ESTABLISHING THE TEAM BASED CELLULAR MANUFACTURING OF HEATING SETS - CASE STUDY

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Abstract

The company KES - Cable and Electric Systems, spol. s r. o. is constantly looking for new ways to improve its manufacturing and logistics processes in order to meet customer needs. Due to the constantly increasing requirements on the supply reliability and the quality of the heating sets, the company decided to implement principles of lean, especially team based cellular manufacturing. The basic objectives in the creation of the cellular heating sets manufacturing system were to eliminate unproductive time, increase production quality, improve material flow continuity and increase production volume. The aim of the paper is to point out the benefits and possible problems of implementing the team based cellular manufacturing system in the automotive industry.

Keywords: Team based cellular manufacturing, heating sets, lean manufacturing, automotive industry

1. INTRODUCTION

Industrial companies in today's competitive and globalized environment strive to improve the effectiveness of their processes, particularly by introducing lean manufacturing principles. They allow them to eliminate typical losses related to transport, inventory, motion, waiting, over-production, over-processing, defects and unused skills. One of the effective lean manufacturing instruments is represented by team based cell manufacturing. The aim of the paper is to point out the benefits and possible problems of implementing the team based cellular manufacturing system in the automotive industry.

2. LITERATURE REVIEW

2.1. Cellular manufacturing system

Manufacturing cells have steadily gained in popularity over the past several decades. Cellular manufacturing system (CMS) is the process which has evolved from group technology that is a method of organisation for factories in which organisational units known as "groups" each complete a particular set or "family" of parts with no back flow, or crossflow between groups, and are equipped with all the facilities they need [1]. There are lots of benefits of CMS over long assembly lines. Heizer and Render [2] state that the cellular manufacturing concept can lead to reduced work in process inventory, as the work cell is set up to provide a balanced flow from machine to machine. It can lead to reduced direct labour cost due to the improved communication between employees, better material flow, and improved scheduling. It prompts for the high employee participation due to the added responsibility of product quality monitored by themselves rather than separate quality persons.

The overall process of designing CMS involves the following four generic phases [3]:

- Cell formation: involves grouping of machines which can operate on a product family with little or no inter-cell movement product.

- Group layout: includes layout of machines within each cell and layout of cells with respect to one another. In fact, the aim of this step is, arranging departments, aisles, machines, tools and instruments in the shop floor in the most efficient way. Layout design is an important decision in CMS and has a tremendous impact on manufacturing performance; hence, evaluating the performance of layout is a crucial issue in manufacturing system. In order to evaluate the layout performance, different criteria can be defined for this mean such as: material handling cost, throughput time, lead time and so on.
- Groups scheduling: involves scheduling of parts production.
- Resource allocation: assignment of tool, manpower, materials, and others resources.

In the most ideal case, these criteria should be addressed simultaneously so as to obtain the best possible results.

2.2. Technical vs social and human aspects of cellular manufacturing system

There exists a significant and growing body of academic research exploring various technical facets of cell formation and design [4,5]. While many of the decisions inherent in cell system design are technical in nature (e.g. how work should be scheduled through the cell), there are significant human dimensions to cell design (e.g. how cell operators will be selected, trained and rewarded). Hyer et al. [5] conclude that many of the problems and failures in cellular manufacturing systems occur at the interface between the technical and social subsystems. Norman et al. [6] state that manufacturing companies can establish a strategic competitive advantage by placing a greater importance on the human elements early in the design and implementation process. The authors explain that the vast majority of the cell formation literature places primary emphasis on grouping similar parts and machines. Once the cells are designed, secondary consideration is given to the assignment of workers to the cells. At this stage, the human element has typically only considered workers in terms of their labour capacity and/or technical skills. In a study of implementation experiences, Wemmerlov and Johnson [7] concluded by making the following point, “the picture that emerges from this study is clear - restructuring the factory to adopt cellular manufacturing should not be viewed merely as a technical, engineering-dominated problem but as a change process where the people element dominates”. Where socio-technical systems such as cellular manufacturing are involved, both aspects need to be considered to maximise success. This is the main idea of the team based cellular manufacturing systems.

