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Is it Possible to Take Advantage of the Product Structure to Improve Shop Floor Ergonomics? Work Characteristics of Collective Working in Long Cycle Time Assembly Systems

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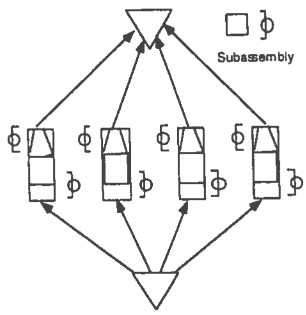
1. Background

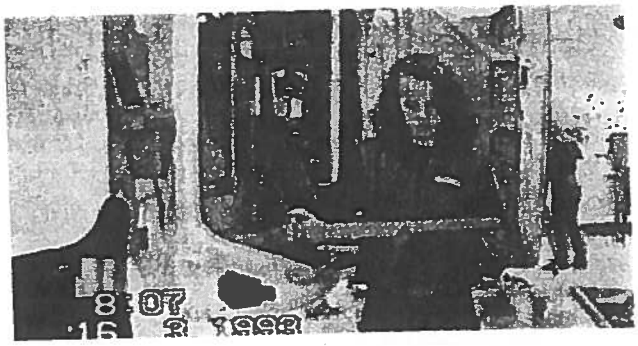
The bill-of-materials is a description of the product's components which operationally forms the basis of the entire automotive manufacturing process. The product structure is the result of the design department's development work and forms the basis for the bill-of-materials. However, in the Swedish automotive industry the product structure is transformed into a bill-of-materials mainly meeting the needs of co-ordinating the materials supply. During this transformation, the inner logic of the product is destroyed, resulting in needs for local preproduction and production engineering work in order to restore the information to suit the specific final assembly system used (Engström and Medbo 1993). Our experiences from designing assembly systems for long cycle time collective working underline the need for a product structure based on the generic characteristics always present in vehicles on the shop floor. The term collective working is deliberately selected instead of e.g. work groups, etc. in order to emphasise the fact that operators work together on one or more products, controlling product flow and having common responsibility for production output as well as product quality. This new assembly oriented product structure is a precondition for material supply systems and efficient learning on the shop floor in parrallellised-flow assembly systems (Engström, Jonsson and Medbo 1993). In fact, the most feasible way to create this new product structure is to incorporate a description of the assembly work into the existing product structure. This is possible, as has been illustrated with regard to e.g. the relationship between variant codification and intra-group work patterns (Engström et al. 1995). In fact, some Swedish assembly systems have been designed using this approach. This new assembly oriented product structure might also attract interest from ergonomic scientists since it might prove to be the key factor for converting ergonomic science, based in individual human work characteristics, into product and process oriented ergonomics. This might in fact prove a more feasible research approach for the scientist interested in fitting the assembly system to the human being. Thus we formulate the hypothesis illuminated in this paper, namely: Is it possible to take advantage of the product structures to improve shop floor ergonomics? – And, if so, To what extent are the true work characteristics of collective working in long cycle time assembly systems worth considering?

2. Method

Within the context of our long term research and development work in co-operation with Volvo Car Corporation we were able to video-record full-pace assembly work in the Volvo Uddevalla plant during its closing down period in 1992 – 93, using one camcorder for each operator. In order to analyse this and similar material we have developed a specialised equipment consisting of a computer synchronised video recorder enabling us to define appropriate activities and to register these activities as a file with unambiguous and precise connection to the video tape through time coding (Engström and Medbo 1996). This specific data collection was complemented with an extensive documentation of all production documents, data files, work instructions etc. In fact the collected materials from the Uddevalla plant consist of an archive of e.g. approximately 2 800 binders, photographs, drawings, etc. located at the Chalmers University of Technology. Thereby our experiences in the design, running-in and full-scale production of this plant during 1985 – 1992 include a large amount of information describing shop floor work in parrallellised-flow assembly systems. These experiences also include more recent experiences of assembly systems within the Swedish automotive industry gained during our ongoing research and development work. Moreover, it has been possible for us to transfer the complete information from the assembly instruction system used in the Uddevalla plant to an analysis data base. This has enabled us to establish and analyse relations between specific work tasks and different characteristics taking account of the influence of variation due to the product.



Schematic function of the collective working in the Volvo Uddevalla plant in assembly workshops 4 – 5



The assembly work in the Volvo Uddevalla plant was facilitated by a tilting device allowing adjustment in height, as well as rotation of the automobile body up to 180 degrees around its mid axis.

Figure 1. Schematic function of and collective working in assembly workshops 4 – 5 in the Volvo Uddevalla plant there nine operators completed automobiles with a cycle time of approximately 80 minutes. The collective work was performed in sub-groups of pairs of operators.

