Design & Build a Prototype of Two Stage Karakuri Lean Model

Ramesh G Pungle, Vinod D Shejwal

***Abstract*— the industry 4.0 is continuously aiming to produce faster, increasing quality, and strictly using what is necessary to achieve efficiency enhancement. Within the wide list of methods used to reach this target, robot automation is usually used, although is expensive and rigid. Alternatively, a Japanese cheap automation philosophy called "Karakuri" is being introduced by Volvo GTO to manage this goal. This paper relies on this philosophy, which takes profit of the existing energy, like gravity, to put in motion mechanisms, in order to reduce costs and improve the production efficiency by developing a semi-automated material handling system. Also proposes to utilize a template procedure for share knowledge about karakuri among beginners.**

***Index Terms*— Karakuri, lean, material handling, productivity and Ergonomics.**

I. Introduction

Lean manufacturing is a methodology resulted from Taiichi Ohno's contribution over decades to Toyota production system (TPS) in Japan. The primary focus of lean methodology is aimed at reducing waste, decreased time and increased quality. Since lean was introduced and its immense potentiality was recognized, industries around the world which are normally inclined towards automation have been making attempts to incorporate lean into their own industrial culture [1].

Karakuri in Japanese translates to trick or mechanism. It was first recognized with the introduction of mechanical dolls capable of achieving complex motion without using any source of power. The same concept was later introduced into manufacturing industries [2]. In this context, it can be defined as achieving motion with no power.

In their book 'Strategic Thrust of Manufacturing Automation Decisions: A Conceptual Framework', C Madu and N Georgantzas mention that industries have a desire to automate process to improve the productivity or speed as a solution to match the ever growing market and demands. This desire to automate may lead to unforeseen circumstances leading to a degree of automation that is neither significant nor economical. An example case study of a penicillin production company was mentioned to illustrate the necessity of automating only to a certain extent to prevent over-automation and might often lead to frustrating results [5].

A highly automated manufacturing plant not only imposes the problem of high initial and operating cost but also demands extremely skilled labor. Automating by just the right amount at the right places can draw huge benefits by creating a semi automated environment with relatively unskilled labour .Karakuri, also known as low cost automation, is a part of Lean manufacturing strategy and often neglected in favor of automation,

II. Common Karakuri Mechanisms

Most elements of a machine are made of simple or basic mechanisms such as lever, cams, linkages, springs, gears and cranks. Even with the advancing electronic technology, simple and basic mechanisms continue to play a vital role in converting and transmitting force from source to the machine. The source can be human power, motor or engine. Karakuri revolves around using imagination to evolve on these simple mechanisms to make operations more convenient and comfortable. In case of Karakuri the force to activate the mechanism is usually achieved with a combination of human power, gravity, magnetism and elasticity, in this following section some of the common mechanisms used in our Karakuri study to achieve kinematic motion and transfer of energy[4], [5].

III. Lever, Gears and Springs

A. Levers

Lever is one of the oldest mechanisms invented by mankind. A lever is used to multiply applied mechanical force or change direction of force. With innumerable applications for a lever, they are often overlooked in our daily activities. A major application of a lever, small force turns into a big force. Through applying a small force over a large distance, a larger force is applied on the opposite end.

B. Gears

A gear is a type of mechanical component consisting of a rotating wheel with teeth (cogwheel) that is capable of meshing another cogwheel or a chain, belt, axle, rack with teeth. Gears are primarily used for transmitting torque while controlling speed, torque and direction of motion.

A cogwheel or a gear which does not have a complete set of tooth around its pitch circle is known as a Mutilated gear. These are used when you do not want the gear to be engaged throughout its rotation or there is no necessity for complete rotation of the cogwheel. By using a mutilated gear you can control the time for which you want to engage transmission of motion, resulting in a discrete rotational motion where input shaft goes through a complete rotation whereas the output shaft undergoes stop and turn motion.

C. Springs

Springs are machine elements or components that go through momentous deformation. The compliance nature of these components enables them to accumulate recoverable mechanical energy. Springs exist in many forms, be it a simple tension bar, or a helical compression spring or an

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extension spring. A tension spring is usually wound with a predetermined pre-load to ensure deformation only occurs after the load acting reaches a certain minimum value. The functioning of Torsion springs are very similar to that of a simple free body that rely on bending for their action. They require a specially designed end to be able to transmit load [4].

IV. OBJECTIVES

The purpose of this project is to Design and Build a Prototype of Two Stage Karakuri Lean Model**;** the suggested model will demonstrate the methodology of Karakuri. The fourth industrial revolution has entered the industries who adopt new smarter technologies which are more readily available and cheaper than before.

