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Abstract. The goal of this paper is to discuss the island-based organization of a manufacturing-assembly system, based on the Seru-Seisan approach, whose main goals are to decentralize the production line and to improve personnel qualification. The aim is to show that a Seru-type production island/cell can be really profitable in case the operator could be supported by augmented-reality tools, such to help him in any complex processing operation. The efficiency/effectiveness of a Seru-type organization will be proved by verifying that it satisfies the main principles of "lean manufacturing", stated in terms of mathematical formulation of both the lean goals and the lean processing model. A practical validation of the Seru-type approach will be done by analyzing an assembly unit, now under development and testing in CNH Industrial, where the operator is supported by an augmented-reality system designed in cooperation with Regola S.r.l.

Keywords: Seru-type manufacturing, cell manufacturing, augmented reality.

1 Introduction

In the last years a deep revision of the organization of manufacturing processes is attracting increasing interest in managers of big and small industrial companies [1]. Two main lines are under discussion, to search a good compromise:

- on one side, the need of an organization of production systems as lean as possible, thus having simple manufacturing stages, continuous forward flows of items and backward flows of internal orders, needs of production management efforts and personnel "reduced to the bone";
- on the other side, the desire of more and more qualified personnel, so as to be secured against inefficiencies and reductions in product quality, but also to be able to decentralize some autonomy to the operators and reduce the management weight.

The first need seems to call for production lines with a "pulverization" of the processing steps, followed by a de-empowerment of operators: this is the situation that is felt in number of manufacturing companies in the automotive industry.
The second desire seems to search for production islands with a “concentration” of the processing operations, with the need of a higher qualification of the staff: this situation is under consideration mainly in the electronic enterprises [2].

This contribution is focused on the second point above presented: the scope is to discuss the island-based organization of production according to the Seru-Seisan approach to decentralizing JIT through personnel qualification improvement.[3]

The goal is to present a seru-type assembling unit, now under development and testing in CNH Industrial, with the design of the augmented-reality support for the operator done by the SME Regola S.r.l.

Seru-seisan (“seru” means cell, and “seisan” means production) appeared to be an innovation of the production management made in Japan, recently [4]. It emerged from a very complicated environment of mixed factors both in and out of Japan: change of demand to high variety and low volumes; low flexibility of the conveyor lines; low employee morale resulting from work circumstance and enterprise culture; limits of the Toyota Production System, i.e. there is insufficient evidence at present to show that the Toyota Production System can achieve as great efficiency in other industries as in the auto industry.

Indeed, “cell production” (also denoted “cellular manufacturing” [5]) has been implemented in different business industries in the US and Europe for decades, based on Group Technology principles.

Cell manufacturing and Seru Seisan both have high flexibility, but the mechanisms behind the two systems are different. Seru Seisan production no longer treats each product separately as job shop does. Instead, it groups similar parts or products into a part/product family according to the characteristics of the parts/products, the similarity of process, and the manufacturing methods. All of the equipment are grouped by the similarities of products rather than the function of machines.

However, Seru Seisan is mainly applied in the electronic industry in Japan, and it seems that it could difficult to implement on heavy products with complex processes.

The aim of this paper is to show that a Seru-type island of production (in the considered case, assembly of a distribution center for the oil pressure driving a small excavator for road work) can be really profitable in case the operator could be supported by augmented-reality tools, such to help him in any complex processing operation.

2 From Cellular Manufacturing to Seru

In a production system, the origin of wastes can be ascribed to different sources: the excessive levels of stocks, the presence of unnecessary operations, the presence of long waiting in the process and the low quality level of manufactured products.
Important results on reduction of wastes and costs have been obtained with the born of the Cellular Manufacturing theory. Cellular Manufacturing is a product-oriented

approach that introduce a reorganization of the plant into cells. Each cell is designed to contain all the necessary resources such as machines, workers, tools in order to produce a product or a family of products from the beginning to the end.

The adoption of the cellular manufacturing reorganization introduce significant quality improvements, moreover, thanks to the product-oriented approach, production systems so organized tend to be more customer focused and responsive to customer needs.

Important role in a cellular manufacturing environment is given to the training of the operators because they have to be able to do a great number of activities for a family of different products. The advantage is that an operator in one area can see how his actions change the product and how it impacts on the downstream activities. This usually generates improvement ideas, a higher efficiency and higher quality levels. This explains why the training of workers plays a crucial role in a cell manufacturing. In this paper an application of new technologies for the support of the operators activities is described.

