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Ergonomics for the new MILLENNIUM

PROCESS ORIENTED ERGONOMICS – THE ERGONOMICS OF THE FUTURE? A CASE STUDY OF INTEGRATED ERGONOMICS AT AN ENGINE ASSEMBLY PLANT

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Ergonomists are, in most cases, focusing on the human being when evaluating assembly system designs. This results in the human performance being expressed isolated from the technical environment. On the other hand, technicians are prone to concentrate on the hardware.These conditions underline the need to pursue a more integrated evaluation and design procedure in order to avoid the drawbacks of these traditional approaches. In this paper, the authors propose an alternative approach, i.e. process oriented ergonomics, which might be a constructive way of tackling some of the more complex aspects of the man-machine interaction in industrial environments such as assembly of engines.

BACKGROUND

Ergonomists are, in most cases, focusing on the human being, when evaluating various assembly system designs. This results in the human performance being expressed isolated from the technical environment. On the other hand, technicians are prone to concentrate on aspects of the hardware. These conditions underline the need to pursue a more integrated evaluation and design procedure in order to avoid the drawbacks of these traditional approaches. The need for such a procedure is evident when, for example, discussing the work along an assembly line in order to bridge some critical gaps between practice and science.

AIMS AND DELIMITATION

This paper reports on a study carried out at an assembly system in Sweden. The aims are to describe the product and manufacturing process and to illuminate and evaluate ergonomic conditions in respect of work postures, workload and musculoskeletal disorders by means of established methods. The results from the application of these methods will be used to discuss the possibility of an amalgamation of product and manufacturing process data with data describing ergonomic conditions – thereby adopting a more integrated approach to ergonomics than is usually applied within the industry. The study focuses on the manual work in three levels of the assembly system, i.e. the total system, a selected work group area and specific work tasks performed at a selected work station. The study was carried out within certain time constraints, and the purpose was to propose a method, rather than proving its generality by means of reporting, for example, all details.

THE CASE STUDY

The assembly system studied is an engine assembly line. It is composed of two sections. The first section is predominantly automatic with a combination of transfer machines and non-paced lines. The second section mostly comprises manual work where the engine is transported between the work stations by means of carriers. The assembly line is composed of seven work

group areas (43 work stations) and one separate work group area for sub-assembly. The study is focused both on a selected work group area comprising in total three manual work stations, which assemble the main engine, and on specific work tasks at a work station within this workgroup area. These tasks are carried out at a sub-assembly loop for fitting pistons with a connecting rod into a magazine. At this specific work station the duration of the total work is approximately 4 – 8 minutes depending on the mix of product variants and disturbances on the main flow, while the specific work tasks studied in depth require approximately 70 seconds work. Characteristic of this work group area is the high degree of automation and disturbances due to variations in the reliability of the equipment and the occurrence of product variants.

METHOD

The method used for describing the product and manufacturing process is denoted "successive assembly system design". It has been used and developed during the last two decades for the design of assembly systems within the automotive industry (Engström, Jonsson and Medbo 1997). This method contains procedures for describing and restructuring product and manufacturing process information by means of, for example, disassembly of physical products. This is combined with the utilisation of a number of interrelated measures in the form of small cards, labels, grouping of physical components, disassembly of products and construction of an analysis database. The results presented in this paper are based on a co-operation project between the company and the university, carried out during 1998 – 2000. Basically, this co-operation is aimed at improving the quality of the data supplied to the operators along the assembly line. This has usually not been the case when designing assembly systems. In short, the restructuring of the information system was first a matter of understanding the existing assembly and information systems containing information which basically is generated from the overall design-oriented product structure (i.e. the result from the design department's work, giving input to, for example, the work order, which is a document specifying all the components to be assembled on each engine). Some of the most vital activities during this procedure were: the construction of small cards, labels and an analysis database composed out of e.g. information from the design oriented product structure. It was also required the fetching of small components along the assembly line, which was complemented by other types of information available. These materials were arranged in accordance with the work station's sequence to guide the disassembly of an engine performed in a separate room located near the assembly line. See Portolomeos and Schoonderwal (1998) for a more detailed description. During this procedure, guided by the materials mentioned, cross-referencing of the removed components arranged on the floor and marking on the appropriate materials resulted in an understanding of the physical product, the existing assembly system and the information systems. This disassembly also provided a basis for the refinement of the analysis database. This refinement was achieved by first focusing on the large components (pistons, connecting rods, crankshaft, water pump, etc.) and later on the small ones (screws, nuts, O-rings, etc.) and by assuming that the large components required were associated with the small ones. This procedure underlined various anomalies in the information systems. The ergonomic analysis was performed, firstly, by illumination of the work conditions for all work stations by means of a general questionnaire. Secondly, by a more detailed evaluation of specific work tasks at the selected work station using video registrations. This work station was selected as being the "worst" in respect of workload factors, according to ergonomic expertise within the company. The work station was also especially suitable to be analysed using traditional ergonomic observation methods due to the large and differentiated body movements. A fact, which also has advantages when simulating the operators' movements with a manikin. In short, the questionnaire comprised questions concerning background variables, musculoskeletal-losketal disorders, workload, work postures, work content and job rotation as well as defining the work group area for the subject. However, the questionnaire could be used for illuminating more far-reaching aspects of the work. Especially so, since it has been utilised for analyses of work conditions at, for example, the Volvo Kalmar and Uddevalla plants (Engström Johansson, Jonsson and Medbo 1995). The questionnaire was applied to the total assembly system for two shifts, in a total of 93 operators, who represented approximately 80% of the total work force (five operators refused to fill in the questionnaire). The evaluation of the ergonomic conditions involved the so-called Owako Work Analysis System (OWAS, Karhu, Kansi and Kuorinka 1977) and the Rapid Upper Limbs Assessment (RULA, McAtamney and Corlett 1993) by observing work postures directly from the video registrations, which were performed manually. However, these analyses were also carried out indirectly, by means of constructing a manikin performing the observed work tasks, taking advantage of a computer program denoted Jack (EAI 2000), a program which contains OWAS and RULA. These ergonomic considerations were carried out during October – November 1999 with the help of ergonomics expertise.

