ANNALS OF FACULTY ENGINEERING HUNEDOARA
– International Journal of Engineering
Tome XI (Year 2013) – FASCICULE 2 (ISSN 1584 – 2665)

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PRINCIPLES OF LEAN PRODUCTION TO DESIGNING MANUAL ASSEMBLY WORKSTATIONS

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ABSTRACT: *This article deals with the specification of basics Lean Manufacturing principles that should help to designing lean production solutions for own applications. The 9 principles discussed in this paper are: continuous flow; lean machines - simplicity; workplace organization; parts presentation; reconfigurability; product quality; maintainability; ease of access; and ergonomics. The presented article focuses on characteristic of possibilities to design "lean" assembly workstations with a modular construction structure made up of aluminium profile and building- block kit. There are specified selected potentialities for a productivity improvement. The goal is to present some examples of flexible workstations construction in ordinary assembly system.*
KEYWORDS: *Lean Production principles, modular workstations, design recommendations*

INTRODUCTION

The main concern of modern active production is to avoid any sources of waste in operation. Lean Manufacturing is the methodology about the elimination of waste, and about doing more with less: less time, inventory, space, labour, and money. The goal of production designing and planning is to create a production system that is as free of waste as possible by continually minimizing waste and changing it into added value. In addition to eliminating waste, this concept led to improved of product flow and better quality. This "less is better" approach to manufacturing depends greatly on flexibility and workplace organization. Cell production is a model for workplace design, and is an integral part of Lean Manufacturing Systems. Modular manual assembly systems are developed strictly in line with aspects for Lean production, enabling simple and fast planning and implementation of Lean production installations.

The three main pillars of manual production systems covered workstations, material supply and linking. Based on using the building block profiles system in design process, it is possible to create for example workstations, as well as entire production lines, that can be quickly adapted to varying work content and avoiding waste in line with "Lean" principles, e.g. [5]:

- *produce only the quantity required and no more,*
- *produce only what the customer needs,*
- *manufacture one at a time in response to the customer's demands,*
- *pull principle: excess inventory is prevented or controlled,*
- *one-piece-flow: increases transparency,*
- *zero faults principle.*

An ergonomic workstation design plays a decisive role in reducing waste during production. From an ergonomic aspect, the main focus is on the worker. The modular system for designing individual workplaces enables optimal adaptation to task and individual employee concerned.

THE BASICS LEAN MANUFACTURING PRINCIPLES IN WORKSTATION DESIGN

Growing pressure to reduce costs with limited sources of financing the modernization in enterprises environment brings the best interest of the method of Lean production and continuous improvement of processes. This management technique aims to simplify workplace layout and assists with the reduction of wastage and other forms of non-value adding activities whilst improving quality, effectiveness, process efficiencies and employee safety. [1]

The basics Lean production principles in workstation design are specified as follows:

- ***Continuous flow***

One of the goals of the lean workcell is to eliminate all non-value-added movement. The preferred shape of the lean workcell is U-shaped. Each subprocess is connected to the next in order of process (see Figure 1). With the worker in the interior of the U, minimum movement is required to move the workpiece or assembly from one workstation to the next. When the worker has finished the operation, he simply turns around and is back at step one. [2] Very heavy parts may be transported on

belt conveyors, manual push or gravity conveyors are ideal for moving parts between workstations. The curved "corners" of the U-shaped workcell can pose a problem - as potential dead space, they may act as a mini storage area, thereby encouraging a return to batch processing. The use of a ball roller transfer should facilitate part movement through the corners of the U-shape.

Figure 1. Example of assembly line constructed from modular aluminium framing [2]

□ ***Lean machines - simplicity***

One-at-a-time manufacturing is another goal of lean manufacturing, it is important that each workstation or machine have been designed to fit within a minimal envelope - this solution ensures the elimination of excess flat space at the workstation or machine and this is done to avoid the possibility of storing parts or subassemblies at the machine. [8]

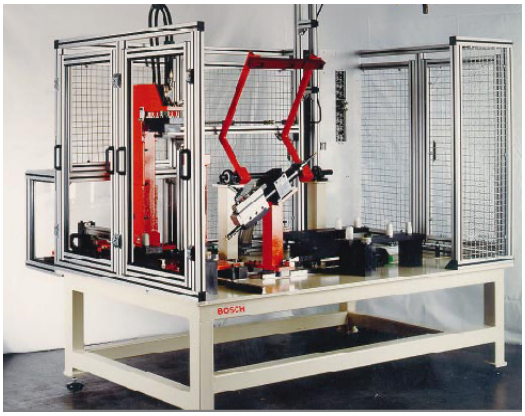

Figure 2. Machine guard with easy to remove panels [8]