3. CASE STUDY

In 2018, KES - Cable and Electric Systems, spol. s r. o., faced a situation where it was not able to meet the given delivery deadlines due to increasing customer demands and, at the same time, a high, inert reject rate. The high reject rate resulted in a high rate of work in progress, material wastage, reduced throughput and, subsequently, unprofitability of the given project. In the beginning of 2019, the company management thus decided to address the situation of the team based cellular manufacturing of the heating sets, continuous improvements of which are still taking place.

3.1. KES - Cable and Electric Systems, s.r.o.

KES - Cable and Electric Systems, spol. s r. o. (KES) was founded in Ostrava - Vratimov in 1992 as a subsidiary of ZKW Group GmBh, which is currently owned by LG Electronics and LG Corporation. The company produces over 1,400 types of wiring harnesses for the automotive and electrotechnical industries. The company products form part of the successful automobile brands, such as Audi, Bentley, BMW, DAF, Daimler, Ferrari, Ford, Lamborghini, Land Rover, MAN, Nissan, Opel, Rolls-Royce, Seat, Škoda, Volvo and VW.

During the last few years, the company has focused on the production of electric heating sets of accumulator units for electric cars (see **Figure 1**). The heating sets for BMW are mounted on an aluminum structure with a circulating cooling liquid. In the winter, the heating set preheats the battery prior to driving and maintains a stable temperature during the ride, thus increasing the battery lifespan and the car's driving range. The preheating procedure can be launched automatically using a timer or a smartphone.

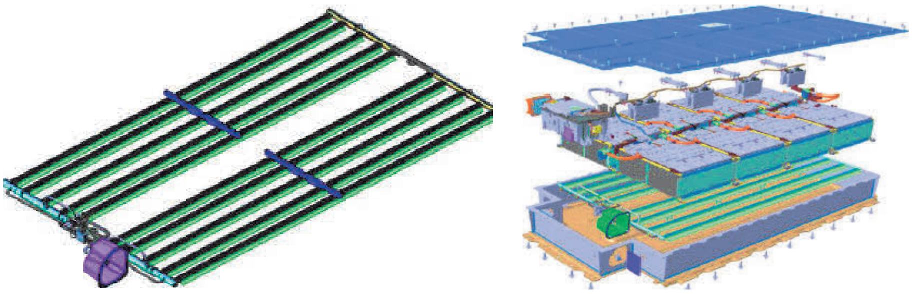

Figure 1 Heating sets

3.2. Heating sets production

The heating set production project was launched in 2013. It is expected that the production will be terminated in 2023. A total of 253,000 sets should be produced during the stated period. The production process consists of six operations:

- Crimping of the resistance conductor connector;
- Inspection of the crimped connections - camera;
- Harness assembly - line input;
- Harness assembly - line output;
- Measuring potting height using a deviance indicator;
- High-voltage test.

A heating set is formed by eight plastic rods, into which heating strips with resistance conductors are pasted. However, free conductors on the heating strips must be uninsulated prior to the pasting. These conductors are subsequently connected to other conductors by means of crimping. The heating strips, prepared in the aforementioned manner, are then put under a camera for a wire inspection. The uncovered parts of the conductors have to be protected against moisture and short circuits. That is why these parts are coated with a hardening substance on a hardening line (see **Figure 2**).

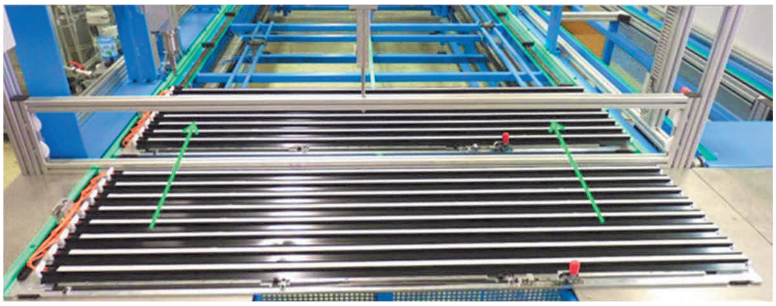

Figure 2 Set of heating rods prior to entering the hardening line

The plasma treating technology is also used on the line - plasma breaks the surface of the plastic rod, thus increasing the adhesion effect of the hardening substance. A high-voltage test is conducted on the line after the application of the hardening substance. The potting height on each rod is inspected after the application of the hardening substance using a deviance indicator. The last operation is yet another high-voltage test, this time conducted by the operator who actually operates the actual tester.

