Design of on-line system for measuring and tracking time of assembly

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Abstract: Manual assembly performed at assembly workstations nowadays still has a unique place in different kinds of production. To increase the productivity and quality of manual assembly it is necessary to analyse the existing workplaces and find ways to improve and streamline work done at these workplaces. The article deals with the design of a model for on-line analysis of a manual assembly process. The proposed model is based on the use of sensors or the so-called button-box and the use of software for recording and evaluating data. Based on the obtained data it is then possible to evaluate the time characteristics of the assembly process, as well as to find sources of delays and mistakes and then take appropriate action to correct them.

Keywords: manual assembly; on-line analysis; workstation

1 Introduction

Humans play an essential role in manual assembly processes. Manual assembly workplaces are heavily dependent on humans in terms of productivity and quality of the assembly process outcome [1]. To increase the productivity and quality of an assembly process, it is necessary to analyse the existing workplaces and the performed assembly procedures [2, 3] to find out ways to improve and streamline work at assembly workplaces. One of the important issues involved in the need to increase the effectiveness of any engineering process is time shortening. How to monitor time, analyse and obtain relevant information about the process, especially in the areas involving a higher portion of manual work, obviously constitutes an important issue. Nowadays, there are trends to use real time data [4–6]. One of such areas is the manual assembly, which has always been and will probably remain present in the engineering industry. Today, sophisticated manual assembly workstations are typically characterized by the application of sensors with a subsequent evaluation and process control. This approach is applied especially in the case of the suppliers of automobile components, where the emphasis is placed on the quality of the final product. Any assembly workplace is inherently unique and the possibility to assemble a completely different product at the same workplace without a substantial change is unrealistic. If the assembly workstations are flexible [7], i.e. designed for a group of products, then the given characteristic have been directly incorporated into the workstation design and are rarely addressed additionally. The above-mentioned variety of manual assembly workplaces complicates the possibility of applying a uniform methodology for assembly process monitoring in terms of time and/or applying it already in the workplace design process. Sometimes it is also possible to use standard methods, such as operation snapshot or moment survey or to use the MTM method in the process of designing a workplace.

It is for these reasons that the concept of on-line analysis of the assembly process has been developed. This concept enables the obtaining of relevant information about the progress of the assembly process, including the time, using either an existing system of sensors at the workplace or a special box in such a way as to gain identical information from each assembly workstation regardless of the specific conditions. This approach ensures consistent information for evaluation, wide applicability and the created model consequently also provides for the process simulation and/or the application in the new workplace design process. The model of on-line analysis seeks to minimise the impact of specific technical conditions while, for instance, the type of applied sensor and its parameters are not essential for this model. The relevant information is the information about the start of an assembly at the workplace, not the information about the physical princi-
ple on which the sensor providing the information works. These technical details are included in the individual specific workstation design.

2 Assembly workplace on-line analysis project

The concept of manual assembly on-line analysis is based on the analysis of precisely specified information. This information about the assembly process enables the identification of the assembly progress at each individual assembly workstation and also the relation among the assembly workstations. The analysis model is based on the information obtained from the maximum of 10 sensors per workstation. Information from five sensors is mandatory – this is a minimum for performing the analysis. It includes the following information:

- Assembly start,
- Assembly end,
- Assembly was successful,
- Components and/or parts needed to start the assembly are present at the workplace,
- Assembled parts or products and/or their subassemblies are ready to leave the workplace.

To perform the analysis for each sensor it is necessary to also define information about its function, further detail fault conditions, determine whether there is a critical fault, define the message and determine the possible waiting time to change the status of the sensor. This information is used to analyse the fault conditions of the workplace and identify the causes of failure.

The other five sensors at the workplace are intended for the identification of the state of workplace elements and equipment. These sensors can provide information such as whether there are enough parts in storage, whether there is an appropriate instrument or a fixture, etc. It is also necessary to define these sensors before starting the analysis, for example, if a sensor is active or not, to define the waiting time, etc. This definition is done in specialized software which has been developed for the purpose of the analysis and the description of which will be provided later in this article.

The analysis model takes into account different types of information sources. The first option is to install sensors on manual assembly workstation for the purpose of on-line analysis only. The second situation is when the workstation already has existing sensors used for the monitoring and control of the process. Out of these installed sensors a selection will be made of the sensors which will be simultaneously used for the on-line analysis. Alternatively it is possible to use a “button-box”, which has been developed specifically for this purpose. The button-box can also be used if the workstation is equipped with sensors for the purpose of workstation management. In this case, the on-line analysis will be independent of the workstation management and the control system. It is also possible to consider entering the information through a software screen, i.e. based on an input software module where it would be possible to validate inputs on the screen installed at the workstation.

Data obtained from the sensors from a real assembly process are certainly not sufficient for the functioning of the model. Part of the data has to be entered within the definition of each workstation. A complete model can only be built on this basis. An analysis algorithm was prepared in the form of decision tables, which were subsequently used as a basis for software development. Decision tables were chosen mainly because they are able to map all states of sensors and their combinations more clearly and the analysis appears to be more transparent. Table 1 shows a simplified example of a decision table for the analysis of the activity of sensors \( s_i \), where \( i = 6 \) to 10, which serves as a basis for creating the software.