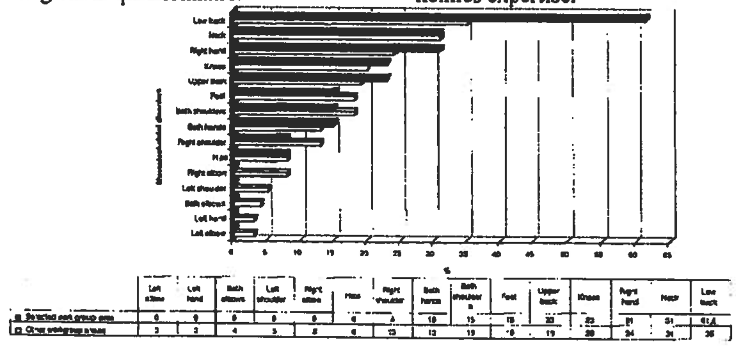

Figure 1. Comparison between profile of musculoskeletal disorders at the selected workgroup (N=13 operators) and other work groups (N=80 operators).

RESULTS

Results Description of the Product and the Manufacturing Process

The total product was described by an assembly-oriented product structure (1 main engine, 2 cylinder head and gas exchange, 3 valves mechanism, 4 cooling system, 5 transmission, 6 lubrication system, 7 fuel system and 8 components and cables). This structure is in contrast to the overall design-oriented product structure mentioned above. It describes the product from an assembly point of view. The assembly-oriented product structure separates the components hierarchically into groups of components that have common characteristics, i.e. product functions, forms, materials, etc. (Engström and Medbo 1993). This product structure formed the basis for the restructuring of the information systems, formalised by the analysis database, taking into account the possibility of describing product variants in clusters of product characteristics and product variation relevant for the assembly work. As a consequence of the information reestructuring, the "work order" proved to be possible to reduce from the initial 43 pages to one page per engine. By using this way of describing the product and manufacturing process it was also evident that approximately 65% of the assembly work, including the definition of the sequence of product variants, along the main flow could be defined seven days before the actual assembly work was performed. This fact has not previously been recognised and utilised at all, and it has strong implications for, for example, intra-group work patterns and the functions of engines as buffers along the assembly line. This knowledge could be used to extend the technical autonomy of the work groups, since they are, in fact, able to plan their work. Since the number of operators along the line was less than the number of engines accessible in the first section along the assembly line, it might also be possible to formalise intermediate buffers between work group areas. Such buffers will be a result of combining the information mentioned above with the work groups' planning, with the definition of buffer areas on the floor of the workshop by means of, for example, paint.

Table 1. Detailed specification of the specific work tasks at the selected work station and the resulting action categories according to the RULA method gained manually through observation of video recordings and by means of a constructed manikin (Jack). The table also shows the action categories according to the OWAS-method obtained by similar procedures

Work tasks:	Action category defined manually (RULA):	Action category defined by manikin (RULA):
START OF WORK CYCLE		
1 Walk to the pallet	1	2
2 Picking two connecting rods	4	4
3 Walk to the work position	3	3
4 Fit the two connecting rods into the magazine	3	2
REPEAT 1 – 4 THREE TIMES		
5 Walk to the pallet	2	2
6 Pick to pistons	4	4
7 Walk to the work position	3	3
8 Fit the two pistons into the magazine	4	2
REPEAT 5 – 8 THREE TIMES		
9 Input of data by means of the keyboard	2	2
END OF WORK CYCLE		
Action categories (OWAS):	60% in action category 1 40% in action category 2	7% in action category 1 20% in action category 2 73% in action category 2
Action categories (RULA):	7% in action category 1 33% in action category 2 20% in action category 3 40% in action category 3	60% in action category 2 13% in action category 3 17%in action category 3