3.3. Initial condition

An analysis conducted by the project and lean manufacturing department employees discovered deficiencies related to the production of the heating sets. These deficiencies can be divided into the areas presented below.

Layout and material throughput

The production process used to take place at isolated worksites, i.e. each operator was conducting a single specialized operation. Upon completion of his/her work, each operator would pass the given unfinished product to the buffer of the next worksite. The production structure was determined by the corresponding technological sequence of individual product operations. Each operation used to have its separate production procedure. However, the procedures were not always observed by the operators and they would adjust their respective worksites prior to the commencement of a given shift as they saw it fit by adding various aids and tools, which would, in the end, result in several inefficient and negative impacts. In order to identify these inefficient activities, a spaghetti diagram was prepared (see **Figure 3**).

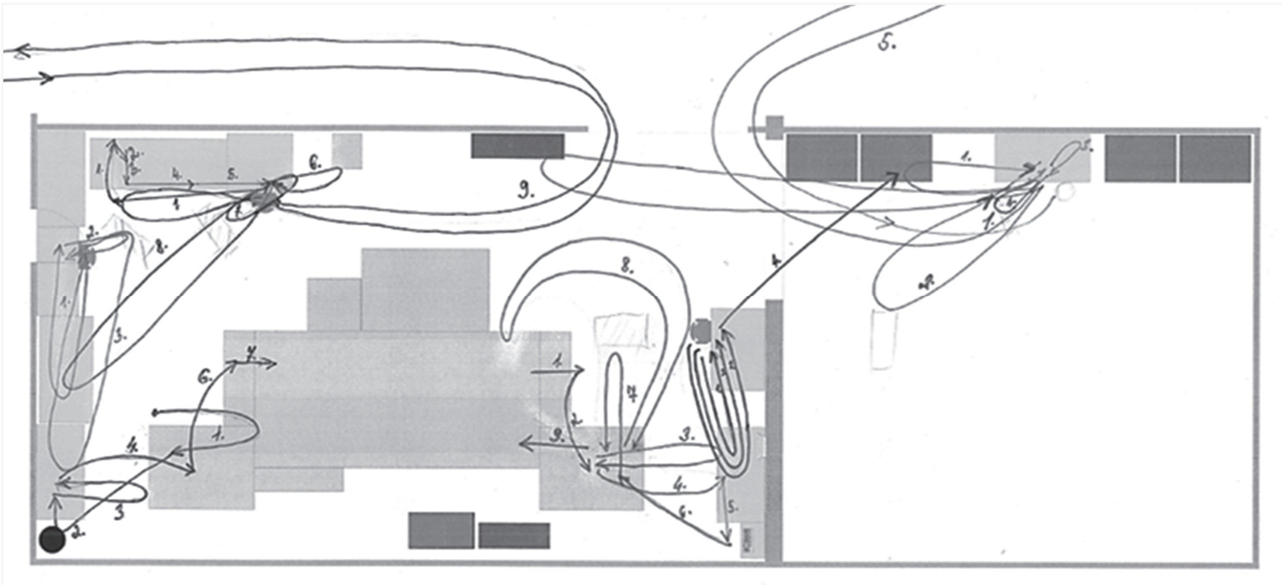

Figure 3 Spaghetti diagram

Some of the main deficiencies included prolonged handling times, the reduced size of the handling areas and increased risks of product damage and operator injuries. Yet another negative phenomenon of a chaotic worksite was the need to search for the needed aids or materials. No precisely defined positions for particular materials or aids were specified within a given worksite.

Quality

Ever since its commencement, the heating set production process had evinced a high reject rate (12 % on average). As part of the monitoring of the operators' work, several causes that had a negative impact on the product quality were determined. One of the main deficiencies was represented by breaches of the given work procedure and by the use of different, unpermitted instruments, which had the ability to damage the products. The operators would often omit the inspection of their work, an activity for which they were not motivated. That is why an error from the first worksite was often not discovered until the end of the production process. This situation generated a high reject rate, idle times and increased material consumption.

