EXPERIENCE WITH THE APPLICATION OF VIDEO ANALYSIS IN THE MANUAL ASSEMBLY

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Abstract: The paper deals with the concept of video analysis for the support of manual assembly operation design and evaluation. Video shots of the real assembly process can be analyzed and used as a basis for further assembly process improvement. A good source for the manual assembly operation analysis is one of the conditions for successfully analysis. There are also some problems, which we can encounter while recording a video.

KEYWORDS: ASSEMBLY, ASSEMBLY PROCESS ANALYSIS, VIDEO RECORDING, VIDEO-ANALYSIS

1. Introduction

The assembly as a final operation in the production process affects the productivity, quality, as well as production costs. Manual work constitutes a significant part of the assembly. The main role in the manual assembly is played by the worker, who realizes the assembly operations. From this point of view there arise different particularities and limitations, which are important in the assembly workstation design. An incorrectly designed workplace has negative impact on the quality and productivity. If the existing workplace is not designed while taking account of the “human factor”, diverse problems can arise (decrease of quality, productivity, worker health problems, etc.). The basic procedure in the problem elimination process is the analysis of the activities realized at the workplace. The assembly process design as a complex and difficult task requires implementation of new approaches, techniques and tools. The effort to innovate these processes leads to the application of various computer-aided tools. Implementation of video analysis is one of the ways that can improve and support these processes.

2. Assembly process analysis based on video

The analysis can be focused on various factors such as sequence of operations, type of movements, speed and frequency of movements, disposition of pallets, buffers, tools, semifinished products and other technical elements. The analysis goal is to find the source of the problems and to eliminate them. Some problems can be discovered very easily by a quick survey at the workplace, but other problems need the assistance of various methods, techniques and tools. The basic problem at the assembly workplaces is often the issue of how to increase the productivity while keeping or increasing the quality too. A typical way to express the productivity is to determine the number of products produced per unit of time. From this expression it follows that the increase in productivity can be achieved by reducing the time needed to produce one piece of a product.

The video enables to precisely record the sequence and the time of the realized operations. Also it is possible to play video repeatedly or play it slowly enabling to catch details which are not clearly evident in a normal view. The working procedure in an assembly operations analysis based on video can be divided in the following steps:

1. preparation of the workplace for recording a video
2. recording a video of the assembly operations
3. analysis and evaluation of video
4. suggesting of the remedies and their testing
5. implementation of remedies in practice
6. checking of the achieved effects

The assembly operations analysis based on video has its own advantages and disadvantages. In general, the advantages of and main reasons for using it can be summarized as follows:

- Real manual assembly can be considered as the best and the most precise information.
- The video can be played repeatedly, speeded up, slowed down, archived, etc.
- The video information can by analyzed by the suggested time and operation model of manual assembly in the form of a software package.
- The results can be transformed into real technical information, equipment etc.

As the basic information for this analysis is constituted by a video, it is necessary to pay due attention to recording a video. Recording a video of the assembly process can be performed in different ways. Basic approaches to the recording of a video are introduced below.

3. Basic approaches to recording a video of assembly operations

Before starting to record a video it is necessary to clearly define the goals and use these goals as a baseline when defining the conditions for recording a video. If the assembly is realized at more workplaces, there arises a question which workplace should be recorded: the best one (with highest productivity), the worst one, or the workplace with average productivity? The answer to this question depends on the purpose of the analysis. If we are looking for reasons for different productivity of workplaces, then all of the above. Furthermore, it is necessary to consider other conditions which can occur in the assembly processes.

After determination of the goals of the analysis the video can be recorded. The actual process of recording a video can be divided in a few categories from the point of view of the place where the video is created and that of the preparation operations. Below are described some basic approaches to recording a video. Every approach has its own advantages and disadvantages.

3.1. Recording of the video directly at the workplace without preparation during a regular work shift

This approach is used if it is not possible to make preparation operations at the workplace (e.g. dangerous workplace, time deficit, workplace disposition not allowing it, etc.)

Advantages:
- Real status of the workplace with all its imperfections, which are directly connected to the assembly process and also other
imperfections (e.g. work space imperfections, etc.) become recorded.

- It is not necessary to spend time on preparation operations.

Disadvantages:
- the video may not include all the important data. The reasons for this can be constituted by various obstacles (various objects, pylons, structures, etc.), as well as the movement of other workers and movement of the technical and handling means at the workplace,
- the effort to record the whole assembly process with all movements can result in a poor quality of the video record (out of focus image) and it can also happen that the camera operator will not manage the coordination of lens zoom and camera orientation and due to this some part of the operation will be not recorded or will be not well visible,
- light conditions at the workplace can cause problems during recording (light reflection, shadows, overexposed places on video, etc.).

3.2. Recording the video directly at the workplace with preparation during regular work shift

The basis of this approach is the same as the previous one, including the advantages. The difference is that it is possible to make preparation operations, which consist in removing all the obstacles that can obstruct the recording. Scene preparation also consists in familiarizing the workers with the fact that they will be recorded in a video, in providing for good light conditions, and in simultaneous recording with more cameras from different angles, which is necessary. Compared to the previous approach, the disadvantage based on the obstacles is not applicable, but there can occur a new disadvantage as a consequence of stopping the work at the workplace in order to provide for the preparation. This stop can result in lower productivity within the work shift during which the video will be video taken.

