Analysis of Selected Organisational Systems of Sewing Teams

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Abstract
Using the team form of organisation for the clothing production process offers many possibilities. The form of processing organisation depends on the technical equipment and personnel qualifications. Thus, the question arises as to which organisational system will be optimal for a given production profile. The answer should be obtained as early as in the process design phase, and computer simulation appears to be the only solution to this problem. In this publication an analysis of the results of computer simulation of the work of a sewing team is presented. Two virtual models were created, which are the most popular – especially in small and medium-sized firms – of sewing teams organised according to the assembly-line and sectional systems. Both teams had identical technical equipment and the same production assortment.

Key words: *sewing team, clothing production, processing organisation, virtual model.*

Introduction

Clothing and other made-up products are manufactured on the basis of the forms of team work organisation. This requires appropriate preparation of the production process which takes into account the necessity of direct cooperation between the particular processing teams.

First of all, a system of production organisation, which largely depends on the assortment of products and the volume of production as well as personnel qualifications, should be selected. The literature offers many classifications of organisational systems, most of which depend on the division criteria. By way of example, depending on the manner of transport of the elements being processed, the systems can be divided into those with and without mechanical transporters. Depending on the processing time regime, they can also distinguished as rhythmic and arrhythmic systems.

The best-known classification of the systems is shown in ***Figure 1***.

These systems are not discussed in the present work since their characteristics can be found in the literature, e.g. [1, 2]. The question arises as to which criteria should be used for selecting the most appropriate system. W. Więźlak's statement (apart from certain exceptions) points to three principles that apply here:
- small batches – small teams,
- simple products – simple organizational forms,
- low qualifications of personnel – greater division of labour.

Depending on the organisational system assumed, tasks should be allocated to the particular work stations. This is the most important problem realised within the framework of the organisational preparation of production. On the one hand, while solving this problem, one should take into consideration the assumed technology of making the product, which makes it necessary to use definite tools and generates definite limitations with respect to the order. On the other hand, the allocation of tasks depends on the interrelationship of work stations in a sewing team (in-series, parallel or in-series-parallel processing).

The allocation of tasks to particular operators is a very complex problem and belongs to a group of issues referred to in operational studies as NP-complete problems. This means that there is no optimal solution here, but the designer has to select one of the permissible variants.

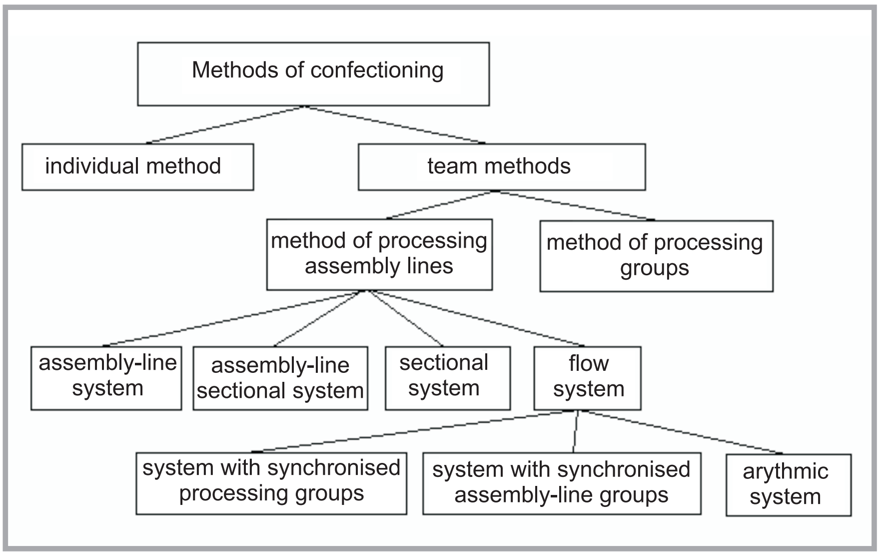

Figure 1. *Classification of organisational systems of clothing production teams [1].*

Sewing team design methods can be divided into three groups.