Smaller, minimal size workstations and machines eliminate unnecessary steps taken by the worker between subprocesses. Significant floor space may be saved by properly sizing workstations and machines. To save on cost, as well as to minimize the operational complications related to disposing of inflexible welded steel structures, preference should be given to material and connector technology that is reconfigurable and reusable. The modular characteristics of extruded aluminium, bolt-together systems make them perfect for the implementation of lean manufacturing concepts. All workstations and workcells must be easy to modify as process improvements are identified. In addition to their superior flexibility in layout and design, lightweight aluminium structures are easier to move when re-configuration is necessary.[2] Example of this solution is presented at Figure 2.

□ ***Workplace organization***

Uninterrupted flow of completed workpieces is the desired result of a properly designed lean workcell. Nothing can stop this flow faster than the loss or misplacement of tools - therefore all tools used at a workstation should have their own holder. Using a modular tool holder system with a specific holder for each tool is ideal - if holders can easily be added to (or taken away) from a workstation, this simply adds to the flexibility of the workstation and increases its usefulness in a lean manufacturing process. Handy accessories are necessary addition to perfect design of an optimal workplace. Of maximum benefit are tool holding structures that allow tools to be swung or slid into the workspace and easily returned to the storage position when no longer needed. [1] Examples of solutions of modular tool holders shows Figure 3.

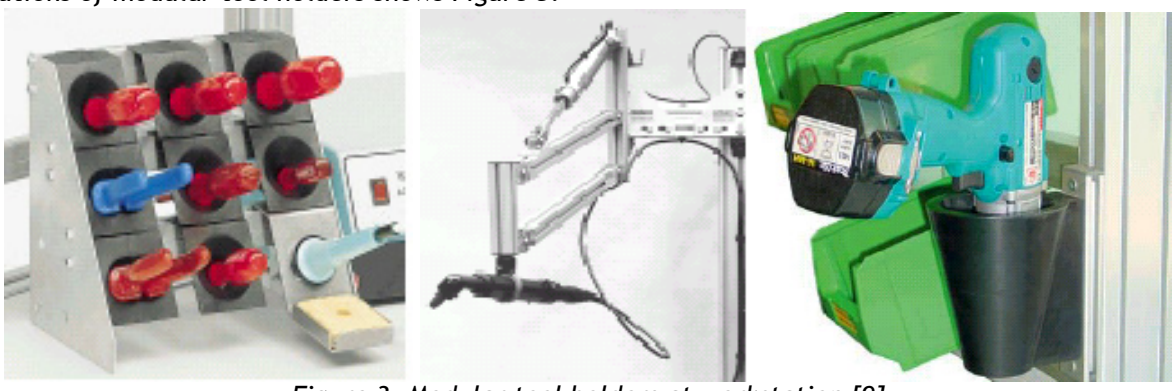

Figure 3. Modular tool holders at workstation [9]

The ready availability of work-critical information also adds to efficiency in a workcell. Supplying the right information at the workplace, such as assembly processes, work instructions,

repair procedures, or even production targets, allows workers to make the right decisions and act on them on the spot, limiting downtime often spent chasing down a supervisor. [6] In a lean workcell the information board should be simple, easy to reposition, and reusable.

□ ***Parts presentation***

During the average work shift, additional parts will be required for material supply to the workcell. Each worker should go about his work with the minimum number of interruptions. Therefore, all parts should be supplied to each workstation from outside the workcell. The use of gravity feed conveyors (or bins) fits the simplified design of the lean workcell. Gravity carries the parts to the worker's reach area. Bins for small parts are easily stackable and provide the ultimate in flexibility when reconfiguring the workplace. The larger parts may be delivered in boxes. In instances where parts are very heavy, lift assist devices are recommended, with electric, pneumatic, or hydraulic power. [1] Examples of supply parts equipment are demonstrated at Figure 4.

Figure 4. Gravity feed parts bins and buffers [8]

The material shuttles offer a wide range of possibilities to link and arrange materials in the workplace.

