Preliminary Note

Senderská, K., Lešková, A., Mareš, A.

DESIGN CHARACTERISTICS OF MANUAL ASSEMBLY WORKSTATION SYSTEM IN THE LEAN PRODUCTION STRUCTURES

Received: 17 January 2013 / Accepted: 25 February 2013

Abstract: The presented article focuses on the design characteristics of lean workstations with a modular design structure. The specification of basics Lean Production principles, that should help to design of flexible manual workstations, as continuous flow, simplicity, workplace organization, parts presentation, re-configurability, product quality, maintainability, ease of access, and ergonomics are discussed in the first part of this paper. Presented principles are applied in the new designed laboratory manual assembly workstations. The closing section of the article provides the specification of the Lean Assembly Laboratory project with some selected methods and tools supporting.

Key words: Lean Production, manual workstation, design characteristics

1. INTRODUCTION

The management techniques Lean production and continuous improvement of processes aims to simplify workplace layout and assists with the reduction of wastage. Identifying the potential for waste and transfer it into facility design considerations is the essence of lean workstations design. Properly designed lean workstation is flexible, low cost, and efficient. Flexibility is the ability to adjust and easily to change. This applies to changes at the individual workstation, as well as changes in the process flow or work cell layout. Modular systems are inherently more flexible than stand-alone units and in this regard they are characterized by sharing of structural components and the ability to create different layouts. The modular structure allows an individual and flexible adaptation of workstations to varying requirements, particularly in regard to ergonomics parameters.

2. LEAN PRODUCTION BACKGROUND

Lean Manufacturing or Lean Production, derived from the Toyota Production System, [8] is an approach based on the effort to maximal satisfaction of the customer requirements. At the same time there is an effort to achieve low costs and minimal time without product quality reduction. These goals are primarily achieved by waste eliminating. The following basic types of waste were identified by Lean approach: transport, overproduction, waiting, quality, motion, over processing and inventory. To eliminating these sources of waste can be applied a lot of techniques and tools.

2.1 Lean assembly

The same principles of waste eliminating as in the manufacturing can be applied also in the assembly. The assembly [15, 16] is an integral part of the production processes and have these specific characteristics:

− assembly process is organized and synchronized, in relation to the parts, which the production is carried out at different times and in different places,
− in the assembly process, very often, are exploited the manual operations because the automation of some operations required too complicated and expensive devices,
− the assembly process is usually the last production process in which manifests the term and qualitative irregularities from the previous phases and processes,
− some operations occasionally are repeated and they can be realized also parallel,
− usually the subassembly process is separated from the final assembly.

2.2 Principles of the lean assembly workstation design

Focusing on a group of seven main areas of waste in the assembly processes means, among other things,
involve these principles into actual design of the assembly workstation or to the technical design of structural elements of the workplace. Next section of the article presents some design characteristics of assembly workstations that support shape generalized lean concept.

Flexible workstation layout

Optimal workstation’s layout, respectively the possibility of a change, is an important aspect that results from the possibility of convert the assembly procedures, respectively from the work organization changes at the workstation. The flexible layout is a feature that enables to modify the assembly task and to adjust the material flow according to changed conditions. Significant floor space may be saved by properly sizing workstations. 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 joining technology that is reconfigurable and reusable. For example, the modular characteristics of extruded aluminum profiles and bolt-together systems make them perfect for the implementation of lean manufacturing concepts; lightweight aluminum structures are easier to move when re-configuration is necessary. A properly designed lean workcell must be easy to reconfigurable or even moved to accommodate assembly of a new product. An adequate modification allows the working table to be integrated easily into existing assembly lines. Bolt-together modular framing is the key to workstation’s flexibility - when new products call for line changes, it can be quickly reconfigure, add to, or re-purpose.

Using module and adjustable components for design

The design principle applied to proposing of assembly workstation’s structure, is usually modular what means, that from the existing modules can be the workstation planned according to the customer requirements. The producers of assembly means and equipments offers own reference solutions, so besides the modular concept insures also complexity of accessories. For that reason it is possible to build complete workstation from components, offered by one producer of modular units kit. Stability of presented standardized components then allows expandability or supplement of workstation. Re-configurability of workstation, respectively re-configurability of its elements, offers ability to adapt workstation according to assembly tasks requirements, also according to employee need. So, the modular structure allows an individual and flexible adaptation of workstations to varying requirements and modular construction permits complete freedom in system configurations. Based on easy-to-reconfigure framing system, modular set let to build an extremely flexible lean manufacturing system with workstations for variable production conditions. Sit-down or stand-up assembly workstations provide an optimum basis for work without fatigue and can be adjusted to the needs of individual employees.