Many companies, like Sony, Canon and other electronics industries, have reconfigured their conveyor assembly lines and adopted seru production; it is considered as the ideal of lean production systems [6]. This innovation in the plant organization consists in a human-centered production system where the long line is replaced by many short ones. Seru Seisan is suitable for processing light and small products, such as electric products, which are mainly manufactured manually, or with simple equipment. Seru Seisan is difficult to implement on heavy products with complex processes. Seru has many benefits. It can reduce lead time, setup time, WIP inventories, finished-product inventories, costs. Seru also influences profits, product quality, and workforce motivation in a positive way [7]. The main issues of implementing a Seru system is to decompose the process line into an opportune number of serus [8] and then to decide the number of workers to assign to each seru and compute the total training costs [9-10].

3 An Insight into Lean Principles

Let us briefly describe the principles of the lean manufacturing and to introduce some formulation in order to identify the theoretical framework that the collaborative system, based on an augmented reality technology and described in next section, wants to respect and with which wants to be compliant. The main concept of the lean thinking is “value”; value can only be decided by the final customer because only a small part of the production activities is recognized, by the customer, to introduce value on the final product. Costs are strictly related to the price, and then to the value, with the profit equation, so we can say that value is a function of costs. If the value increase with the cost, we can say that the operation is of value added, otherwise the operation represents a waste. In a formal description we can say that if

$$\partial V_i / \partial c_{ij} > 0 \,. \tag{1}$$

the operation *j* on product *i* adds value, otherwise the value doesn’t increase.

Once the real value (i.e. the price that a customer can spends for the product) for the final customer is identified, all the activities with a non-positive derivative must be targeted to be removed. The value stream is the sequence of activities j=1, …N, that add value on the product.

In order to reduce waste due to the levels of inventory, in a lean manufacturing the production system follows a “pull” approach where production is “dragged” from demand requirements and not on forecast or to produce products for the inventory. The pull system is quite easy and efficient, with few information it is possible to drag the production and satisfy the customer demand. If I is the inventory level, by applying this principle we can say that the inventory level is minimum and it does not change, in formula the two equations are true:

$$\partial I_i/\partial t = 0 \qquad \text{and} \qquad \partial^2 I_i/\partial t^2 > 0 \tag{2}$$

A characteristic of the lean manufacturing is the “one piece flow”: it is a way to organize production with a continuous flow of pieces from a production phase to another. The advantages from this principle are the reduction of Work In Process, more flexibility and a more comfortable layout in the plant because machines can be allocated into a logical way following the pieces’ flow. With the one-piece flow it’s also possible to easily decompose the total cost into the unit cost for each product like the sum of the unit cost of each operation. If we consider a production system that is a line with N activities, the unit cost for each product i is:

$$c_i=\Sigma_j c_{ij} \qquad j=1,\ldots,N\ . \tag{3}$$

The Takt time is the time when a productive unit must be obtained from the production process. The takt time is defined as

$$\text{Takt time} = \text{Available working time / demand}\ . \tag{4}$$

The Hejunka principle is to reduce production lots to the minimum size in order to have no variation on the inventory level. If there are no variation on inventory costs they can be considered constant, so every consideration and every effort on cost reduction doesn’t involve the stocks.

An important prescription of the lean thinking is to stop the production as soon as a problem occurs avoiding the production of products affected by defects, in this way the defects detection is at each stage of the production line and before to go on with the next process the correction of the error is required. This principle has relevant consequences on the real cost computation of each product, in fact, the real cost of a particular activity depends from the output of the previous activity. If the output is not affected by defects, the cost of activity j is equal to the typical production cost of activity j, otherwise, if the output of the j-1 activity is affected by errors or defects, the real cost of activity j on the product i is equal to the effective cost of activity j plus the defects correction.

$$c_{ij}=f(c_{i,\,j-1})+p_{ij}\ . \tag{5}$$

where f is a Real non-negative function that relates the cost spent in the previous activity with the defect that must be detected and adjusted during the current activity and p_{ij} is the characteristic cost of the activity j for product i.

Another consequence of this principle is the importance of the presence of tools that can support the defect detection and the correction of errors in order to reduce the value of function f. The lean thinking allows and suggests the utilization of visual and automatic control in order to put in evidence every problem on the product.

An important suggestion of the lean thinking, that we will see implemented in the application described in next section, is the utilization of every tool that could help by supporting process. An example of support given to the workers is a real time training tool that can help the worker in order to identify the operation that he has to do in a specific process activity.

4 Application of an Augmented Reality Technology for a Lean Production Cell

The project, designed and developed by Regola S.r.l., consists in the study and implementation of a pilot software/hardware installation at the plant of New Holland Construction in San Mauro. The installation is a tool that must support the assembly operations of joint Mod 35-39 by showing the operator, the mounting sequences in augmented reality and by creating checks and controls in order to reduce or eliminate the possibility of human errors.

The goal of the project is to eliminate the human error in the assembly even when the operator does not have the specific experience. The solution found is so versatile that can be seen both as an important tool of training and a controller for the error detection and correction.

This is a pilot project to assess the use of technology choices and possible engineering solutions; it provides outputs useful for a possible application of the same instrument in other stages of production.

