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LOAD EQUILIBRATION OF WORKING PLACES ARRANGED ON CONVEYORS USED FOR FOOTWEAR UPPERS MANUFACTURING

HARNAGEA Florentina[1], HARNAGEA Marta[2], SECAN Cristina[3]

[1]Technical University of Iasi, Faculty of Textile, Leather and Industrial Management,"Gh.Asachi", Dimitrie Mangeron, No. 28, Iasi, 700050, România, E-Mail: harnagea@tex.tuiasi.ro

[3] University of Oradea, Faculty of Energy Engineering, Department of Textiles-Leather and Industrial Management, B.St.Delavrancea str., No. 4, 410087, Oradea, Romania, E-Mail: cris_secan@yahoo.com

Corresponding author: Harnagea Florentina, E-mail: harnagea@tex.tuiasi.ro

Abstract: *In the present paper there is presented how to achieve a load equilibration of workstations for a conveyor with imposed pace, in the case of manufacturing uppers for a women boots model. Equilibration of work charging is done by switching worker's operations in order to use at full time each worker placed in the technological flow process. In the manufacruring process of shoe uppers of the considered model, there have been established the operative time and production rates per operation. Thus there has been calculated the work necessary amount Nci for accomplishing different production rates: Q=600,650, 700, 750... 900pairs/ 8 h and the necessary amount of work Nai was adopted.*
A technology line of manufacturing a footwear item is used at its optimum capacity when the number of work vacancy is minimum, 0.013 corresponding to a flow production of 700pairs / 8h the highest labor productivity being obtained, ie 17.5 pairs / worker • 8h. By equilibrating the work charge for each operation, it is obtained, for a daily production of 700pairs / 8h, a reduction of the number of workspaces from 40 to 36 workers and hence a labor productivity of 19.44 pairs / worker • 8h.

Key words: *flow technology, women boots, degree of non occupation, work productivity, optimum capacity*

1. INTRODUCTION

The footwear industry is a labor intensive one, with many production processes done manually. Companies look for seting a condition where operator employment can generate more output, for increasing efficiency of the operations and thus reducing the production cost.

Researches on production time management of shoe making process reveals important for arranging production schedule, being also the significant index for estimating work cost, ensuring quality and proceeding smoothly.

In the footwear manufacturing process, the handling of cut pieces is done in three different workrooms, based on the nature of the materials used:

- ✓ workroom for processing and assembling flexible components (PC);
- ✓ workroom for processing and pre-assembling rigid components (PR);
- ✓ workroom for uppers closing and finishing (TTF). [1]

The characteristic of the activity carried out in these workrooms is that the distinct processing and assembly operations must be executed in a precise order, imposed by the technological process. Production and process analysis are significant for the footwear manufacturing companies to improve their productivity and to optimize usage of resources [2]. To assure high productivity while maintaining the established order in the shoe manufacturing processes, the parts and components are moved in a continuous flow defined by: cadence, speed, direction and orientation.

The technological process of manufacturing footwear uppers is usually organized in a continuous flow, and the transport between operations is automated by the use of conveyor belts, which have a predefined cadence.

Organizing production on the conveyor belt with a predefined cadence requires certains rules to be followed, such as:

- set up operations in a strict order prescribed by the technological process;
- minimize operative time for the workstations, if the conveyor belt speed is calculated correctly;
- ensure a high level of work distribution;
- reduce the volume of unfinished production if the assembling is done by a worker within the working area;
- for a single operation, divide the work load equally between workers, to ensure production goals are met or even surpassed etc.[1].

However, it is not always the case that these conveyor belts are used at their optimal capacity. The optimal capacity is defined as the capacity which ensures the best indicators for productivity, worker load, equipment usage etc.

Starting with these considerations, the present paper is looking for a solution to balance the working places in the technological flow along a conveyor belt with predefined cadence for manufacturing shoe uppers.

2. CASE STUDY

The efficient running of the tasks on upper-making lines depend on analysis and optimized scheduling of production techniques, which are the key points for fulfilling specific production rates.

In a footwear factory, the assembling and sewing of shoe components is done at different time intervals, depending on:

- type of operation;
- speed of the manual equipment (in the case of manual operations);
- speed of the equipment's working components;
- characteristics of the materials used [1], [3].

Equilibration of working places can be obtained by coupling operations. This coupling leads to situations where certain workers will have to execute compatible operations (which are done on the same machine or are manual operations that require the same, or similar, qualifications) [3], [4].

Regardless of situation, the coupling of operations must lead to a complete use of the operative time by each worker of the technological flow [5, 6].

The considered footwear item is a boot model for women, figure 1.