□ ***Reconfigurability***

A properly designed lean workcell must be easy to reconfigure or even moved to accommodate assembly of a new product - the faster the changeover, the less production time is lost. The modular structure, and comprehensive accessories from various producers of aluminium profiles sets, allows flexible adaptation of workstations to varying needs. Open system dimensions and numerous components of profiles and connectors kit enable individual designs for workstations. The ability to move each component of the workcell quickly becomes extremely important. Quick-change fixtures are one way this can be accomplished and e.g. lockable casters on machines or workstations provide the mobility necessary for rapid and efficient changeover. [6] Examples of this solution are presented at Figure 5.

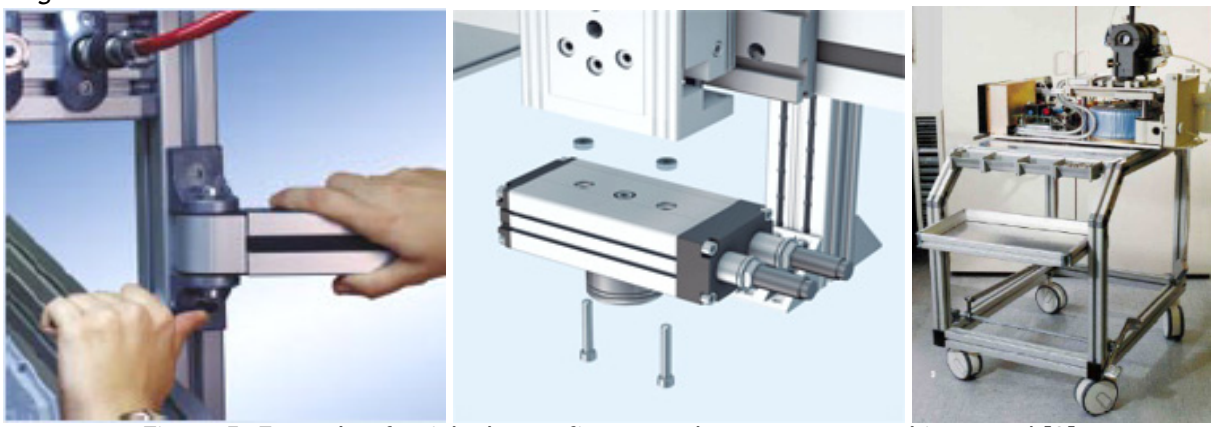

Figure 5. Example of quick-change fixture and casters on a machine stand [8]

An adequate modification allows the working table to be integrated easily into existing assembly lines.

□ ***Quality***

As each part is produced, visual inspection by the worker can verify that it is correctly assembled. A flawed process or malfunctioning machine may be the source of the quality problems. The structural aluminium profiles framing system (bolt-together construction) allows changes in a minimum amount of time. A malfunctioning machine may also be easily replaced, particularly if quick disconnects for all pneumatic or electric lines are provided for when the lean cell is designed. [1]

□ ***Maintainability***

Ease of service is another requirement of a lean cell - long down times cannot be tolerated in a pull-through system in assembly line. A modular structural framing system provides the ultimate in maintainability - components can be replaced or reconfigured; bolt- together construction ensures machine stands, guards, workstations, or parts presentation equipment can be serviced in a matter of minutes. With standardized modules, profiles and components from building- block set, a minimum number of tools are required to maintain (build or repair) a structure. Aluminium profile system constructions are quick to assemble, and no finish work is required - no cutting or welding, no grinding or polishing, no painting. [8] Another benefit is that common components eliminate the need for a large inventory of spare parts.

□ ***Ease of access***

Using an aluminium framing system as the foundation of a lean cell, all necessary work components can be mounted in easily accessible locations because each surface is a potential mounting surface. Parts bins, tools, shelves, and fixtures can all be positioned in the optimum location for efficient work. The T-slot on the profile framing system's surface also allows quick repositioning of pneumatic or hydraulic components if clearance space is critical.

Components may be added quickly to any workstation and easily repositioned to insure accessibility for each worker; entire guards or individual panels can be removed quickly with simple hand tools, enabling service technicians to perform maintenance in a matter of minutes. [4] Example of easy accessibility and serviceability of workstations structure shows Figure 6.