Regola S.r.l. noted, during its market research and by contacting various companies in the industrial sector, that there is a real need to provide instructions to the operator in real time and to verify the correctness of the operations performed during the assembly of complex components. Regola S.r.l. is developing an integrated tool that, using computer vision techniques, will verify the correct execution of the assembly or maintenance operations in terms of sequence of steps and correct positioning of parts and components to avoid mistakes and dangerous operations.

The application involves the combined use of augmented reality for the visualization of correct procedures and technologies with RFID tags applied to tools (i.e. torque wrenches) and mounting hardware for verification and operational control. The augmented reality is a variation of virtual environment in which the user is immerse inside a virtual environment. While immersed the user can see virtual objects superimposed upon or composited with the real objects around him. So the virtual reality doesn't replace the reality but introduce supplement objects that can give important information [11]. The acronym RFID stands for Radio-Frequency IDentification; it is a wireless use of radio frequencies to transfer data with the objective to identify tags attached on objects.

The installation consists of two computers connected to each other via a network switch. The computers are equipped with a keyboard and mouse that are used exclusively for service needs (software updates).

To the network switch is also connected an RFID reader connected to the computers via a local network. The player is equipped with two antennas necessary to read the RFID tags. The two antennas are connected through coaxial cables, arranged so as to cover the two external mounting (mounting fittings and hose assembly). Each PC is equipped with a monitor (box 1 in Fig.1) connected via VGA cable, a functional keypad and a camera connected via a USB hub.

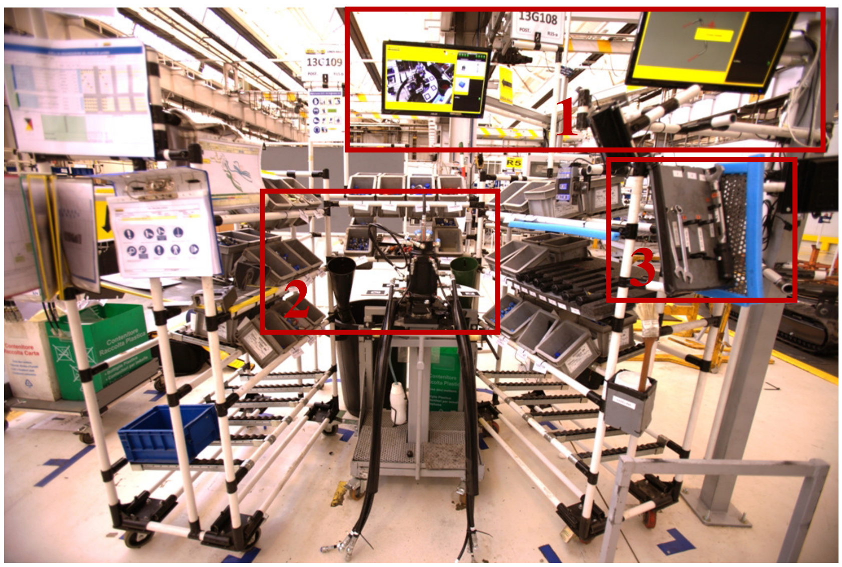

Fig. 1. Prototype of a Cell. Box 1: monitors connected with the computers; box 2: assembly station; box 3: control unit.

The cameras are connected to the USB hub with a USB cable, shielded and amplified. The position of the piece to be worked is highlighted with box 2 in Fig. 1, in box 3 of the same figure the control unit, using by the operator to manage the application, is shown. During the assembly, for a correct positioning of the virtual objects on the monitor, a DIMA with MARKER is used. The system reads the position of the markers using the camera, and according to it, place the virtual objects in the scene. Incorrect positioning of the jig will lead to a misalignment of the virtual objects. This technique allows to follow all the stages of assembly of complex components, showing the operator the correct sequence of assembly, dropped on the real scene and establishing operational checks and controls. The torque wrenches, used during the assembly operations, are equipped with Tags. The tags are glued on the keys on both sides to ensure the reading by the antennas regardless of the position with which they are presented. Once the model of the coupling is selected, the first step of the procedure is shown on video together with several information that can be expressed in different forms: textual form, graphic form, in the form of 3D animation of augmented reality. The animation of augmented reality are superimposed on the video stream taken from the camera and the operator can manage the video if he wants to see again the procedure, to go back to the previous procedure in case of defects or to go on. Information available on video is shown in Fig. 2.