Fig.1: *Women boots*

After determining the production process for the uppers, the operative time and manufacturing rates were calculated (table 1):

Table 1: *Operative time and manufacturing rates for uppers*

Op. no.	Operation name	NT min/ pair	Np, pair/ 8h	Op. no.	Operation name	NT min/ pair	Np, pair/ 8h
1m	Cutting the uppers	0,80	600	15 M	Stitching quarter 1 on heel counter	0.92	522
2M	Skiving the uppers components	1,76	273	16 M	Stitching bellows to vamp and quarter 1	0.92	522
3m	Applying PU foam on the collar	0,40	1200	17M	Sewing quarter lining to vamp lining	0.91	527
4m	Cutting the textile strip	0.30	1600	18M	Sewing the lining to the tongue	0.61	787
5M	Sewing the label on the heel counter	1,32	364	19m	Applying PU foam on the tongue	0,50	960
6M	Stitching the textile strip on the shoe tongue	0.87	552	20m	Applying PU foam on the lining	0,50	960
7M	Applying and pressing the stiffener on the vamp	0,62	774	21M	Stitching quarter lining to heel collar	1,32	364
8M	Applying and pressing the stiffener on the quarter 1	0,62	774	22M	Inserting metal clips	0,80	600
9M	Applying and pressing the stiffener on the quarter 2	0,62	774	23M	Stitching rigid heel counter	0.87	552
10M	Stitching the bellows tongue	1,38	348	24M	Stitching toe cap	0.79	608
11M	Stitching the textile strip on the quarter 1	0.87	552	25m	Adjusting tongue and heel collar	1,60	300
12M	Stitching quarter 1 lining on to quarter 2	1.32	364	26m	Cleaning the lining of the upper part of quarter 1	1,60	300
13M	Stitching collar on quarter 1	1,32	364	27m	Quality control	0,80	600
14M	Stitching quarter 1 on quarter 2	1,32	364	28m	Transport to regrouping storage work room	0,80	600
					Total	27.08 min/pair	

m-manual operation; M-mechanical operation

According to table 1, the minimal and maximal operative time values of the technological process of manufacturing the product [3]:

- ✓ t_{min}=0,30 min/pairs, the minimum time corresponding to the most productive operation – cutting the textile strip;
- ✓ t_{max}=1,76 min/pairs, the maximum time corresponding to the least productive operation – skiving the flexible uppers components.

Under these circumstances, productivity within the technological process is also not uniform, and will show varying values for each operation. For the model used in this study, the maximum productivity is 1600pairs/worker/8hours relative to the minimum operative time and 274pairs/8hours corresponding to the maximum operative time.

The required human resource Nci was calculated for different production goals: Q=600, 650, 700, 750, ..., 900pairs/8h. The required human resource expressed in integer values - Nai – (rather than the calculated values) was used, showing a varied degree of idleness.

The following table (table 2) exemplifies the calculated required human resources and the adopted values, corresponding to a production rate of 600pairs/8h.

Table 2: *Work resources corresponding to a production rate of 600pairs/8h*

Op. no.	Nc_i	$\pm \delta_i$	Na_i	Op. no.	Nc_i	$\pm \delta_i$	Na_i	Op. no.	Nc_i	$\pm \delta_i$	Na_i
1m	1,00	0	1	11M	1.08	-0.08	1	21M	1,65	0.35	2
2M	2,20	-0.20	2	12M	1.65	0.35	2	22M	1,00	0	1
3m	0,50	0.50	1	13M	1,65	-0.65	1	23M	1.08	-0.08	1
4m	0.38	0.62	1	14M	1,65	0.35	2	24 M	0.98	0.02	1
5M	1,65	0.35	2	15M	1.15	-0.15	1	25 m	2,00	0	2
6M	1,08	-0.08	1	16M	1.15	-0.15	1	26m	2,00	0	2
7M	0,78	0.22	1	17M	1.14	-0.14	1	27m	1,00	0	1
8M	0,78	0.22	1	18M	0.76	0.24	1	28m	1,00	0	1
9M	0,78	0.22	1	19m	0.62	0.38	1				
10M	1.72	0.28	2	20m	0.62	-0.62	1	Total	33.05	2.19	36

In the shoe manufacturing the production line is used at its optimal capacity when the number of workstations assures a minimal degree of idleness [3].
Therefore, the idleness degree was calculated with the following formula:

$$K = \frac{\sum \delta_i}{\sum N_a} \qquad \textbf{(1)}$$

The resulting values of the idleness degree for different values of production rates on the flow are shown in table 3.

Table 3: *Idleness values for different production rates*

Q [prs/8h]	N_c	$\sum \delta_i$	N_a	K	Q [prs/8h]	N_c	$\sum \delta_i$	N_a	K
600	33.05	2.19	36	0.061	800	44.05	1.99	46	0.043
650	35.99	1.50	37	0.041	850	46.81	2.99	50	0.060
700	38.51	0.53	40	0.013	900	50.81	1.77	53	0.033
750	41.32	1.84	43	0.043					

It is considered that a technological line is used at its optimal capacity when the number of working places assures a minimal value of idleness (δ_i) per working place.

The graphical illustration in Figure 2 shows a minimal value of idleness 0,013 corresponding to a production flow of 700pairs/8h.

