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Transférabilité / hybridation des modèles :
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Transférabilité / hybridation des modèles :
Japonisation des systèmes industriels ou indigénisation des transplants japonais
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Uddevalla : nouveau modèle ?
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Design Criteria and Production Principles for Parallellized Flow Assembly Work

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This paper reports on implemented production principles used for long cycle-time parallellized flow, final assembly work. The results are based on long collaboration between practitioners and researchers. We also report on the consequences of the application of these principles and discuss their influence on the utilisation of buffer volumes and on production planning and scheduling.

1 Design criteria and design assumptions

Our research and development work within the Swedish automotive industry has emphazised the need to initially specify the technical and social demands of a new production system without consideration of production principles or details. Only then will it be possible to evaluate if the suggested production principles or if a specified production system design fulfils these demands. [1]

This articulation and evaluation process obviously ought to involve aspects of technical and administrative autonomy in relation to more obvious parameters like productivity, quality, flexibility and ergonomic aspects.

This is of course a complex, not fully explored problem area, and it is in the practical design process far to easy too base the evaluation on generalised assumptions gained from empirical experiences from other production systems or from the popular literature. There is then a risk of missing some fundamental understanding.

An example of this type of generalisation concerns the use of buffers in final assembly. The current interest in increasing the capital turnover by reducing the amount of capital tied up in stocks and in the manufacturing stock itself has underlined the philosophy of successively trying to dispense with buffers. It is also argued that by eliminating buffers, the technical disturbances in the production system are exposed, which makes it possible to eliminate the causes of the disturbances. By further elimination of buffers ,other sources of disturbances may be identified and eliminated.

This argument ignores the fact that buffers, besides compensating for technical disturbances, frequently also serve social needs, fulfilling an integrated part of an incentive structure, which, correctly designed, in fact simultaneously reduces the need for buffers and increases the production output.

If elimination of buffers should be required in a serial flow, the technical autonomy and the freedom to control boundary conditions by the autonomous groups themselves would disappear. This would ruin one of the basic ideas of work-group organisation.

It is possible to explicitly state that a successively smaller part of the buffer during, for example, a running phase may be used for technical reasons. By entrusting the responsibility for both technical and social buffer volumes to an autonomous group, an incentive is created inside the group to attack the cause of technical disturbances. [2]

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[1] These demands should be articulated in both abstract and detailed terms, for example; (1) the work cycle should contain 20% overcapacity (excluding technical disturbances), (2) workers within a work-group shall be positioned so that they can be seen and heard when calling to each other, (3) the buffers between many work-groups with responsibility for quality and production output shall be 4 – 8 hours. 4) the buffers between work-groups of six workers shall be 0.5 – 4 hours, (5) 4 – 3 workers at the most should be dependent on each other, (6) no mechanical pacing, etc.

[2] In, for example the Volvo Truck plant in Tuve, the work-groups have the responsibility for levelling out assembly time variation caused by product variants along an assembly line; an assignment to the group based on a predetermined total buffer size. This requires that the production engineering detailed planning is distributed in advance to the work-groups.

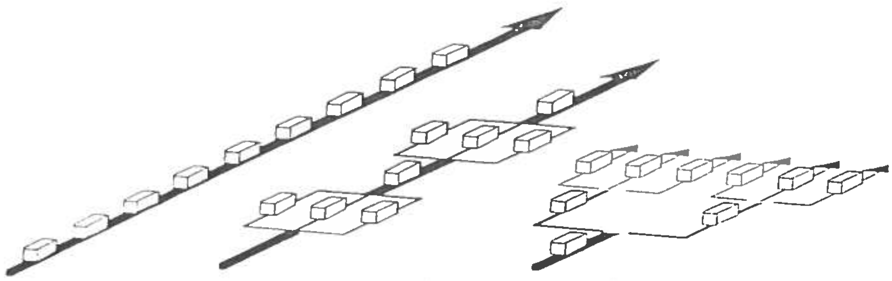

Figure 1. Different flow patterns for production systems for final assembly. The organic flow leads to parallellisation, implying high technical autonomy and extended cycle-time. This requires a non-traditional materials feeding technique, by kitting materials for individual products. This is necessary because of space requirements and the necessity to secure that the correct components are fitted, which is vital, since the product and product information are constantly shifting due to product changes.