The first of these is the commonly used classical method [1, 2]. This based on the assumption that the operation times are described by 'rigid' real numbers. Making such an assumption greatly facilitates designing a team; however, the assessment of team work effectiveness (e.g. the extent of use of work stations and related machine standstills) can be performed only after the launch of production. Although the team synchronisation factor can be determined, it only indicates deviations of task performance times from the rhythm assumed and cannot be used for the determination of the behaviour of a real team. This method is based on the team rhythm (a quotient of the labour consumption of the product, and team size), according to which indivisible operations are grouped. From a technological point of view, the flaw in this method is that the grouping of indivisible operations into organisational ones (so that the total time of the operation is in agreement with the predetermined team rhythm) does not always lead to the optimal combination of operations.

The second group includes a method for the optimisation of the time wasted in a team, proposed by Więźlak and Szmelter [3]. It is also based on real numbers, but takes into account a certain interval of variation of task performance times, called tolerances. Their magnitude depends on the character of operation performed at a work station and is ±5% for a machine, ±10% for a machine-manual and ±15% for manual operations. This method allows one to predict potential time losses at particular stations and for the whole team depending on the team rhythm selected [3, 4]. Due to its high labour consumption, this method has not found application in industry.

The third group comprises methods based on the calculus of probability. Here a significant role is played by computer simulation based on random numbers generated according to the assumed probability distribution. By means of a probabilistic model, sewing team work can be simulated and different aspects of its functioning (e.g. efficiency, standstills, inter-operational reserve) can be analysed.

The latter method appears to have highly positive aspects, especially considering the fact that the problem of allocation of tasks to particular operators is an example of NP-complete problems. Probabilistic methods may be proper for analysis of the correctness of the choice made.

What is in favour of a designing process based on computer simulation is the fact that in the classical method the final result of the organisational activities performed can be assessed only after launching production, which can result in the occurrence of certain disturbances in the process. Remedial steps are taken in the course of the process, which may have a negative effect on the efficiency of a processing team. The analysis of 'work' of a virtual processing team allows one (depending on the assumptions made) to approximately assess the correctness of the organisational preparation of a production process as early as at the design stage.

The aim of the publication is to present the results of a comparative analysis of virtual simulation models of two sewing teams organized according to the assembly-line and sectional systems carried out using computer simulation.

Assumptions for simulation models

For the analysis of the virtual work of assembly line and sectional systems, the following assumptions were made:

- the assortment of clothing made are men's trousers, whose labour consumption is 55.66 minutes,
- both teams are of the same size and employ 20 persons each, (the consequence of the two assumptions is a team rhythm of 2.78 minutes),
- the allocation of tasks for the particular work stations was made by the classical method – according to which – the work station rhythm is equal to the team rhythm (assembly-line system) or its multiple (sectional system),
- duration times of the particular operations are described by normal distributions, cut off according to the three-sigma rule [5]; permissible time deviations were the following: ±10% of the mean value for manual-machine operations and ±15% of the mean value for manual operations. Each work station is characterised by the diagram shown in ***Figure 2***.

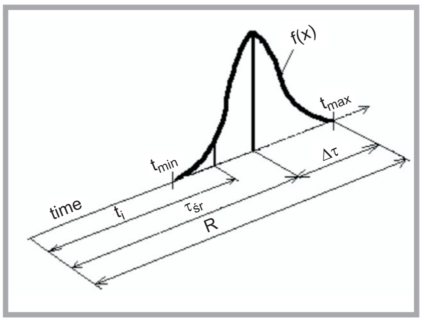

Figure 2. *Production rhythm vs task accomplishment time.*

On the one hand, we have here the planned magnitude of the rhythm R expressed by a real number, the estimated time of task accomplishment $\tau_{śr}$ and its permissible deviations $\Delta\tau$, also expressed by a real number, while on the other we have a set of probabilistic times of production task accomplishment t_i, determined by the probability distribution of the density $f(x)$.

- in the assembly line system, no parallel stations are allowed,
- one worker can operate not more than two machines (two-machine work station),
- two principles, called occupancy rules, must be obeyed in the team:
  - a work station cannot be idle when there is work that can be allocated to it,
  - if a work station has started some work, that work station must complete it.