Figure 6. Detail view to expose accessibility in workstations [9]

□ ***Ergonomics***

Aluminium profiles and building- block kit provide all the modules needed to design and arrange workstations ergonomically. Ergonomic workstations are at the centre of assembly line. Maintaining the work at the ergonomically correct height throughout the workcell is always important. Ergonomic experts recognize [7] that making slight adjustments in workstation set-up (e.g. flexible workstation design) can lead to healthier employees, enabling them to experience less fatigue and be more productive throughout the shift. Correct adjustment of the table, chair, footrest, and grab containers, as well as the position of tools and material shuttles, minimizes movements, thus reducing physical exertion.

By incorporating ergonomic aspects into the design of production equipment in assembly workstations, it will be able to optimize working conditions and thus increase the motivation of workers. To maintain performance and promote productivity, all work equipment near the workstation in assembly system must be precisely adjusted to the employee and their activity.

In order to prevent delays in manufacturing caused by faulty design, a software package that allows testing the ergonomics of a workcell before the workcell is constructed can be a powerful tool - use of such a software package lets settle ergonomic issues in the design stage rather than on the factory floor, providing significant potential savings in both time and money.

Interpretations of the basics of Lean production principles, discussed in this paper, are summarized in Table 1.

Table 1. Factors of Lean Production designing of modular assembly systems [4]

Lean principle	Characteristics	Benefits
Continuous flow	- U-shaped cell - Connect sub-processes - Value-add-to-value-add operation - Machines in order of process - Parts arrive as needed - One-piece flow (small lot flow) - Non-cyclical work done outside cell by support people	Elimination of non-value added movements, work in process, and inventory.
Lean machines - simplicity	- Continuous flow - Save factory floor space - No excess production - No extra shelf/drawer space	One-at-a-time manufacture, quick production change-over, easily modified, customizable production.
Workplace organization	- Organize tools with appropriate tool holders - Insist on flexible tool mounting structures - Put the right information where it's needed	Minimize downtime, reduce wasted motion, un-interrupted workpiece flow, improve quality.
Parts presentation	- Supply parts as needed - Parts loaded from outside the cell - Use gravity feed as the preferred method - FIFO (first in first out) parts presentation	Easy reconfiguration, reduce wasted motion, un-interrupted production, quick changeover.
Reconfigurability	- Fixtures must be easy to change - Mobility is critical - Good part to good part as quickly as possible	Minimize downtime, quick changeover, uninterrupted workpiece flow.
Product quality	- Visual inspection is the primary means of quality assurance - Test fixtures and gages must be easy to replace or change out - Easy reconfiguration encourages changes for quality's sake	Immediate feedback on quality as workers inspect parts; platform for continuous improvement; eliminates rework areas; rapid change of quality gages as assembled product or process changes.
Maintainability	- Ease of service; manual back-up - Put the operator manual on the machine - Standardize as many components as possible - Use common tools and fixtures - No finish work required on system components. - Minimum spare parts necessary	Minimum down time, easy-to-source replacement parts, quick service.
Ease of access	- All controls or fixtures positioned with ergonomics in mind - All serviceable components at rear of machine/workstation to eliminate interference of maintenance personnel with production - Clearance for all tools for ease of use - All guards easy to remove with simple hand tools	Minimum down time, easy serviceability, optimum ergonomic design.
Ergonomics	- Position workpiece at optimum height for worker - Use standards to determine maximum lifting loads - Position all tools within the worker's field of reach	Fewer work-related injuries, lower employee turnover, better working environment, fewer cumulative trauma problems.

CONCLUSIONS

Lean production is usually associated with manual production/assembly systems. This manufacturing concept provides an optimum framework for efficient, competitive production - through: reduce inventory, eliminate downtime, reduce space requirements, avoid errors, avoid inefficient processes, avoid overproduction, and shorten transport routes.

The key to "Lean" implementation is construction of workstations with components that are easily reconfigured. Flexible assembly systems using aluminium framing as the main structural element allow companies to mix and match manual and automatic operations at will, and to change them at any time in the future. The result is a worker-friendly, economically- sound system designed for optimum production.

Modular structure of assembly system, and aluminium profile system kit, offer a wide range of variable components for the individual and flexible configuration of workstations. As a result, waste in production is minimized and available work spaces are used effectively.

The lean approach is not the solution for all manufacturing problems. But it does offer a uniquely flexible solution for assembling more complex products.

ACKNOWLEDGEMENT

This contribution is the result of the project implementation: Centre for research of control of technical, environmental and human risks for permanent development of production and products in mechanical engineering (ITMS: 26220120060) supported by the Research & Development Operational Programme funded by the ERDF.

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