3.3. Recording the video directly at the workplace outside a work shift

This approach enables better possibilities for preparation operations than the previous approaches. It is possible not only to remove disturbing factors caused by the operation, but also to make changes in disposition of the workplace, of course only if it is allowed by the character of the plant.

Advantages:
- it is possible to change the position of components to verify various variants of the assembly,
- no effect on the productivity during the work shift,
- real status at the workplace is recorded.

Disadvantages:
- it is not possible to use it in the plants with a 24 hour operation,
- the assembly workers must stay at work after the work shift. It can negatively influence the motivation and the performance.

3.4. Recording of the video at an experimental workplace

In this case it is assumed that there exists a specialized testing workplace focused on the assembly operation analysis.

Advantages:
- it is possible to prepare and to test different assembly sequences,
- it is possible to prepare ideal conditions to record a video.

Disadvantages:
- this kind of recording is not possible if the assembled part or product has dimensions or weight which do not allow them to be transported to the testing workplace,
- if special devices, tools and fixtures are to be used during the assembly operations, it is necessary to obtain these components. If these components are unique, expensive or cannot be used for any reason at the experimental workplace, the analysis cannot be realized.
- it is necessary to have trained workers familiarized with the specific assembly operations. Ideal solution is that the workers working at the testing workplace are those who also realize assembly operations in practice, but it is not possible every time. In this case the assembly operations must be performed by other workers and it can cause misinterpretation of parameters of assembly process (time, performed movements, etc.).
- the equipment and accessories for such workplace can be cost demanding, if this workplace is to be an all-purpose one and if it should allow for the realization of a wide range of assembly operations.

None of the approaches mentioned above has a universal use. The choice of an approach depends on many factors. As mentioned before, it is necessary to determine the goal of the analysis and consider the properties and characteristics of the workplace and then choose the way how to record the video. Account must also be taken of various problems during the recording which follow from character of the assembly process. Very often, especially during the assembly of small parts, the hands of the worker obstruct the view of the operation being realized (see fig.1), or when taking a part out of the storage container, the hands cover each other and it is not possible to recognize the movements. In these cases it is possible to use more cameras to record the operations from different angles of view, or to use for analysis a time sequence which begins with the last clearly identifiable operation and ends with the next clearly identifiable operation.

4. Assembly Operation Analysis Software

After recording a video and its processing it is time to analyze it. For this purpose it is very suitable to use some software tool. A decision was made to create own software tool. The developed software AOA (Assembly Operation Analysis) works with a video record of a real, manual assembly process (fig. 2). The prepared software tool enables to analyze this video record from the viewpoint of time and type of operation. The suggested model of manual assembly constitutes a base for the evaluation and comparison of the results. This software can also be used for analysis, documentation and training purposes. The software enables:
- To define the basic actions and/or operations according to specific requirements.
- To precisely observe the assembly process thanks to the ability to slow down, stop, return back the video.
- Divide the time of assembly in parts, save these parts and use them for next analysis.
Besides the time characteristics themselves, it is also necessary to pay attention to the way of performing the movements during the assembly operation analysis. The time data indicate the duration of the operation, but it does not indicate anything about whether there exist any reserves in the performance of the movement, or whether the movement was performed in the most economical and effective way. When relying on the philosophy that ineffective performance of movements leads to longer duration of the assembly, then it is possible to detect these inefficiencies either by comparing the actual data against the actual data from another workplace where the same assembly operations are performed, or by comparing the former against the times based on one of the predetermined time methods, or by recording the same assembly process under changed conditions.

Figure 2: Example of the assembly operation analysis in the AOA software

Data gained from AOA software can be processed in a spreadsheet software, e.g. Microsoft Excel that enables to use powerful tools included in it to make different analysis and graphical representations of the results, as shown in fig. 3.

Figure 3: Example of the assembly operation analysis results – time of inserting the parts into the assembly in percentage

5. Application range

This concept was tested on various assembly operation processes, for example: carburettor, ventilation grid for automobile, circuit breaker, interior light for automobile, etc. Based on the gained experiences it can be stated that the possible applications are based on the following main expected results: time of the observed assembly operations, structure of the assembly operations and the efficiency of the assembly process. This system enables especially:

- to observe the assembly process for study purposes
- to give precision to the own CAD model
- to generate input for statistical purposes (malfunction, number of defected products, etc.)
- to support the training
- presentation and documentation of the assembly process
- to use it in e-learning assembly courses
- to support the selection from several variants of workstations
- to support the selection from several variants of suggested technical means
- to verify the assembly process organization
- to verify the planned assembly time
- to find out the influence of product design changes on the time and structure of the assembly process
- to find out the influence of the new design or design changes on individual technical means

6. Conclusion

The video of the assembly operation is a valuable source of information if it is clearly recorded, including all the relevant parameters of the assembly process. Recording a "good" video often requires to change the conditions for the process of recording the video. The changes should be based on the goals of the analysis for which the video was created. Despite some of the drawbacks, using the analysis of assembly operations based on video is very valuable and helpful for searching a hidden reserve in the existing process.

The concept of manual assembly workstation design supported by video indicates an interesting and helpful direction in terms of manual assembly design innovation. The related evaluation of assembly operation efficiency can be used as one of the criteria for the selection of the best solution.

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