Investigation results

According to the assumptions made, a plan of loading work stations in sewing teams

Table 1. *Characteristics of sewing teams.*

Parameter	Assembly-line system	Sectional system
Product labour consumption, min	55.66	55.66
Team size	20	20
Team rhythm, min	2.78	2.78
Number of sections	-	4
Number of two-machine stations	9	9
Critical path length, min	55.66	42.97
Team synchronization factor,%	10.09	11.07
Relative time wasted in the team, %	17.18	16.83

was prepared. Their characteristics are presented in ***Table 1*** (see page 91).

The parameters of both teams are very similar, excluding the critical path length (the longest time interval from the moment the elements come for processing to the moment the ready-made product leaves the team) which in the sectional team is 23% shorter compared to that of the assembly line team, which results from the fact that there are three sections processing certain elements of the product in parallel.

The synchronisation factor presented in ***Table 1*** was determined from relationship [1]:

$$S = \frac{\sum_{i=1}^{k} \left| t_i - n_i \cdot R_z \right|}{R_z \cdot \sum_{i=1}^{k} n_i} \qquad (1)$$

where: t_i – the duration of an i-th organizational operation, n_i – the number of parallel stations performing the i-th operation, R_z – the team rhythm, k – the number of organisational operations.

The time wasted in the team was determined from relationship [3]:

$$p_i = \frac{1}{2}\left[\left| t_{di} - \tau_i \right| + (t_{di} - \tau_i)\right]$$

where: $t_{di} = n_i \times R_z$ - the time at the team's disposal for doing the i-th operation, $\tau_i = t_i + \varepsilon \times t_i$ - the longest permissible time for performing the i-th operation, ε - the permissible deviation from the rhythm magnitude ($\varepsilon = \pm 5\% \div \pm 15\%$).

The relative time wasted for the whole team is:

$$\eta = \frac{\sum_{i=1}^{k} p_i}{R_z \cdot \sum_{i=1}^{k} n_i} \qquad (2)$$

A diagram of the organisation of processing teams is shown in ***Figure 3***.

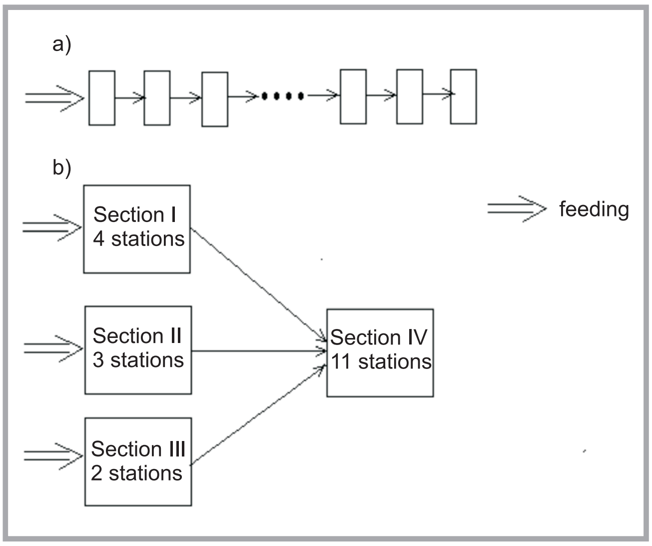

Figure 3. *Diagram of processing teams: a) assembly-line team, b) sectional team.*

In the assembly line team, the first work station is provided with elements, and sets of elements are transported successively to all work stations.

In the sectional team four processing groups (sections) are marked out: I – the section of front and side pockets – it has four stations; II – the section of back legs and back pockets – it has three stations; III – the section of small elements comprising two stations; IV – the assembly station, comprising eleven work stations. The first three sections are provided with elements independently, while in the assembly section processes, the elements are provided by earlier sections.

Diagrams of the loading of work stations for both organisational systems are presented in ***Figure 4***.

The values of indices determined for the synchronisation and time wasted (***Table 1***), and the diagrams of the loading of work stations (***Figure 4***) do not indicate significant differences in the functioning of both teams. It is the computer simulation performed that makes it possible to assess the efficiency of their work.