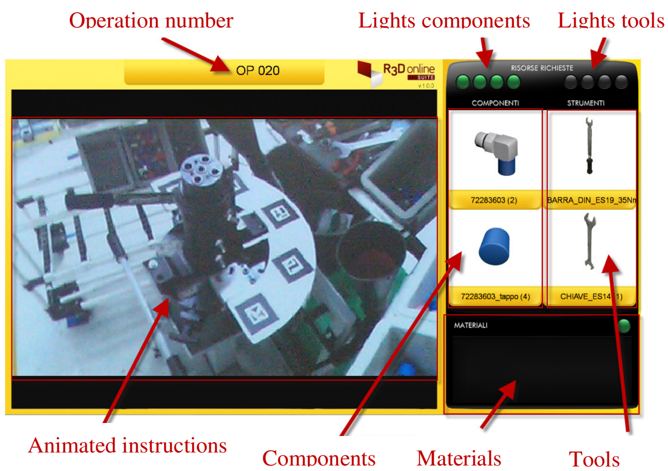

Fig. 2. An example of a video visualization.

The numbers at the top correspond to the code of the operation (operation number) visualized on the display. In the main central part of the video are provided to the operator the instruction with the animation in augmented reality. Cameras positioned in the working cell can recognize the working step and the operation that must be done ant it is suggested to the operator with an animation that shows the correct operation. On the right of the video there is the list of components, materials and tools that must be used, both in graphic form and as codes. If necessary (transactions with torque wrenches) the system reads, through RFID antenna, the tag pasted on the torque wrenches, to determine if it is the correct one or not. The system is calibrated to detect the torque wrenches without the need to bring the instrument to the particular antenna. If it detects any incorrect torque wrenches it is displayed a visual signal with the ignition of the red traffic light in correspondence to the tools. At the same way a correct reading of the instrument will turn on the green lights in correspondence of instruments.

The described system is an integration of different technologies and software and it is connected with informative systems able to collect information coming from the productive cell that are used from other functions of the production system.

5 Conclusion

In this paper a formulation of the lean principle is proposed in order to underline the consequence of the application of lean principles in the computations of costs and value for the customer. The functions and the uncertainties for the costs computation can be controlled with tools, compliant with the lean prescriptions, that can support the production in a system reorganized according the cellular manufacturing approach. The application described is an innovative example of how new technologies, in this case based on the augmented reality and RFID, can support the workers during an assembly operation in order to reduce training times, to reduce requirements on the worker expertise and improve the quality level. The described tool has the double role to train the operator on the correct operation reducing the training time and improves quality by including a system of detection of errors providing also instrument for their correction. The presence and the action of the tool does not influence the production time, does not increase the production times and redesign the system in a way that is still compliant with the WCM methodology.

References

1. Villa A., Taurino T., 2009. From New-Taylorism to human sustainability – Extending management concepts outside industrial sector, Invited paper in The Journal of Japan Industrial Management Association (NIHON KEIEI KOGAKKAI RONBUNSHI), 60, 3E
2. Yin, Y., Kaku, I., Murase, Y. and Yasuda, K., 2006. Converting Flow Lines to Manufacturing Cells Another Revolution? Cellular Manufacturing Implementations in Japan, Proceedings of the Third Int. Conf. on Group Technology/Cellular Manufacturing-GT/CM, Groningen, Netherlands, July 3-5, 94-104.
3. Liu, C.G., Yang, N., Li, W.J., Lian, J., Evans, S., Yin, Y., 2013. Training and assignment of multi-skilled workers for implementing seru production systems.(Int. J. Adv. Manuf. Technol. 69 (5-8), 937-959 (2013)
4. Villa A., Taurino T., From JIT to Seru, for a Production as Lean as Possible, The Manufacturing Engineering Society International Conference, MESIC 2013. Procedia Engineering Volume 63, 2013, Pages 956–965.
5. Burbidge J.L., The introduction of group technology, John Wiley & Sons, ISBN 0470123001, 9780470123003 (2007).
6. Miyake, D.I., 2006. The Shift from Belt Conveyor Line to Work-cell Based Assembly Systems to Cope with Increasing Demand Variation and Fluctuation in The Japanese Electronics Industries, CIRJE Discussion Papers, http://www.e.u-tokyo.ac.jp/cirje/research/03research02dp.html.
7. Stecke K.E., Yin Y., Kaku I.: Seru Production: An Extension of Just-in-Time Approach for Volatile Business Environments. DOI: 10.4018/978-1-4666-5958-2.ch003
8. Liu, C.C., Li, W.J., Lian, J., Yin, Y.: Reconfiguration of assembly systems: from conveyor assembly line to serus. J. Manuf. Syst. 31 (3), 312-325 (2012)
9. Liu C.G., Dang F., Li W.J., Lian J., Evans S., Yin Y.: Production planning of multi-stage multi-option seru production systems with sustainable measures. Journal of Cleaner Production 1-15, (2014).
10. Liu C.G., Stecke K.E., Liana J. and Yina Y.: An implementation framework for seru production. Intl. Trans. in Op. Res. 21, 1–19 (2014).
11. Azuma R.T., A Survey of Augmented Reality. PRESENCE: VOLUME 6, NUMBER 4