Design of framework of Hybrid RMS for Ball Manufacturing Industry

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Abstract. This paper discusses the possibility of implementation of a reconfigurable manufacturing system to aid a manufacturing organization to manufacture tennis and rubber balls simultaneously or exclusively with minimum changeover time. The tennis balls and rubber balls come under a single part family, that is, Ball. They constitute 8 types of products in total. The proposed manufacturing system consists of three individual and parallel manufacturing lines that are capable of manufacturing both tennis and rubber balls. As per the change in demand, the line can be reconfigured to manufacture any product within the part family.

1. Introduction

In recent times, the focus on product design and manufacturing with respect to time and money has increased the importance of development of a high ranged system to maximize desired outputs. A lead in developing a system for a variety of products will help in better market exposure and eventually success in sales.

The manufacturing systems are classified as Dedicated Manufacturing System (DMS), Adjustable Manufacturing System (AMS), Flexible Manufacturing System (FMS) and Reconfigurable Manufacturing System (RMS). G. Zhang et al [1] has compared the cost and performance of DMS, AMS, FMS, and RMS analytically. A DMS is used to produce a single product for mass volumes. It consists of special-purpose machines with a fixed control system following a fixed path. An AMS is used to produce a range of products for mass volumes that are almost similar and can be produced with minor adjustments in the system. It consists of standardized machines with limited adjustable control system following a fixed path. An FMS is used to produce a range of products for mass volumes that are almost similar and can be produced with minor adjustments in the system. It consists of standardized machines with limited adjustable control system following a fixed path. An FMS is used to produce small batches of a large group of products. It consists of CNC machining centres with a programmable control following a flexible path. An RMS is used for producing mass customizable products. It is a platform that can be deployed to manufacture a family of products with minimum change over time, with no sacrifice in quality, even though production quantity for a given specific product is not high [2]. A reconfigurable manufacturing system is specifically designed to handle the demands of a highly volatile global market where product demand forecasting is a complex problem. [3]

RMS was developed in recent times and is confused with FMS by a lot of individuals. The goal of FMS is to maximize the variety of the generated products, while, RMS targets to give a quick response to the customer and the prevailing market. FMS offers general flexibility while RMS offers customized flexibility. Meaning that, its flexibility is limited only to the development of a part family. RMS benefits in fast scalability to the target quantity and convertibility at a reasonable cost to the manufacturers. Y. Koren et al [4] defined 6 core characteristics for an RMS as Modularity, Integrability, Customization, Scalability, Convertibility, and Diagnosability. M. Nakao et al [5] used an RMS in Mold design and manufacturing industry to reduce lead-time for less...
quantity but more variety in production. Deif et al [6] demonstrated a systematic approach for designing an RMS and controlling the design process by development of an open mixed architecture for PCB assembly line.

A study indicates that the valuation of the global sporting goods market was 60900 mn USD in 2018 and will rise to 83300 mn USD in 2025. It can be said that this industry is of a substantial size, and optimization in this area can save tremendous amounts of energy, time, and financial resources. It is often observed that the manufacturing processes used to produce these articles often consist of significant input by a human directly without the use of any machine. And these inputs impart quality, accuracy, and finesse to the product. For example, two oblong pieces of fabric are carefully stuck to the rubber surface to form the outer covering of the tennis ball. This step has to be done with care so that the uniformity is seen in all balls, and the worker is able to do this very fast, considering the rate at which production is done. The key attribute of an RMS is combined functionality and scalability, it is capable of responsiveness to intrinsic (machine failure) and external (market changes) unpredictability. This is desirable for the sports goods manufacturing industry where the demand for a particular product in a product family may keep in varying with uncertainty.

In this paper, the authors have made an attempt to develop the framework for a Reconfigurable Manufacturing System that can be applied to a factory setup where tennis balls and rubber balls are being manufactured simultaneously.

2. Existing manufacturing system
The authors did a field visit to a manufacturing organization that manufactured tennis and rubber balls and studied the process for tennis ball and rubber ball manufacturing. As shown in Figure 1, Ball as a part family has two variants – Tennis and Rubber balls. The sub-variants for Tennis balls are Hard and Soft Tennis ball with two color variants each – Yellow and Maroon. The sub-variants for Rubber balls are basically color variants – Red, Blue, Orange and Purple. The study allowed to understand the process and pick out some common processes and process equipment.