The author began the comparison of the assembly-line and sectional team by determining the product processing time in each of the teams. The determination of the critical path for both processing methods suggests that, at least theoretically, in the case of the assembly-line team the critical path is equal to the product labour consumption, while in the case of the sectional system – due to the possibility of the parallel processing of some elements – the length of the critical path is much shorter than the product labour consumption. For the example analysed, the time of product processing of the sectional team is 77% of the product labour consumption. The real times of the 'stay' of the product in the team are considerably longer, which is caused by the following three factors:

- times of performing the operations at the particular stations are not identical, which results from the necessity of combining indivisible operations with organizational ones. In addition, these times are not constant values but are described by certain probability distributions. Consequently, the stations will generate standstills result-

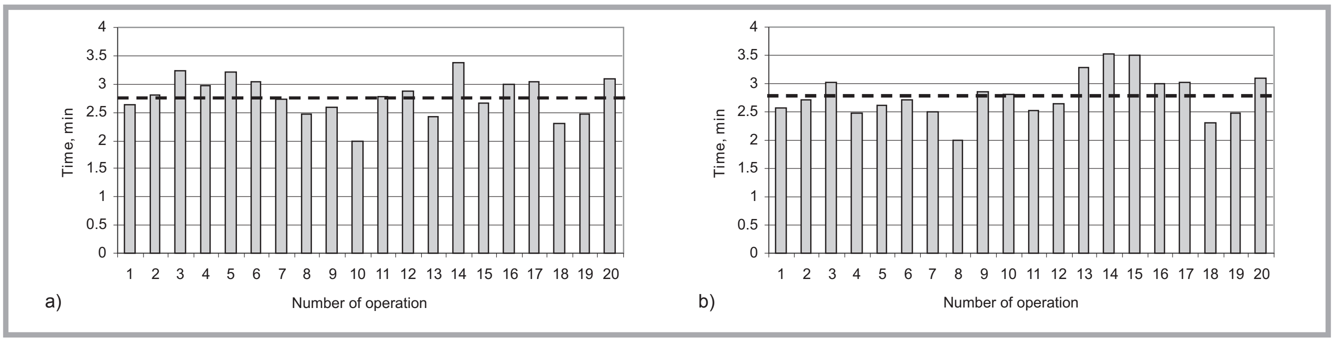

Figure 4. *Diagrams of the loading of work stations; a) assembly-line system, b) sectional system.*

ing from the necessity of waiting for elements to be processed,

- in a team it is not always possible to eliminate 'returns' (the elements leaving a work station must, after undergoing several successive operations, return to the station for the processing to be finished). This occurs, for example, during inter-operational ironing and forces out standstills in the team,
- the assumption that the worker cannot be distracted from the operation being performed (the second rule of occupancy) can prolong the time of waiting for the element to be processed.

Discrepancies between the theoretical and 'real' time of product processing are presented, where the computer simulation of the cooperation between the three stations in the in-series system (***Figure 5***) is given as an example.

When analysing ***Figure 5.a***, it was found that, theoretically, ('rigid' times of performing an operation) an element should reach station 3 for processing after 5.43 minutes. Due to differences in the processing times at particular stations and random values of these times (according to the assumed normal distribution), after a start-up period lasting two supply cycles, the elements reach station 3 after 6.5 minutes. In the case of the 'return' of the element from station 2 to station 1 to perform operation 3 (***Figure 5.b***), the time after which the element will reach station 3 for processing is 9.7 minutes (the start-up time of the 3-person team was 7 supply cycles). Thus, the 'return' of the element caused an extension in the time of reaching the next station by approximately 50%.

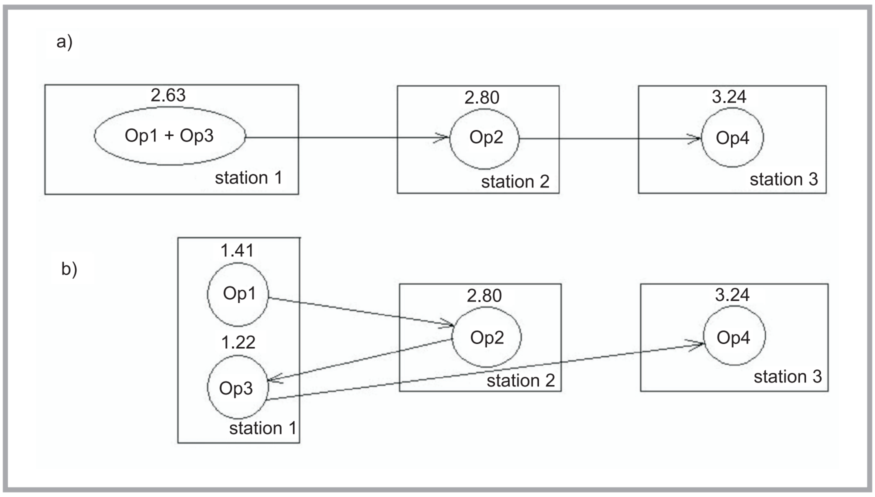

Figure 5. *Fragment of the assembly line team; a) without return of the elements, b) with return of the elements.*