Results from the Illumination and Evaluation of the Ergonomic Conditions

The questionnaire was utilised for verifying how the selected work station and work group area were related to the other work stations and work group areas. This illumination was delimited to consider musculoskeletal disorders, see figure 1. However, the data collected through the questionnaire implies a more extensive analysis outside the scope of this paper. The questionnaire has shown a similar profile of musculoskeletal disorders for the other workgroup areas in relation to the selected workgroup area (see figure 1). For example, there were similar patterns regarding the sequence of the most predominantly musculoskeletal disorders, i.e. (1) low back, (2) neck and (3) right hand. There was also a quantitative predominance of low back, neck and right hand disorders for the total assembly system and at the selected workgroup area. Differences in recommended actions in the ergonomic evaluation using the OWAS and RULA methods, expressed in the table 1, may depend on difficulties in simulating combined work postures, for e.g. bending and turning or due to the short cycle time of the specific work tasks. In fact, it proved necessary to simplify the modelling of the work postures. Even when using this simplification, the simulation proved to be time-consuming. All of the OWAS classifications were available in Jack but seemed to be improperly implemented This implies that the user of this manikin requires knowledge concerning established ergonomic methods or computer software or both. Anyway, it is not an evaluation tool directly applicable for any user.

Discussing the Amalgamation of Product and Manufacturing Process Data with Data describing Ergonomic Conditions

The method proposed assumes that data describing ergonomic conditions could be related to product and manufacturing process data. Fortunately, in the case reported above, the authors already had access to appropriate product and manufacturing process data through the co-operation mentioned. In principle, one line of action is to start the description of the ergonomic conditions at a low level. Later, this mapping is connected to a higher level. Alternatively, the line of action could be the other way around. The first way (i.e. starting at the low level) may have the benefits of initiating an immediate ergonomic action, which might be directly appreciated by the operators involved. This may then result in some specific ergonomic conditions being focused up on that might be far too unique to be generally applicable to the rest of the assembly system. That is, if, for example, the mannequin data presented above specifically pinpoints a work task, such as picking pistons, as requiring immediate action. On the other hand, starting by sketching a panorama of ergonomic conditions (i.e. starting at the higher level) generated from surveying the total assembly system will nuance the understanding of the ergonomic conditions in a specific case by pointing out a far more complex spectrum. This would, in the case presented above, imply that the noted low back musculoskeletal disorders may be caused by frequent turning and bending during lifting of components and fitting of the studs on the engine block. Furthermore, these musculoskeletal disorders could also be caused by bad sitting postures. The noted right-hand musculoskeletal disorders are generally associated with torque tools (there is only one torque tool at group one). However, this is a more time-consuming process since it requires application, and in some cases construction, of a method for surveying the ergonomic conditions. In this case reported above, a similar profile of musculoskeletal disorders was obtained when comparing the selected work group area with the other work group areas, which implies possibilities for generalisations. Connecting the detailed analysis of the specific work tasks obtained by the RULA and OWAS methods calls for some intriguing procedures outside the scope of this paper. The indirect evaluation of the ergonomic conditions by means of the manikin proved to be far more time consuming than the direct manual method, and the results, at least when considering long periods of work, need to be questioned. The simplification of the requirements for large and differentiated body movements also need to be questioned. This even though the manikin has holding features like the possibility to simulate and evaluate non-existing assembly systems, etc. Still, the time-consuming task of transferring the work to a manikin will remain. Introducing the proposed method at a too detailed level might be worthwhile but time-consuming. On the other hand, starting by sketching a panorama implied questions like; is the internal turnover distorting the panorama of, for example, musculoskeletal disorders or is the distortion due to various intra-group work patters and continuous reallocation of work tasks within a work group area? All this underlines the fact that the authors are still, after almost two years of co-operation, not familiar with all important details of the assembly system reported above. To conclude, introducing the proposed method from a higher level will, if carried out to its full extent, result in yet more questions. As for discussing integrated ergonomics, this approach needs to be based on an observing manual work for a longer period of time than 70 seconds. This period of time represents approximately 0.3 – 0.9% of the total manual work carried out within the assembly system's 43 work stations. Longer periods of work could be described based on the product and manufacturing process data available at hand. Therefore, the integrated ergonomics through the amalgamation of data ought to comprise longer periods of work.

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