Idle times

Apart from idle times caused by a chaotic material throughput and the production of low-quality products, described above, the monitoring process also discovered additional idle times, particularly in the following areas:

- Shift changes and breaks - the line would be shut down during lunch breaks or shift changes. Its restart after such breaks of shift changes could be done only by a maintenance employee, who was not present at the given worksite. This would result in additional time losses.
- Material supplies - the operators would take care of material supplies on their own. They would only start obtaining a given material when they completely ran out of it. They would do so by requesting such material in person and waiting for it until it was released from the warehouse.
- Work aids - pursuant to a given work procedure, the corresponding work equipment must be used for executing the given work operations. Should the equipment become damaged, the replacement equipment was not stored at the worksite and the operators would ask the given foreman or technologists for it or, alternatively, they would wait for a maintenance technician to repair the damaged equipment, thus being forced to suspend their work.
- Incorrectly conducted work - as part of the monitoring and pursuant to the reject rate analysis results, it was discovered that each operator conducts his/her work differently. The operations in question particularly included the operations prior to entering and after leaving the line. The operators would conduct these operations incorrectly, thus causing defects and/or shutdowns of the hardening line.

The total idle time amounted to 23 % of the overall available time.

Bottleneck

Based on **Figure 4**, it is clear that the bottleneck of the production process is formed by the hardening line with a capacity of 10 sets/hour. The maximal capacity of the entire production process limited by this bottleneck is thus 80 sets/eight-hour shift. Based on an assessment of a two-month production, it was determined that the actual average number of the produced, sufficient-quality products per shift amounts to 52. The overall effectiveness of the production process amounted to only 65 %. The main reasons for this situation were the aforementioned reject rate and idle times.

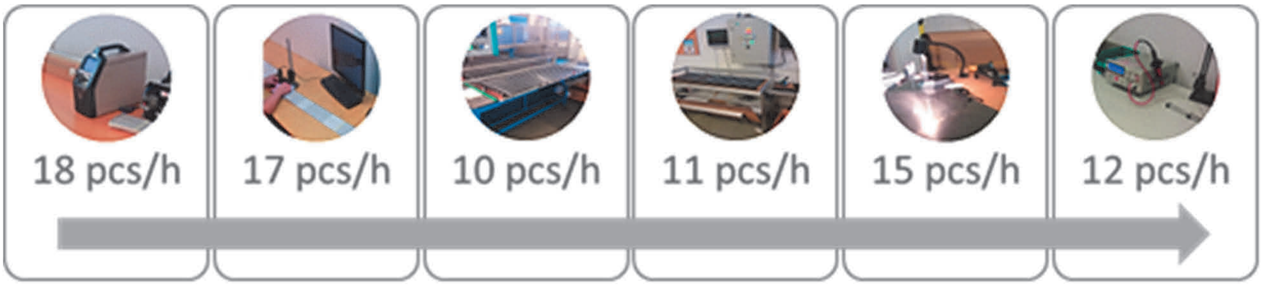

Figure 4 Performances of individual production process worksites

Since the performance at the worksites outside of the hardening line was significantly greater, large supply quantities of unfinished production were forming at these worksites.

Work system

The heating set production was conducted by six operators who worked in a three-shift schedule. Due to the bottleneck and to the fact that the operators were not versatile enough, they were insufficiently utilized at the worksites with a higher performance. Moreover, it was discovered that performances significantly varied from shift to shift. The reward system was based on the total number of produced pieces (of a sufficient as well as an insufficient quality) and the operators thus did not care about the product quality.

3.4. Proposed changes

The solution to the aforementioned problems was based on the creation of team-based cell manufacturing and on the application of lean manufacturing principles.

Layout and material throughput

Partial worksites have been merged into a single manufacturing cell worksite. The operators have become universal, i.e. each of them had to learn how to conduct all operations within the manufacturing cell. A new standardized work procedure has been created. It is based on the best experience and procedures gathered from individual shifts. At the same time, a worksite standard pursuant to the 5S principles has been created.

The overall layout has been preserved since it corresponds to the given technological procedure. The change only applied to a modification of the work benches, when seven tables of various sizes and heights have been replaced by two compact benches. Unfinished products are thus moved along a single plane only. This measure reduces the percentage of possible damage caused by product handling and makes all excess moves unnecessary.