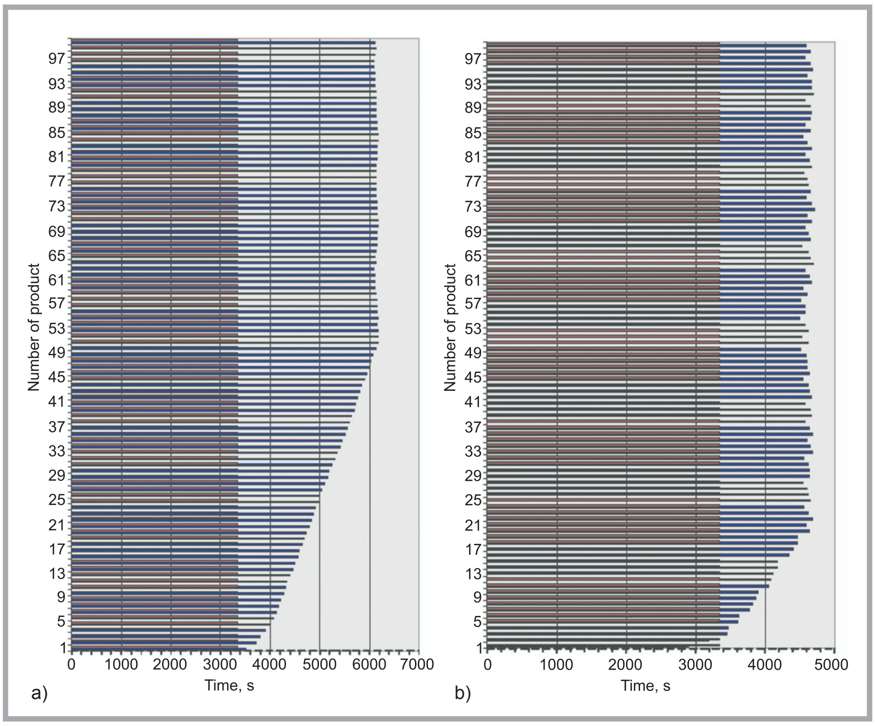

Figure 6. *Processing time of successive products in a processing team; a) assembly-line system, b) sectional system.*

A greater number of returns in the team not only complicated the flow of production between the stations but also significantly prolonged the processing time of the products.

When analysing the work of a team, two production phases should be distinguished: the start-up and the stable work. The first takes place after the start-up of the team and is related to the saturation of the team with the elements being processed. The second lasts from the moment of completion of the first phase until the end of the working shift. The particular phases can be distinguished by analysing the time of stay of particular products in a team, from the moment the elements are supplied to the first station until the product leaves the last station. The processing times of the particular products in an assembly-line team are shown in ***Figure 6.a***. For comparison a line has been drawn to show the theoretical manufacturing time (product labour consumption).

The processing time of the first product is similar to the theoretical time since all the stations are ready to work. As successive products are gradually transported to the team, their processing time extends, which results from the 'occupancy' of the