![Fig. 1. Classification of Ball as a part family](image-url)
The process involved in hard and soft tennis ball manufacturing comprises of the following steps:

- Preparation of standard rubber base consisting of latex and necessary additives.
- Liquidizing the above-prepared base to the right consistency by using thermal methods.
- Injection molding using a liquid base to prepare ball halves of different wall thickness for hard and soft variants.
- Gluing and joining of halves by using thermally activated adhesive.
- Cutting of fabric to obtain pieces of required shape.
- Application of thermally activated adhesive to the faces and sides of fabric.
- Joining of fabric to prepare a hollow rubber sphere by activating adhesive by heat curing.
- Labelling of ball with company logo.
- Quality testing
- Individual packaging
- Box packaging
- Warehousing

The process involved in rubber ball manufacturing of any given colour comprises of the following steps:

- Preparation of standard rubber base consisting of latex and necessary additives.
- Liquidizing the above-prepared base to the right consistency by using thermal methods.
- Preparation of irregular shaped rubber lumps with imparted coloring and heat-activated chemical additives.
- Enclosing of rubber lumps into spherical metal enclosure.
- Heat treatment of specimen in the enclosure to obtain uniformly expanded specimen in form of hollow ball.
- Cooling of prepared ball.
- Quality testing
- Individual packaging
- Box packaging
- Warehousing

Both the processes and their equipment were placed in different sections and spaced at irregularly large distances. Also, the whole line is highly labor-intensive with most of the operations having some or the other human involvement. This is due to the fact that these operations are of complex nature and if these tasks were to be done by machines, it would be highly inefficient from time, energy, and quality perspectives. And it also must be noted that these operations must be done at a high speed, which a trained person is capable of doing.

When it comes to tennis ball manufacturing, the application of adhesive to the molded ball halves is done entirely by hand. All operations except heat curing with regard to joining of the fabric to the rubber base are also done by hand. These operations are cutting of fabric, gluing of fabric, and the pressing of the fabric onto the rubber. The application of the company logo onto the prepared ball surface is also done partially by hand. In the case of rubber ball manufacturing, the insertion of prepared lumps into the metal enclosure is done by hand. All the inter-operational transport in
the line and the addition of chemical compounds into the machine with specific proportions for chemical processes are also done manually. The quality testing, box packaging and warehousing processes are done manually as well.

3. Proposed manufacturing system
As shown in Figure 2, except the fabric cutting, gluing, and heat curing machinery, the remaining machines are utilized by manufacturing processes of both the balls either directly or with a product family specific attachment. The previous sentence actually states a feature of the system that gives it a minimum changeover time when there is a change in the type of product that is being manufactured. This is the major feature of any Reconfigurable manufacturing system. To be able to manufacture a variety of products of a product family with minimum changeover time with no loss in quality and no substantial decrease in the rate of production.

![Proposed manufacturing system diagram]

When rubber balls are manufactured, a conveyor system can be used to transport the balls across the fabric gluing and curing platforms. The proposed system actually consists of three parallel manufacturing lines. Each line is capable of manufacturing, both rubber and tennis balls. The idea is to use the central line to manufacture tennis or rubber as dictated by the demand. The mixing and liquidizing machinery can be used to prepare the rubber base for tennis or rubber balls. The molding machinery can be used to prepare halves of hard or soft tennis balls based on the mold used, or can be used to make rubber ball lumps with chemical additives. This can be done.
by using adjustable attachments. Adhesive will be applied to ball halves and the heating - joining arrangement can be used to activate the adhesive to prepare tennis ball rubber base or it can be used to expand the specimen to form a rubber ball inside the metal enclosure. In the case of tennis balls, the fabric gluing and curing machinery is used to make the outer fabric cover of the ball and make a complete tennis ball. After this, the quality testing phase is similar for the entire family of products. The packaging and warehousing method and machinery are also the same. The human involvement in the existing system remains the same but it takes place in process-line and the process is not halted for the same.

In this RM system, the mechanisms involved are the same mechanisms involved in the manufacture of tennis and rubber balls. There is no overall specific mechanism involved. This system focuses more on the simple modification that can be done to the manufacturing system as a whole in response to the change in demand. Hence, this reconfigurable manufacturing system can be effectively used to manufacture tennis and rubber balls simultaneously in a ratio that is decided by the instantaneous market demand.

4. Results
It can be very well said that the proposed implementation of a reconfigurable manufacturing system for manufacturing the concerned family of products will benefit the manufacturing organization tremendously. Unprecedented fluctuations in the demand will be handled with confidence and ease with minimum changeover time with no depreciation in finished product quality. It must be noticed that the proposed RMS is a hybrid RMS, with humans participating directly as a system element. The participant is skilled in manufacturing operations required for the manufacturing of various products.

5. Conclusion
In this paper, an approach has been proposed for the manufacturing of tennis and rubber balls using a hybrid reconfigurable manufacturing system (HRMS) where human workforce is a direct part of the manufacturing system. The specific feature that is paramount in the proposed system is high functionality, since the manufacturing route employed for manufacturing tennis and rubber balls has little differences. Changeover effort is lower compared to completely machine-based RMS since a part of the manufacturing system is humans which are well versed with the manual procedures involved in the manufacturing process. The work done in this paper can be developed further to implement such kinds of reconfigurable manufacturing systems for manufacturing of products in various industries.

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