Quality

The aforementioned standardization of the production processes and 5S application have ended the use of the operators' own work aids for the production. Thanks to the records on insufficient quality, it was possible to determine the shift that had conducted its work the best. This shift has then shared its work-related knowledge with the operators from the other shifts, thus reducing the number of rejects. The quality component has become part of the reward system. The measure has increased the interest of the operators in the product quality as part of every operation and, moreover, the number of rejects has declined even further. Quality is assessed on a daily basis. Since the hardening line forms a production process bottleneck, a short inspection activity was added prior to the product entering the line. The objective of this inspection is to eliminate products of insufficient quality entering the line and thus reducing its performance.

Idle times

The team manufacturing cell works continuously. The operators can therefore change during the breaks in a way that the line does not have to be stopped. The same applies to the shift change times. The incoming shift always comes in a few minutes earlier and the finishing operators can thus pass the given unfinished products on to the new operators. A shift handover book is used for this handover. The incoming shift checks the standards set at the worksite. The supplying process has also been affected by the change. A handler was assigned to each shift. In the beginning of and during the shift, this handler monitors the material needs within the framework of the entire cell. The handler also supplies the necessary material and removes any empty packages. The worksite has been equipped with spare work aids. Furthermore, a maintenance technician was also assigned to each cell. The technician monitors the line condition from a long-term perspective and ensures its error-free operation. On top of that, there is a mechanic assigned to each shift. This mechanic carries a walkie-talkie on him/her. Should there be a sudden line defect, the operators can quickly contact him/her.

Bottleneck

Due to the aforementioned deficiencies and the impossibility to itemize the operation, a proposal for changing the work system of the operators from individuals to a team has been accepted. Since the operators are only rewarded for products of a sufficient quality that have passed through all operations, they are able to switch during the shift in a way that no large supplies of unfinished production are created anywhere.

Work system

The original number of operators (six) has been reduced to five, the corresponding reward has been set as a team reward and the operators have become universal. It means that each operator has been trained for each operation. The operators are currently being rewarded as a team for the number of pieces produced in a sufficient quality. Daily shop-floor management has been introduced at the worksite. Each shift has a leader who monitors the cell performance and records the results on a prepared form. Individual shifts can thus be compared among themselves, which creates, from a psychological perspective, a competitive environment.

4. RESULT AND DISCUSSION

The introduction of the team based cell manufacturing had led to the following results:

- Reduced reject rate from 12 to 2 %.
- Reduced idle time from 23 to 11 %.
- Increased overall production effectiveness from 65 to 87 %.
- Savings related to the reduction of the number of operators on each shift (the additional activities of the handler and maintenance technician have not resulted in an increase of the number of these employees within the framework of the company).

Thanks to the above, the heating set production project profitability has increased from -10.3 % (loss) in the end of 2018 to the current 19.8 % (October 2019).

Pursuant to the case study, we can summarize and generalize the following benefits of the introduction of the team based cell manufacturing:

- Individual employees switch individual tasks and move within the frame of the cell in a way that they help one another and balance the given work.
- The best employees share their experience with other team members, thus increasing its productivity.
- The employees know the entire production process and thus assist in the process of its continuous improving, reducing idle times and improving the production quality during all stages of the production process.

Nevertheless, when introducing team based cell manufacturing, the process of selecting individual members of each team (and particularly selecting a strong leader) and setting an effective motivational system are very important. It is clear based on the aforementioned facts that the technical part of the project and the human and social part should be identically emphasized.

5. CONCLUSION

Thanks to reduced wage expenses, reduced material consumption, increased throughput and improved product quality, the project has, after many years, become profitable once again. The operators are now able to detect error causes earlier than at the end of the process, thus preventing the production of rejects. They control all production process operations, thanks to which they have reached a greater qualification, obtained new knowledge and skills and grasped the entire production process in more detail. As part of the implementation of the team-based cell manufacturing, they come with their own innovative ideas. They have been continuously improving the process even further. It was this team spirit for which they have been awarded by the company management as the best team in 2019.

Thanks to the aforementioned results, we can declare today that we have eliminated time and financial losses by applying suitably proposed, team-based cell manufacturing. The auxiliary buffers in the form of unfinished production supplies have disappeared. In this system, individual problems have become more visible and we are forced to deal with them, thus continuously improving the corresponding processes.

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