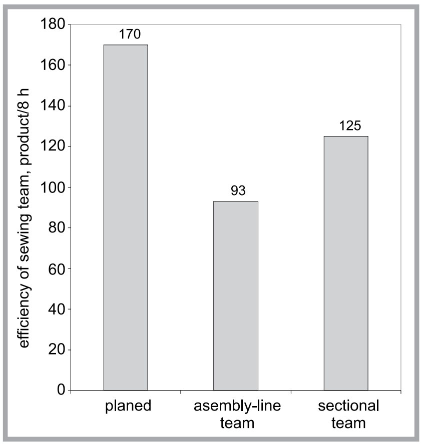

Figure 7. *Efficiency of sewing teams.*

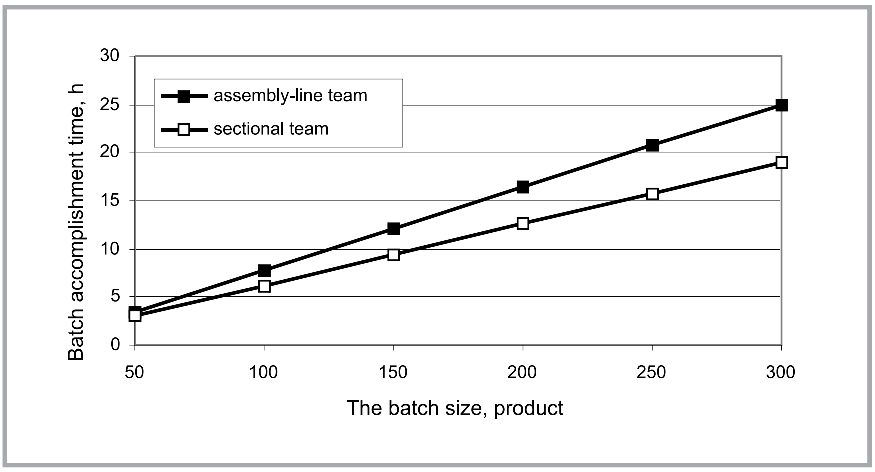

Figure 8. *Batch accomplishment time depending on the batch size.*

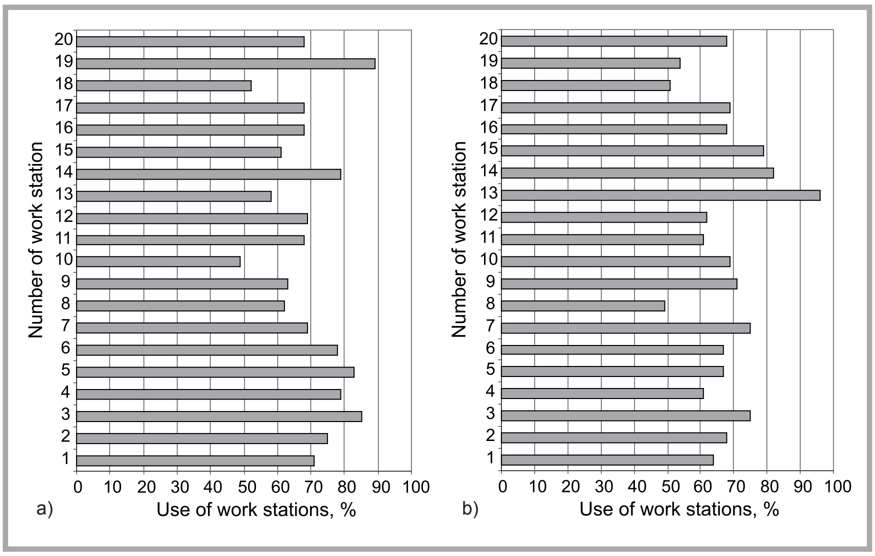

Figure 9. *Use of work stations during a working shift; a) assembly-line system, b) sectional system.*

successive stations and the necessity to wait for processing. The extension of the processing time lasts until the moment of saturation of the last station with the elements for processing. As can be seen in the picture, the assembly-line work is stabilised after about 50 products have been transported for processing. The length of the start-up depends on the team size and number of 'returns' occurring. After the 'start-up' the time of manufacturing one product is approx. 103 minutes. Thus, it can be estimated that the team efficiency will be about 93 pairs of trousers per day (the planned output was about 170 pairs).

The analysis of the product processing times of the sectional team (***Figure 6.b***) showed that the start-up time was significantly shorter. The teamwork is stabilised after about 20 products have been transported for processing. At the same time, during a period of stable work, the time of making one pair of trousers is approx. 77 minutes, which gives an output of 125 pairs of trousers per day. It is considerably higher than that of the assembly-line team, but approx. 26% lower than the planned output.

Juxtaposition of the efficiency of both teams is shown in ***Figure 7*** (see page 93).