Continuous material flow and transport

Uninterrupted flow of completed workpieces is the desired result of a properly designed lean workcell. Optimized solution of material flow [2] is a core task mainly because this is source of potential time - saving and also because to achieve the main goal - be “lean” is the need to minimize inventory in the workplace as

---

Fig. 1. Examples of adjustable work table, work chair [4] and shelf [5], [6]
well as in stores, and synchronize the transport of parts and workpieces between workcells. The current offered solutions include automatic guided vehicles (Fig. 2) or different types of conveyors.

Fig. 2. Automatic guided vehicle [5] and modular transfer system [7]

**Optimal storage**

System of storage of components, parts and prepared sub-assemblies is one of the important tasks and, in principle, it is possible to identify store space in the workplace, or storage among workplaces directly on the production area, which create stock of supplied parts between assembly stations (Fig. 3). In doing so, it is important to achieve synergies with the transport system and central storage.

Fig. 3. Example of shelf system for storage and transfer parts from firm Trilogiq [5]

**Quality assurance**

The final product quality assurance process should be an integral part of the assembly process, started by quality control of parts and components, through the control during the assembly process to the testing and inspection of the final product at the end of assembly cycle. During assembly workplace design, this requirement is reflected mainly in construction of the fixtures and equipment, in the control of the assembly process by means of application the sensors and also in implementation of POKA- YOKE principles. As an example, it is possible to exemplify the solution in Fig. 4, where the manual assembly operations are controlled by sensors and give notice to worker, for example in case of part absence and do not allow to proceed in assembly process until everything is done correctly. If each part is produced, visual inspection by the worker can verify that it is correctly assembled.

Fig. 4. View at manual assembly workplace, equipped with sensors to control assembly process [1]

**Accessible tools**

Lean workstation must be comfortable for the operator, and include the tools and supplies necessary to complete the manufacturing process. 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 on 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. The tools an operator is going to use every cycle should be located the closest.

Use of tools in the assembly can have an impact on a number of monitored factors, such as the time, ergonomic comfort, respectively quality. Their accessibility, arrangement, respectively good to grasp position are key factors. In Fig. 5 is the example of suspension mechanism [6].
Part feeding

Supply of components and parts on assembly site is also possible to realize by various ways. In manual assembly there are often used simple hoppers for small parts and worker removes parts from them. Although the choice of container type, combined with the characteristics of taken away components may impact on the various monitored parameters such as time or the need to fill the container. At Fig. 6 is the example of modeling the impact of the type of container to the time required to take away components. Although at first look it may seem that time differences are very small, it should be noted that these operations are often repetitive.

Ergonomics

From an ergonomic aspect, the main focus is on the worker, workstations are designed to fit each employee and this reduces waste during production. The adjustment to meet ergonomic requirements may be achieved, for example, with height-adjustable chairs and footrests or by using case lifters, to move containers into more convenient positions for employees. Ergonomic simulation can be used to evaluate a work cell to reviewing the interaction between the human model and the work environment (such as e.g. reach analysis or posture requirements). A wide range of manikins can be used in the simulation to determine how different types of people will interact with the assembly workstations.

3. DESIGN OF THE LEAN MANUAL ASSEMBLY WORKSTATIONS

3.1. Concept of Lean Assembly Laboratory

Within the scope of the international project LEAN LAB HUSK was proposed a concept of the assembly laboratory for the Lean Manufacturing approach application and verification.

According to specification, the laboratory will consist from 4 workstations intended to the assembly of defined product group such as brake cylinder, pump, ventilation grid, oil filter and so on.

In this context, it is essential not only this, that the actual workplaces were created by using the Lean Manufacturing approach, but also that in the assembly can be applied means and tools that support this approach.

At Fig. 7 is the example of two assembly workplaces created from the components and modules of the Boschrexroth company. The workplaces were designed in CATIA by using of the 3D models modified in the specialized Boschrexroth software Mtpro.