In this first phase, the analysis model takes into account 4 assembly workstations and one stock of parts and components. In addition to defining the sensors in the model it is necessary to identify the relationships between the workstations and storage. It is only the time at which the signal from the respective sensor appeared that can be obtained from the real assembly process. The entire data processing, which will follow, depends on the other defined data and on the algorithm of data processing. Figure 1 shows a diagram of an on-line analysis model.

Defining the parameters of each assembly workstation enables the identification of the material flow and the structure of the relationships between the individual workstations. The data which should be entered are the following:

- information about the workstation if it is active or not,
- defining workstation’s input and output, i.e. where a component or components came from and where they will go when the assembly is finished,
- if the components’ movement is in batches or not,
- the number of parts in a batch,
- estimated parts’ transport time from one workplace to another,
- etc.
Table 1: Example of a decision table for the analysis of sensors definition and functioning.

<table>
<thead>
<tr>
<th>Condition Specification</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is the sensor active?</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Is the sensor defined?</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Is the sensor signal present?</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Is the error critical?</td>
<td>Y</td>
<td>-</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5. Has the defined time elapsed?</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6. Acknowledgement concerning the possibility to continue?</td>
<td>Y</td>
<td></td>
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<tr>
<td>7. Is the sensor activity defined?</td>
<td>Y</td>
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<tr>
<td>8. Define the sensor activity</td>
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<td>x</td>
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<td>9. Define the sensor function</td>
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<td>x</td>
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<tr>
<td>10. Select the sensor type</td>
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<td></td>
<td>x</td>
</tr>
<tr>
<td>11. Define the error type</td>
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<td>x</td>
</tr>
<tr>
<td>12. Define the waiting time for sensor status change</td>
<td></td>
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<td></td>
<td>x</td>
</tr>
<tr>
<td>13. Select the message in case of error</td>
<td></td>
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<td></td>
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<td>x</td>
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<tr>
<td>14. Stop the process at the workstation</td>
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<td></td>
<td>x</td>
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<td>15. Report error</td>
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<td>x</td>
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<td>16. Wait for the defined period of time</td>
<td></td>
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<td></td>
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<td></td>
<td>x</td>
</tr>
<tr>
<td>17. Acknowledge to continue</td>
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<td></td>
<td></td>
<td>x</td>
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<tr>
<td>18. Assembly in progress</td>
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<td></td>
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<td>x</td>
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<td>19. Return to the beginning of table</td>
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<td></td>
<td>x</td>
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<td>20. STOP</td>
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<td>x</td>
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</tbody>
</table>

Figure 1: Basic characteristics of the on-line analysis model.

Certain parameters are then monitored during the on-line analysis. These include, but are not limited to the number of parts between workstations, exceeding of the defined times, data about product errors and about failures and their causes. In the long run it will enable the obtaining of relevant data for failure analysis and perhaps information about reasons for delays. Figure 2a) shows a diagram of the analysis of 3 linked assembly workstations.
Figure 2: Examples of possible workstation links in the on-line analysis model a) three active assembly workstations (AW); b) four linked assembly workstations, of which two are parallel in terms of material flow.

Figure 3: Chart of complete data of the on-line analysis model.

- the AW4 assembly workstation is inactive. Figure 2b) shows an example of four workstations where workstations 1 and 2 are parallel in terms of material flow.

Figure 3 shows a chart of complete data of the on-line analysis.
Hardware and software for on-line analysis

Hardware shown in Fig. 4 was designed and implemented for the concept of on-line analysis. Its detailed description has been published in [8]. In principle, there are two key elements:

- interface designed to capture the signal from the sensors implemented at the workstation, signal modification and its subsequent transfer to a computer for further processing. This solved two main problems, namely incompatibility of sensor signals output with input to the personal computers and also that the number of sensors is greater than the number of the PC input ports.
- console so-called “Button-Box”, which is intended to replace the inputs from the sensors if the workplace is not equipped with sensors.

The software was created in Microsoft Visual Basic .NET. This software allows the user to read and process data from hardware. In the Fig. 5 a screenshot from the
software for on-line manual assembly analysis is presented. The gained results and their processing can be modified according to the specific requirements of the assembly process.

4 Conclusions

Above presented on-line system for measuring and tracking time of assembly respond to current trends in the field of assembly process time analysis. The proposed solution is particularly interesting in building laboratories for lean assembly research. Fully functional and tested hardware and customizable software allows for the expansion of the number of possibilities of using model in the design process of assembly workplaces. Analysis models can operate on the basis of inputs from sensors simulated by computers respectively on the basis of analytical data or time data obtained by one of the methods predetermined times combined with considering the probability of failure and errors in the assembly process.

Another option is the integration of the aforementioned analysis method with simple so-called “Pick and Work” system into one comprehensive unit designed to support assembly processes and support their analyses. In the future, it seems to be an interesting possibility to connect the analysis method with software for video analysis respectively with data glove applications in the CATIA environment, which is also under development by the authors.

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References