A CONCEPT OF PHYSICAL RECONFIGURABLE CONVEYOR SYSTEM

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ABSTRACT: Conveyor is one of the most important materials handling equipment which is able to transfer the product from one place to another. A concept of the physically reconfigurable conveyor system was developed in order to meet the market responsiveness at a reasonable cost with less maintenance cost and work. The concept of physical reconfiguration of the conveyor system was analyzed and the design of the concept for the physically reconfigurable conveyor system was modelled and verified using design software using Solidworks. Different layouts were arranged using the designed modular components. Five requirements of the reconfigurable conveyor system were proposed; adjustable height, adjustable magnet lock, modularity, convertibility and short layout change over time. In future, the prototype of the concept for the reconfigurable conveyor system can be developed in order to get a realistic result.

KEYWORDS: *Reconfigurable, Conveyor System, Automation.*

1.0 INTRODUCTION

A conveyor system is a common type of mechanical handling equipment which transfers and moves materials [1]. However, the technology needs to cope with high-frequency market changes and other challenges due to globalisation in this 21st century. A new conveyor system should be implemented because most of the manufacturing organizations possess conveyor as a material handling system.

Reconfigurability is an ability to change and rearrange the behaviours of a system by changing its configuration [2]. Truly reconfigurable conveyors are like LEGOs which provide ultimate reconfigurability [3]. A reconfigurable conveyor system comprises a combination of physical and logical configuration. Physical conveyor unit is the hardware of the conveyor whereas logical conveyor unit is the controller [4].

The current manufacturing systems are mainly dominated by Dedicated Manufacturing system (DMS) and Flexible manufacturing system (FMS). Due to some problems which occur in this manufacturing system, a new type of manufacturing system which is very responsive to all these market changes is needed. Reconfigurable conveyor system offers significant flexibility, efficient use of available space [5], repetitious reconfiguration and low maintenance costs. This paper presented a concept of the physically reconfigurable conveyor system.

2.0 FLEXIBILITY VS. RECONFIGURABILITY

FMS provides generalised flexibility designed for the anticipated variations and built-in a priory. Flexible material handling systems (FMHS) have been widely used to enhance productivity involved with product proliferation, and thus far, only fixed-track material handling systems in the apparel industry are commonly used [6]. This system is convertible and able to provide scalable capacity but the system is costly and has long cycle time.

Reconfigurable Manufacturing System (RMS) is a new manufacturing system that aims to achieve a cost-effective response to market as needed and when needed and is able to react to changes quickly and efficiently. A reconfigurable conveyor system is a system designed for adjustable structure [6] that enables system scalability in response to market demands and system design around the part family [7].

Building a system with adjustable structure, scalability, and flexibility basing on a part family creates a responsive reconfigurable system. The flexibility of RMS despite its "customised flexibility" provides all the flexibility needed to process the part family, and therefore is less expensive than the general flexibility of FMS [7]. Table 1 shows the comparison features for reconfigurable manufacturing system and flexible manufacturing system.

Table 1: Comparison of system features for RMS and FMS (Heisel et. al, 2006)

Characteristic	RMS	FMS
System structure	Adjustable	Adjustable
Machine structure	Adjustable	Fixed
System focus	Part Family	Machine
Scalability	Yes	Yes
Flexibility	Customised	General
Simultaneously Operating Tool	Yes	No
Productivity	High	Low
Lifetime Cost	Medium	Reasonable

2.1 Physical Configuration vs Logical Configuration

Physical configuration refers to the hardware of the conveyor such as conveyor components, conveyor types, and system design layout whereas logical conveyor unit is the controller such as Programmable Logic Control (PLC) which controls the movement and direction of the transport item through the conveyor system. The physical configuration of the conveyor system includes the design of the conveyor, materials needed for the conveyor fabrication and types of sensors and mechanisms used. A logical configuration of the conveyor system consists of program codes, types of PLC used and circuit or ladder diagram to activate the whole system [8]. Both the physical and logical configuration must be exactly similar before the control logics of the system is programmed into the simulation software [9].

2.2 Characteristic of Reconfigurable Conveyor System

For a reconfigurable conveyor system, three several key characteristics such as modularity, customization and convertibility are needed and must be designed at the outset using hardware and software modules. The modular components can be reconfigured or rearrange to better suit new application if necessary. The conveyors in modular forms are easier to store and change the layout than the whole conveyor system.