3. Results

What are the work characteristics of collective working in long cycle-time assembly systems? In order to answer this question we will assume that this work can be divided into (1) more "pure" assembly work where specific components are fitted and (2) work where pipes and cables already fitted are connected. In the first case it might be possible to find a direct interrelationship with the existing product structure since, when transformed into a bill-of-materials, it designates specific components to specific work tasks. In case two, on the other hand, the components are already fitted. Hence specific work tasks designates conglomerates of components not readily available in information contained in the product structures. Of course, this is a simplification since, among other things, the operators are in fact also helping each other, shifting work positions along the products during the work, bringing more or less of the materials to the work position, adjusting and controlling work tasks, etc. However, if we consider the assembly of a complete automobile, as in this case, this simplification might be arguable. In figure 2 we have compiled a number of diagrams illuminating the work of nine operators.

	Share of "pure" assembly work (%):	Share of connecting work (%):	Mean length of "pure"assembly work (sec):	Mean length of each connecting work (sec):	Total number of occasions:
Operator 1:	64	36	87	53	45
Operator 2:	74	26	121	47	60
Operator 3:	49	51	96	103	29
Operator 4:	37	63	73	123	33
Operator 5:	67	33	110	60	96
Operator 6:	58	42	84	56	67
Operator 7.	54	46	83	73	54
Operator 8:	45	55	72	99	26
Operator 9:	56	44	111	107	44

Figure 2. Table of compiled information concerning nine operators performing assembly work on a complete automobile in the defunct Volvo Uddevalla plant according to figure 1. The information is derived from the existing product structure. The assembly work is categorised into "pure" assembly work where specific components are fitted, and work where connecting of pipes and cabling is also already fitted. Source of information: our own calculation based on work mapping, assembly instructions and the existing product structure.

Operator 2 is chosen as an illustration of a large share of "pure" assembly work. In this case the fitting of components within the automobile includes e.g. cable harness, heater unit, pedal unit, etc. Operator 8, on the other hand, represents a large share of connecting work. In this case including finishing the assembly within the automobile body, as well as finishing within the boot involving fitting components such as seats, windscreen, boot panels etc. Thus operators 2 and 8 respectively characterise the assembly work in the beginning and at the end of the work on a complete vehicle. The beginning of the total work on the vehicle is characterised by fitting discrete components which usually requires a torque with the correct force to achieve the correct quality. The work at the completion of the vehicle is, on the other hand, characterised by adjusting interrelated components to the correct tolerances, which is a work more related to cosmetic quality demands. As is evident from the two diagrams in figure 3, initial work on the automobile is in fact fragmented into short bursts of work, even though the "pure" assembly work task is quite coherent (Operator 2). The finishing of the vehicle contains relatively few but coherent work tasks (Operator 8). To conclude, the total assembly work performed on the automobiles studied has quite different work characteristics both according to the information available in the product structure as well as concerning the true work performed. This fact is certainly important to note if the sketched research approach above is considered in the future.

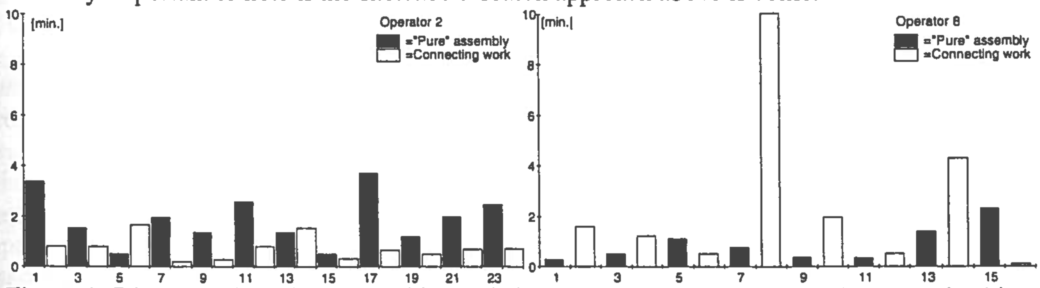


Figure 3. Blow up of detailed assembly work for two operators, Nos. 2 and 8, categorised into "pure" assembly work where specific components are fitted and work whereconnecting of pipes and leading etc. is already fitted. Each diagram illuminates approximately 30 minutesof assembly work, a third of the total work cycle, divided into sequence, 24resp 16 occasions. Source of information: our own calculation based onwork mapping, assembly instructions and the existing product structure.

4. Comments

We have in this paper illustrated and assessed the potential oftaking advantage of product information already availablefor the design of e.g. collective working for the purpose of improving the ergonomics. These results are relevant for a generalmethod for assembly system design. A general method which could e.g. illuminating merits and malfunctions of using various types of product structures for grasping ergonomic aspects of assembly work in the form of e.g. ergonomic intra-group work patterns which may be designed allowing for individual characteristicsof specific operators. Based on figures 2 and 3 we can conclude that about half of the assembly work is closely related tothe product structure, as well as to our other information and experiences from this specific plant, as briefly described aboveThis condition is especially striking for the first half of the work onthe automobile. We are convinced that the information contained inthe product structure cloud be used in the above mentioned research approach. Future analyses ought to include how and to what degree the product structure can be used to decide and describe connecting work.

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