularity framework presented and a framework proposed.

2. Background

DMTs are designed to be fully dedicated for mass production of a specific product, involving operations like cutting or bending sheet metal. FMTs are designed prior to knowing the operational requirements, hence possess more features than will be required in their daily operations [16]. The increase in part variety and reduced product life cycle requires new production machinery capable of handling the changing product varieties as demand changes, hence the development of reconfigurable machines. Most research work on reconfigurable machines has been based on machining or metal removal processes and recently in bending presses and other related areas. Some of the developments in reconfigurable machines can be observed from machines such the Reconfigurable Bending Press machine, [9], Towards a Reconfigurable Inferior Limbs Exoskeleton for Assistive Rehabilitation and Empowering Application, [21], Design, Refinement, Implementation and Prototype Testing of a Reconfigurable Lathe-mill, [1].

Due to their design, it may be very expensive to change DMTs' configuration as product varieties change. FMTs are flexible but their flexibility is not commensurate with operational requirements and the manufacturer pays for the flexibility they may never use. Reconfigurable Machines Tools (RMTs) are developed to supersede DMTs and FMTs by adopting best features of dedicated and flexible machine tools to produce a machine that can handle changes in product and production requirements.

3. Reconfigurable Machines

Reconfigurable machines are designed around a specific part family of products and allow rapid change in their structure, [14]. The basic design of RMTs should include the following characteristics, Modularity, Scalability, Integrability, Convertibility, Diagnosability and Customisation, [5,13]. These characteristics can be explained as follows:

- *Modularity*: Hardware and software designed as modules that can be added or removed from the machine.
- *Scalability:* The machine should be able to adapt to new requirements like increasing the capacity of the machine.
- *Integrability:* Interfaces of modules are designed and used to connect various modules through transmission of motion, power and data.
- *Convertibility:* Changing from one configuration to another to be conducted with minimum effort.
- *Diagnosability:* The machine should be able to identify sources of poor quality products after reconfiguration. Inline inspection machines are installed to monitor inaccuracies and sources of error and thus improving ramp-up time, [13].
- *Customisation:* This is through design around a part family of parts, making it imperative that part families are clearly defined to match the production process, [13].

The key concept of modularity lies in the fact that the machine is designed from a library of precompiled modules. It employs modular design principles where components are grouped into modules according to similarities in their functions and manufacturing processes, [5]. The process has been used in the design and development of some machines, among them a reconfigurable bending press and reconfigurable vibrating screen, [9,18]. It is noted from literature that modular design also enables the manufacture of products simultaneously by allowing rapid changes to the manufacturing system. Developing a module for part family for instance, a dendrogram may be used. A dendrogram is a branching diagram that represents the relationships of similarity among a group of entities. Fig. 1 shows a Dendrogram of part families as they are developed.

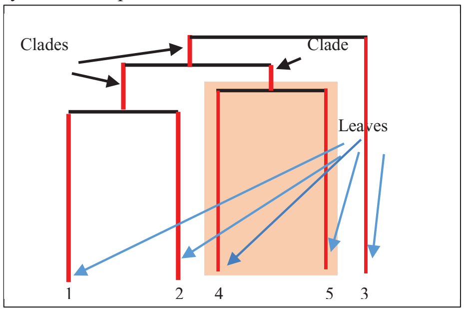

Fig. 1. Dendrogram of part families

The clades, which form different branches of part families, signify the number of part families in a module. The arrangement of clades indicates families with similar part features and the height indicates how similar or different these are from each other. Fig. 1 shows a dendrogram with 5 chunks and these chunks can be grouped according to similarity, for example chunks 1 and 2 can form a group and similarly chunks 4 and 5 form another group. Chunk 3 stands alone as it has totally different features from the rest. Using this graph, modules are designed for reconfigurable modular design of machine tools.

The development of a RGS&BPM must take into account its responsiveness to production requirements. RMTs are designed to deliver exact functionality and capacity when it is needed. Reconfigurability is achieved by changing the functionality and capacity of the machine through adding/removing and/or readjusting the existing auxiliary modules, [8]. This capability gives the machine its responsiveness as production demands change. To achieve the responsiveness RMT structure consists of a modular structure consisting of basic and auxiliary modules along with the open architecture software, [8]. The outlined six RMT characteristics determine the ease and cost of reconfigurability of manufacturing systems, and thereby enabling rapid

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