The research paper objectives based to the purpose was recognized as follows:

- Develop demonstrative model of two stage karakuri for improving productivity and improvement in ergonomics
- A template procedure for share knowledge about karakuri among beginners

V. LITREATURE REVIEW

In this section, situation surrounding Karakuri technology including various efforts by industries and past research is summarized. Distinctive activity that must be mentioned is Karakuri Exhibition managed by Japan Institute of Plant Maintenance (JIPM), which was launched in 1993. This event has been held every year in Tokyo and Nagoya alternatively and, before the launch of this event, long-term, deep and substantial experience have been accumulated among driving industries such as car assemblers and parts suppliers [3].

Looking at academic research, there are very few papers on this subject. Therefore, international conference is a quite important in the meaning of knowledge sharing and transfer especially on this subject.

VI. METHODOLOGY

This study was carried out on two stages that covered both experimental and perceptions analysis on the Two stage karakuri model designs. The first stage would be the model design stage. Second stage would be the data analysis stage

"(a)"

"(b)"

Fig. I, "(a)" and "(b)" overview of the karakuri model

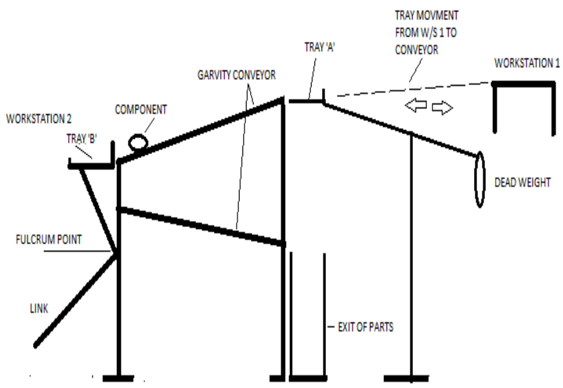

Fig. II, Structure of the Karakuri model

Elements	Functions	States (Code No.: Description of Status)	Way of State Transition/Mechanism
Tray 'A'	-Work Holding -Work Transportation	0 : Initial state (Before parts entry)	Gravity Force and Implemented Mechanisms
		1 : Tray with parts is at the entry point	
		2 : Tray with parts is at the exit point	
		3 : Empty tray is at the exit point	
		4 : Empty tray is at the tray return point	
Tray 'B'	-Tray Holding	0 : Initial state (Vacancy)	Mechanism of Stopper and
		1 : Tray with	

	-Tray Transportation	parts is loaded 2 : Tray without parts is loaded	Weight Slide Mechanism
Conveyor	-Deceleration of tray -Acceleration of tray forwarding by inclination mechanism	Initial state component move	Gravity Force

Table I, Definition of the elements and their states of Karakuri mechanism.

Critical issues for creating this table are to identify composed elements of Karakuri and to define the possible states of each element. Then, we can move to the next step, investigation of state transition of each element, by using table No.1.

VII. Analysis of Karakuri Mechanism

Purpose of Improvement	**Cases** **Objective Operations**
Improvement of Work Efficiency	Stacking
	Turn-rounding
	Return Operation
Work Automatization	Work Rotation
	Pallet Supply/Return Operation
	Pallet Stacking/Return Operation
Work-load Reduction	Transportation
	Lifting by Equipment /Transportation
	Manual Lifting/Transportation

Table II, Set of improvement purposes.

VIII. Result & Discussion

For productivity, main contributors of non-value-added activities that exist at previous Drawing process workstation design shall be identified first in order to reduce or eliminate it through Karakuri Kaizen implementation. Therefore, by reducing the non-value-added activities time, cycle time will be reduced and improved the productivity at the same time.

Time study has been carried out in this study in order to record the time spent by operators on variety of tasks at previous Drawing process workstation design and to identify the non-value-added activity time. Same individual operators who was working in both previous and improved workstation design will participate in this controlled time study (no any outliers such as temperature, humidity etc.).

IX. Conclusion

In conclusion to the study of Karakuri, it was able to determine that Karakuri is an ingenious mechanism used to automate an operation. Karakuri works on the principle of using readily available energy such as gravity, elasticity and magnetism. There is no external power sources such as electric motors or engines used to drive the mechanism. This principle and functionality of Karakuri can be seen in various forms around the world and has been around since the advent of wheels and levers. Although only these mechanisms were further developed in only some parts of the world compared to the rest.

The findings from the study can be briefly concluded through the following points:

- It is possible to automate almost all simple manual tasks using Karakuri
- Karakuri solutions should be developed by doing or to get down to the "Gemba" in Lean terms.
- Ergonomics is one of the most critical factors to consider while designing Karakuri

Karakuri design contradicts the traditional design method of PDCA cycle and stresses more on the 'D

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