2 Production principles implemented in Swedish automotive industries

The base for the technical concept of the now defunct Volvo Uddevalla plant was the proved efficiency of parallellization, which is a result of the elimination of inefficiencies (Engström 1983, Karlsson 1979, Linder 1990 and Wild 1975).

The design assumption behind the design of this most non-traditional production system for final assembly was that human capabilities and needs as well as market demands should be the starting point for the design of technical and administrative preconditions, the common denominator being the product itself.

The parallel flow and the extended cycle-time used implied the need to prestructure the information and materials to facilitate the assembly work. This prestructuring called for non-traditional materials feeding techniques (materials being supplied as kits for individual products) combined with advanced information systems (relying on precise verbal networks as a complement to traditional part numbers and variant codification).

The complete product constituted a whole that should form the basis for work structuring. The product was described in detail in the design phase and the long cycle-time assembly work itself could be said to verify the prestructuring of information and materials.

The nature of the design of the technical and administrative preconditions in the production systems we advocate ought to be such that the individual and the work-groups become and have to become increasingly skilled, since knowledge pays off in the form of extended technical and administrative autonomy. [3]

The Volvo Uddevalla plant, which had a parallellized flow, was based on five newly developed production principles:

(1) Organic flow pattern and true autonomous group work. The group members carried out assembly work on several products simultaneously, although it seldom occurred that more than two workers were working on the same product at a time. Thus it was possible to vary method and pace, depending on how the work proceeded, independent of other work-groups' work status and variation.

(2) Prestructured materials supply to individual products. The larger components with their obvious positions in the product were brought to the place of assembly in kitting fixtures. On the kitting fixtures there are also a number of plastic boxes containing medium-sized components as well as plastic bags

[3] A phenomenon not fully achieved at the Uddevalla plant because, among other things, the development of a "bureaucratic" production planning and scheduling system not fully suited to the shop floor characteristics.

containing small components (Johansson and Johansson 1990). These plastic bags contained the small components needed for every product and they had been grouped in a structured way in the plastic bags. There was a large number of these small components and they represented the greatest share of the assembly time. Through grouping and structuring them, a considerable reduction in materials-handling time was achieved. Moreover, this way of displaying materials functioned in itself as a work instruction.

(3) Naturally grouped assembly work, which presupposes that the traditional disintegration is broken and professional skills created (the characteristics of a skill are; natural rhythm, holistic view, functional grouping and result orientation). The skills involve a number of tasks being combined in work functions (Ellegård, Engström and Nilsson 1991). In pratice, this means that the natural relationships, between material display, administrative work description and the method of working are preserved. This in turn has led to the development on the shop floor of a professional language and concepts which draw on the designer's work to a greater extent than usual.

(4) A reformed product description system. This leads to more efficient information handling, where the product and the work derive from an assembly-oriented material grouping and where they are described using a number of predefined interrelated "charts". The naturally grouped assembly work is supported and formalised by an information system which is capable of breaking down the product into its smallest components and relating this information to the group-based, long cycle-time assembly work.

(5) Material and production control based on the principle that products that are similar for assembly purposes are also principally similar when it comes to materials handling and product description including work instructions, so-called assembly variants. This means less need for replanning and also a materials consumption sequence, which is more consistent with the planned sequence, leading to reduced buffer volumes, better just-in-time efficiency and a reduced number of variants in the final assembly.

The application of these production principles has had the following not obvious, or initially not generally accepted, effects, among others:

- Reduced space requirements including buffer volumes compared to traditional line assembly, since few products were placed in intermediate buffers between different production phases, and the need for transport areas was reduced (most automobiles in the product workshops were "assembly active", i.e. subject to assembly work).