In the design process in CATIA were subsequently applied available tools for ergonomic design.

Unlike assembly workstations dedicated for real assembly, the laboratory workplaces must satisfy also the criteria that results from the fact, that at the workstations will be assembled several types of products, can exist different technological procedures and requirements to the workplace facilities.

Therefore, the workstation must to be adjustable, some devices re-configurable and also interchangeable so, that can be realized different assembly tasks.
3.2 Application of the POKA-YOKE principles

Poka-Yoke is a Japanese term that means “to prevent inadvertent errors.” The author of this approach is the Japanese Shigeo Shingo. Poka-Yoke is an integral part of Kaizen.

The basic objective of the Poka-Yoke is to reach a mistake free product. It is the application of such a relatively simple and effective measures, which ensure, that errors in the manufacturing and assembly process did not affect the quality of the final product.

The mentioned principle can be applied also at the laboratory workstations. In this context, one possibility is the development of own pick to light system, the concept of which is indicated at the Fig. 8.

Fig. 8. Experimental Pick-to light system

3.3 Catia ergonomic modules application

In the procedure of the workplace analysis as well as the assembly procedure can be applied several CAD system modules [10, 11, 12, 13], that support the workstation ergonomic characteristics [3, 9, 14]. In this procedure can be used for instance the Catia ergonomic modules as a base of analysis. The advantage is that the entire laboratory is created as a detailed 3D model what can be the base of the “Digital Factory” approach. In Fig. 9 is an example of the ergonomic analysis result realised at manual assembly workstation.

Fig. 9. Catia ergonomic analysis results

3.4 Videoanalysis

The further applicable tool dedicated to assembly support is the videoanalysis software developped and used at our department. On the Fig. 10 is presented an example of the software screenshot. This software application enables the detailed assembly operation analysis with the goal to determine the real assembly time, the operation structure and the assembly efficiency.

Fig. 10. Videoanalysis software screenshot

3.5 Data glove application

Data glove can be used as a tool in phases of workstation design and also as an tool to evaluate real assembly workstation.

In first case there is a possibility to simulate assembly process without have the real workstation and parts, and it is also possible to use numerous of analytics tools included in some CAD systems e.g. in CATIA it is RULA analysis, NIOSH, Push-pull analysis, Cary analysis etc. as it was mentioned in chapter 3.3.

In second case there is a possibility to make analysis of real workstation, by using data glove during assembly operation and recording movements and time (Fig. 11). Gained data are transferred to appropriate software and then they are processed. Result is finding out of ergonomics deficiencies of real assembly workstation (Fig. 12) and propose of actions to remove these deficiencies.

Fig. 11. Gaining data from real assembly process by using data glove
Fig. 12. Analysis of assembly process by using data gained by data glove

4. CONCLUSION

The key to “Lean” implementation is construction of workstations with components that are easily reconfigurable. Modular structure of assembly system, and construction 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 workspace is used effectively.

Modular components and accessories from building-block construction system are incredibly flexible and can be used to build everything from a simple workbench all the way up to a full assembly cell or even a production line. Workstations can be designed to accommodate a wide product mix and reconfigured if the process changes. Conveniences from modular kit can also be incorporated into a workstation to hold parts bins (which are compatible e.g. with Kanban systems). Continuous improvement is also simplified as the profiles and joints used to build the workstation can be rapidly changed during Kaizen events. Finally if the workstation is no longer required, it can be disassembled and the parts used to build other, e.g. frames structures.

ACKNOWLEDGEMENTS: This contribution is the result of the international project implementation: Hungary - Slovak Republic LEAN LAB HUSK/1101/1.6.1 supported by EU founds.

5. REFERENCES

[1] AUTIS MASCHINENBAU GmbH, Montagearbeitsplatz für Cockpitelemente.[on line], [cit. 2010-10-09], Available at: http://www.autis.de

Authors: Ing. Katarína Senderská, PhD., Ing. Andrea Lešková, PhD., Ing. Albert Mareš, PhD. Technical University of Košice, Faculty of Mechanical Engineering, Department of Technologies and Materials, Miasiarska 74, 04001 Košice, Slovakia. E-mail: katarina.senderska@tuke.sk andrea.leskova@tuke.sk albert.mares@tuke.sk