Considering the time of accomplishment of a production batch, it should be stated that, for small batches of of 50 pieces, the assembly-line team will be at the end phase of start-up, where the mean time of making a product is approx. 83 minutes. For the sectional team this time will be approx. 73 minutes. For a production batch of 130 pieces, these times are 100 minutes and 76 minutes, respectively. This translates directly into the production batch accomplishment time and consequently into production costs. The dependence of the production batch accomplishment time in both systems on the batch size is shown in ***Figure 8***.

In processing teams there occur order limitations which cause particular stations to be inter-dependent. There are three variants of their cooperation: in the first when the cooperating stations perform tasks at the same time, the transport of the objects being processed proceeds without disturbances. The second variant is when the following station cannot process the elements because the preceding station has not done its task. This variant will occur if the time of doing the task of the preceding station is longer. There are two typical cases in this variant: the first one is when the preceding station is overloaded (time necessary for performing the task is longer than the rhythm magnitude of the team); the other is when the following station is under-loaded (the task is done in a shorter time than the team rhythm). The third variant is the situation when the preceding station cannot transport the element processed to the following station because it has not yet performed its task. This is opposite to the case in the previous variant.

The latter two variants cause standstills of work stations thereby decreasing their efficiency. In ***Figure 9*** the use of particular stations during a working shift is shown.

Irrespective of the organisational system, the use of work stations in a sewing team ranges from approx. 50% to slightly over 90%. There are two reasons for such a large variation in the use of working time by particular stations. The first is the labour consumption of the task allocated. Overloaded stations are character-

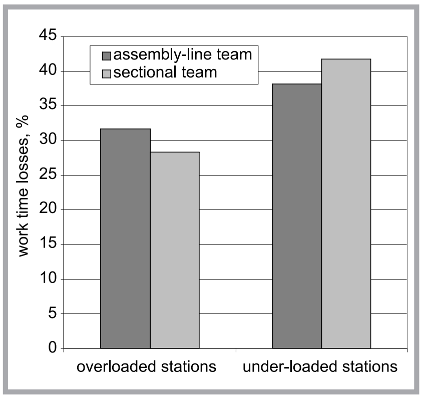

Figure 10*. Mean work time losses at a station.*

ised by higher use of the working time (***Figure 10***). However, this is not due to higher efficiency of the overloaded work station but the fact that it is not blocked by neighbouring stations. And it is the blocking of neighbouring stations by the overloaded station that the other reason is related to.

It can be estimated that, on average, the station, as a work team, works effectively approx. 65% of the working shift time irrespective of the organisational system of the processing time. Therefore, losses in a sewing team are important as they amount to 56 man-hours in a 20-person team during one working shift.

It should be stressed that information about team work efficiency i obtained before the start of a production process, which allows different variants of a team work to be tested. Having developed a simulation model of a processing team, one can also assess the effectiveness of the remedial activities resulting from the disturbances of a real team. This can restrict the economic effects of not- always- successful- solutions introduced in sewing teams functioning in reality.

Conclusions

The selection of an organisational system has a significant influence on the effectiveness of a sewing team. This statement is in agreement with expectations and refers to the qualitative analysis. Quantitative analysis can be performed by comparing the effectiveness of real teams. The problem arises when it is advisable to estimate the effects before the start of production. In such a case computer simulation of a sewing team is the only possibility.

Based on the simulation studies carried out, the following was found:

- a team organised in a sectional system is characterised by greater efficiency than that of an assembly line system due to identical equipment and same size yeams. This results from the division of the team into sections, which perform certain operations in parallel. Depending on the production batch size, the effectiveness of the work of a sectional team is 12% - 25% higher than that an assembly line,
- the combination of indivisible operations with organisational ones can lead to the occurrence of 'returns' in the team. On the one hand, they can hinder the flow of production, but on the other they significantly reduce team efficiency,
- different organisational systems teams reach different efficiencies at similar effectiveness magnitudes of the processing stations. With a difference in the efficiency of the teams of 25% in both systems, the use of work stations is, on average, 65%.

Editorial note

1. *For building the virtual models of sewing teams and the analysis of their work, a simulation program of the Witness Lanner Group was used.*
2. *Team output can be estimated as a product of the quotient of the working shift time, the time of making one product, and the team size.*

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