Customization enables the design of a system for the production of a part family rather than a single part. Customization provides the flexibility needed for those specific parts in order to reduce cost. Customised control can be achieved by integrating the control modules with open-architecture technology and providing the exact control functions.

Convertibility is an ability to transform the functionality of the existing conveyor systems easily. Advanced mechanisms for an easy conversion between parts and fast calibration [10] should be implemented in order to achieve convertibility.

3.0 THE PROPOSED PHYSICAL RECONFIGURABLE CONVEYOR SYSTEM CONCEPT

Some specifications of a reconfigurable conveyor were proposed. The proposed specifications were using a pneumatic cylinder with turntable, adjustable height of the conveyor, short changeover time of conveyor layout and modularity of the conveyor. Figure 1 shows the module of the reconfigurable conveyor system.

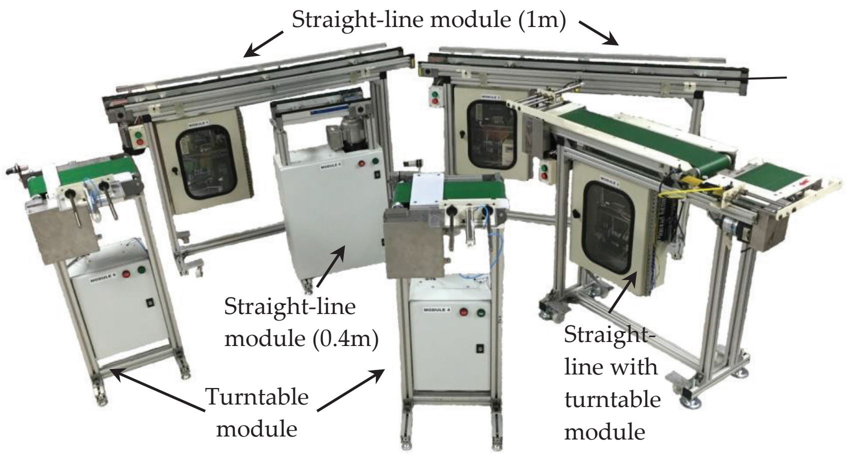

Figure 1: Module of conveyor system

3.1 Pneumatic Cylinder with Turntable and Straight Line Belt Conveyor

Pneumatic cylinder with turntable consisted of two adjuster wheels, two adjustable steel combine stands, one pneumatic cylinder with turntable, and belt conveyor. This type of turntable used double acting cylinder. The table could turn 90° and 180° each in clockwise and anticlockwise direction for the positioning mechanism. Single straight line belt conveyor consisted of four adjustable steel combine stand with one single belt conveyor. The length of this straight line conveyor was one-meter long. The changeover time of the conveyor system could be reduced due to the standardised units of the modular components.

3.2 Adjustable Height

Another proposed specification of the reconfigurable conveyor was adjustable height of conveyor. The height of conveyor can be adjusted using an adjustable steel combine stand/support by taking off the screw and then put back into the height level that is needed.

3.3 Adjuster Wheel

This type of wheel was called integrated casters & levelling mounts. The adjuster wheel consisted of a support/stand and a wheel. This type of adjuster wheel provided a better balancing and stability for the conveyor.

3.4 Magnet Locking Mechanism

After the full assembly layout arrangement of the reconfigurable conveyor system was created, a locking mechanism between the modular components was needed. It is important because the locking system could make the reconfigurable conveyor system stable and reliable when material handling was carried out. The length of the magnet lock was adjustable. The type of magnet used for this project was NdFeB magnet.

4.0 POSSIBLE MODULE LAYOUT OF RECONFIGURABLE CONVEYOR SYSTEM

All the possible module layouts could be created using the modules that had been designed and justified; module 1 – pneumatic cylinder with turntable and module 2 – single straight line belt conveyor [3]. There were four possible module layout arrangements for the reconfigurable conveyor system. There was Straight line layout arrangement, L-shape layout arrangement, U-shape layout arrangement, Closed loop layout arrangement.

(i) Straight line layout arrangement ii) L-shape layout arrangement

(iii) U-shaped layout arrangement (iv) Closed-loop layout arrangement

Figure 2: Possible Layout Configuration

4.1 Layout Changeover Time Analysis

One of the proposed requirements of the concept for reconfigurable conveyor system was shorter layout change over time. Analysis method was implemented in order to minimise the tools and steps in the manufacturing process and standardised or modularized the components that needed changes.