- Reduced need for expensive tools compared to traditional line assembly for several reasons; (1) the degree of mechanisation was lowered on account of a greater work content and more but less complicated tools, (2) fewer tools with a fixture function were required, as the assembly workers in the work-group commanded the whole tolerance chain and were capable of fixing the component, adjusting its position and finally fitting it to the required torque, (3) expensive production equipment was utilised jointly by several work-groups and (4) glued components were fitted using small fixtures with low pressure but were allowed to be applied for a longer period – as opposed to short-cycle work and products that move from work station to work station, implying that gluing requires high pressure and a short application period.

- The efficient information handling led to a speeding up of the time and resources needed to implement a change of model and to effect change orders. In this respect the Uddevalla plant also proved superior to Volvo's other automobile plants.

- Successively reduced need for technical production support (production engineering and supervisory functions) to the work-groups.

- Flexible work scheduling, which has led to shorter lead-times than the traditionall ones. It has in practice only become possible to manufacture automobiles which have already been sold to the customer.

The fact that the unique production principles have led to superior performance due to reduced inefficiencies [4] has confirmed the relevance and validity of the theoretical frames of reference not fully explained in this paper (see for example Engström, Lundberg and Medbo 1993).

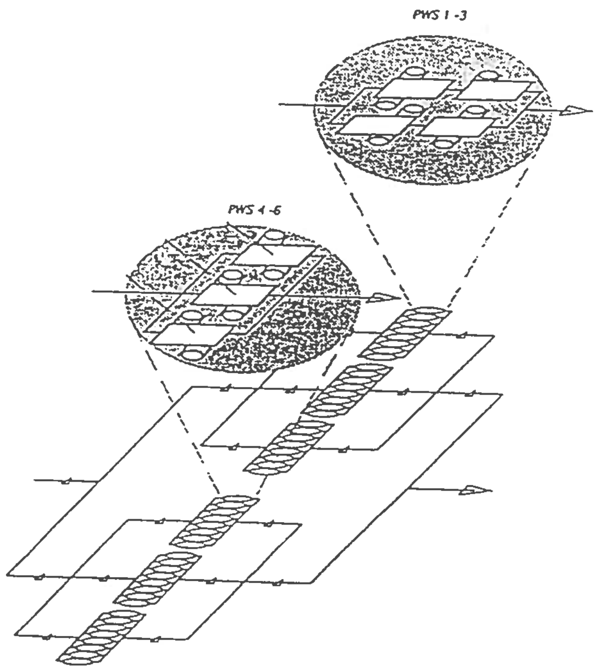

Figure 2. Schematization of the flow pattern in Volvo's final assembly plant in Uddevalla. Here, work-groups of 2 – 12 workers assembled complete automobiles. Note that these work shops were not identical. In work shop 4 – 6, the body was standing still at one internal work station during the whole assembly, in work shop 1 – 3 the body was moved once. There are also other dissimilarities with regard to the location of the subassembly stations, assembly tools, etc. However, the same basic work modules were used in all work shops.

3 Implications for production planning and scheduling

Given certain preconditions, the more parallel work-groups there are, the fewer breaks there will be in the assembly sequence for the single work-group determined by the production plan. Each sequence break then represents a greater amount of work.

The individual parallel work-group, which for a given production volume consists of fewer individuals if the parallellization is increasing, will be able to master their own preconditions to a greater extent and due to their smaller size, will also be able to distribute the work and vary the work pace more easily.

Through the reformed product description system, it is possible to allow high frequency variants, identical from the assembly point of view, to replace each other so that the factory as a whole can follow the planned sequence, so-called assembly variants. This implies a combination of separate and common queues of products and kitted materials, as well as separate and common buffer volumes.

Production planning must also take into account the necessity of variant-resistant work patterns within the work-groups performing final assembly, i.e. the distribution of work within the group in a predetermined way with regard to the effect of different variants spread over time, when certain individuals are undergoing training, when members are absent etc.