The modular components of the reconfigurable conveyor system were fixed and standardised. The number of support stands needed, the type of conveyor used, and the layout arrangements were fixed and standardised. In this case, the changeover operation procedures for the modules of the reconfigurable conveyor system could be standardised and the changeover time would be reduced.

The concept for reconfigurable conveyor system used adjustable magnetic locking system to connect the modular components. It replaced the fasteners with a better quick-change performance and fewer tools were required. The overall changeover operations would become less complex and faster.

Maynard Operation Sequence Technique (MOST) analysis was used to conduct the predetermined time system of the conveyor system.

The unit used for the MOST analysis is time measurement units (TMU) where 100,000 TMUs was equivalent to 1 hour. Two sequence models were used to analyse the setup time of the existing conveyor system and conceptual reconfigurable conveyor system. A total of 5 operations must be carried out by a dedicated conveyor system whereas only 3 operations were carried out by a reconfigurable conveyor system.

Table 2: Comparison of total time needed to assemble the L-shape layout

Type of Conveyor	Operation	Changeover Time (min)	Total Time (min)
Dedicated Conveyor System	Fasten 14 steel bars	33.6	81.72
	Fasten 8 support stands	20.64	
	Fasten 4 steel bars	10.32	
	Loosen 4 steel bars	10.32	
	Miscellaneous	6.84	
Reconfigurable Conveyor System	Fasten 10 combine stand	12.00	39.24
	Fasten 10 bolts for 2 modules	21.00	
	Miscellaneous	6.24	

Table 2 shows a comparison of the total time needed to assemble L-shape layout between a dedicated conveyor system and reconfigurable conveyor system. Reconfigurable conveyor system only needed 39.24 minutes to make L-shaped configuration compared to a dedicated conveyor system which took 81.72 minutes. Almost 50% of the changeover time was reduced through reconfigurable conveyor system.

5.0 CONCLUSION

A concept of physically reconfigurable conveyor system has been discussed and designed. The concept of the reconfigurable conveyor system is cost-effective and responsive to the market changes. Reconfigurable systems deal with modules and modular arrangement,hence, different layout arrangements can be created. The animation for working principles and procedure to create possible layout arrangements is carried out using Solidworks. In future, the concept of reconfigurable conveyor system can be developed to get a realistic result. The functionality of the prototype could be tested and validated using experimental approach.

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REFERENCES

[1] W.J. Palm, "Just The facts101 – System Dynamics" Content Technologies, Inc., 2013.

[2] R.M., Setchi, and N. Lagos, "Reconfigurability and reconfigurable manufacturing systems: a state-of-the-art review" 2nd IEEE International Conference on Industrial Informatics, Berlin, June 2004.

[3] J. Batka. (2011). *What to look for in a modular, reconfigurable conveyor system.* Available:http://www.ptonline.com/articles/what-to-look-for-inamodular-reconfigurable-conveyor-system.

[4] M. Wentzel and B. Mueck, "Conveyor with Dynamic Logical Queuing" *United States Patent Application 2012/0185085,* 2012.

[5] A. Kyoungho, K.A. Trewyn, A. Gokhale, and S. Sastry, "Model-driven Performance Analysis of reconfigurable conveyor systems used in material handling applications" Second International Conference on Cyber-Physical Systems, Chicago, pp. 141-150, April 2011.

[6] B.D. James, N.K.S. Lee, and W.S. Cheung, "Performance analysis of flexible material handling systems for the apparel industry" Int J Adv Manuf Tech, vol. 44, pp. 1219-1229, Oct. 2009.

[7] A.A. Abdul Rahman and N.R Mohamad, "Software-in-the-loop technique: an approach to support reconfiguration of manufacturing system" J Eng Appl Sci, vol. 11, pp. 9789-9795, Aug. 2016.

[8] U. Heisel, and M. Meitzner, "Progress in Reconfigurable Manufacturing Systems" Springer-Verlag Heidelberg, 2006.

[9] A.A. Abdul Rahman, "Approach for Integrating Predictive-Reactive Job Shop Scheduling with PLC-Controlled Material Flow" Ph.D. Dissertation, Faculty of Transport and Machine Systems, Technische Universität Berlin, Germany, 2013.

[10] Y. Koren, "General RMS characteristics comparison with dedicated and flexible systems" Springer-Verladg Heidelberg, 2006.