These work patterns are recommended as a starting point, not a prescribed working method. The work patterns must, however, describe the work both as a whole and in

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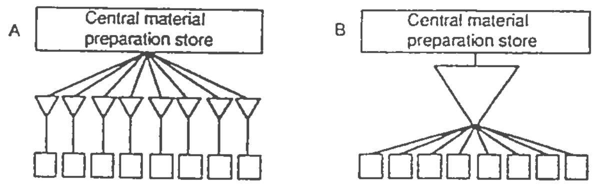
[4] Through our observations, interviews and video recordings in one of the cases, we found that the performance of the work-groups exceeded that calculated by the production engineers by 14 – 16%.

detail at the same time. One must know when the product has to be assembled, how much time is required, and be able to control materials and quality.

In these new production systems it is not, therefore, a question of eliminating the production engineering work, as this takes a different form, and parts thereof can be performed by most knowledgeable persons as regards details in the work process, i.e. by the workers. In this context, for example, both the traditional methods of quality measure techniques/instruments and the principles of standardised work (Adler 1993) are inconsistent with the tangible achievement of the parallellization assembly principles.

It is not a question of abandoning the traditional production methods, and the international debate focused on management, organisation theories and participation does not adequately explain the result in, for example, the Uddevalla plant and some corresponding, less well-known project at the Volvo Truck Company. Note that these theories and plants have a prehistory [5] not generally recognised, of reporting the same positive results (Rosengren 1974), but missleadingly noting the lack of a theoretical frame work (Eckerström and Södahl 1981).



Separate buffer volumes and queues

Buffer volumes exploited for reasons of commonality

Figure 3. To the right; a schematic illustration of a highly parallellized production system for final assembly in which the material is kitted and supplied as kits to each work-group. Illustration A shows separate buffer volumes for each work-group and B buffer volumes exploited for reasons of commonality through the use of assembly variants. [6]

4 Final comments

The development of long cycle-time, parallellized flow, final assembly work has so far proved to be a mix of development, research, running in and learning. The experience gained during the design and running in of some non-traditional Swedish assembly plant is today mainly tied to a few people and not fully articulated, in some aspects not even fully developed – even if we today can glimpse a more consistent theory.

The acceptance of this theory within the international automotive industry is therefore questionable, partly because of organisational resistance, partly because of the general recession. Not least does the closing down of the Uddevalla plant have a symbolic value, implying that the production principles worthless.

The facts about what happens when one tries to introduce these production systems in a traditional plant not recognising the need for technical knowledge, have been described by Granath (1991). He says "it is hardest to introduce the ideas where they are most needed, as that is where the resistance is most compact", refering to the production principles as "socio-technical ideas" thus including the total process of change.

[5] At the beginning of the 1970s the most radical changes in the assembly work took place within the manufacturing of trucks. The same concept was used at Volvo in Sweden and at British Leyland in the United Kingdom (Brown and Miller 1975). The production system in the Volvo case was the same as the one the Volvo Truck Company are currently reintroducing, a parallell flow with integrated subassembly, characterised by unpaced high autonomy collective work. At this early small work shop in Arendal, were to be built two trucks a week, but after four months the production output had risen to three trucks a week. At that time there was no theoretical explanation for this effect.

[6] This principle was to be introduced in Uddevalla and would have eased the strains of precise scheduling of the materials preparation store, due to the limited space to buffer prepared kitting fixtures waiting for delivery to the assembly work shops.

There is a need for some sort of mechanism which, in the running-in and full-scale production phases of complex production systems, successively substitutes adequate development for responsibilities. [7]

It has not been possible to combine all aspects of management's traditional call for a detailed control of the work process and need to satisfy the committed production goals with the development of the production principles or with the theoretical frames of reference.

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[7] The constant revision of the wage system during the development and running of the Uddevalla plant is an example of this effect. It was started as a bonus at plant level and ended as a bonus to individuals and work-groups.