Work productivity is calculated as below:

$$W = \frac{P}{N_a} \qquad \textbf{(2)}$$

where: P- flow production;
N_a- total number of working places;

$$N_a = \sum_{j=1}^{n} N_{a_j} \qquad \textbf{(3)}$$

N_{aj}- total number of working places used for operation j.

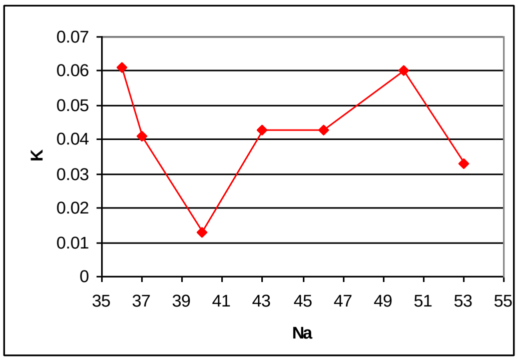

***Fig. 2**:The variation of the degree of idleness K*

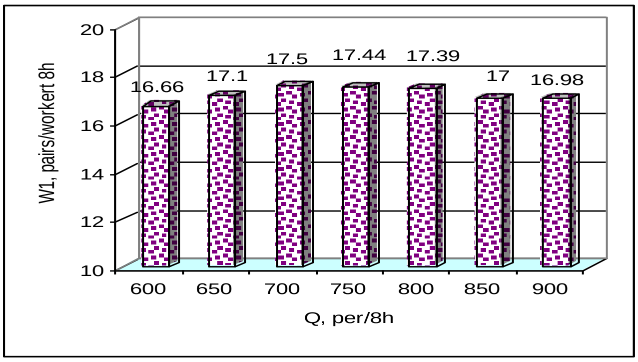

***Fig. 3**: Work productivity before equilibration of the working places*

Work productivity, calculated as the ratio between the production value and the number of workplaces used, defined as pairs/worker/8hours, is illustrated in figure 3.

As shown in figure 3, the greatest value for work productivity, 17.5 pairs/8h, is obtained for a production capacity of 700 pairs/8hours, corresponding to a minimal degree of idleness of 0.013.

For this type of conveyor belt it is possible to couple operations for load equilibration of working places. Therefore, table 4 illustrates the number of workers resulting from load-equilibration of workstations for a production of 600pairs/8h.

***Table 4:** Load equilibration of working places*

Q=600pairs/8h											
Op.op	Nc	Na	Na’	Op.op	Nc	Na	Na’	Op.op	Nc	Na	Na’
1m	1.00	1	1	11M	1.08	1	1	21M	1.65	2	2
2M	2.20	2	2	12M	1.65	2	2	22M	1.00	1	1
3m	0,50	1		13M	1.65	1	1	23M	1.08	1	1
4m	0.38	1	1	14M	1.65	2	2	24 M	0.98	1	1
5M	1.65	2	2	15M	1.15	1	1	25 m	2,00	2	2
6M	1,08	1	1	16M	1.15	1	1	26m	2,00	2	2
7M	0,78	1		17M	1.14	1	1	27m	1,00	1	1
8M	0,78	1		18M	0.76	1	1	28m	1,00	1	1
9M	0,78	1	2	19m	0.62	1					
10M	1.72	2	2	20m	0.62	1	1	**Total**	**33.05**	**36**	**33**

Na’- number of working places adopted, based on load equilibration

After load equilibration of the working places, the productivity was recalculated, showing improved values, table 5.

***Table 5:** Productivity rates after equilibration of working places*

Q pairs/8h	Na	Na’	W2 pairs/worker ·8 h	Q pairs/8h	Na	Na’	W2 pairs/worker ·8 h
600	36	33	18.18	800	46	42	19.04
650	37	34	19.11	850	50	47	18.08
700	40	36	19.44	900	53	50	18.00
750	43	40	18.75				

Following the load equilibration of working places, a maximum value of productivity of 19.44 pairs/worker·8h resulted, which corresponds to a flow production of 700 pairs/8h and an increase in work productivity of 1.94 pairs/worker/8h, figure 4.

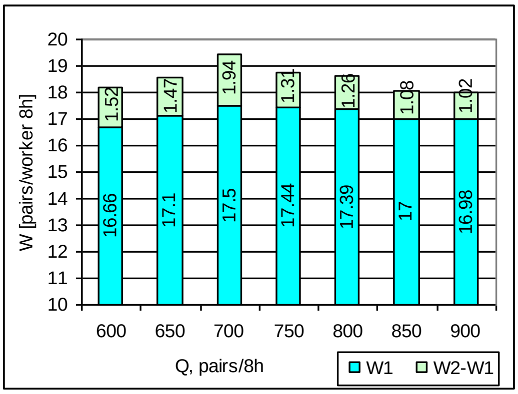

Fig.4: *The difference of productivity after equilibration of working places*

3. CONCLUSIONS

In this study case, variations in size for a production rate Q determine a modification of the degree of idleness for the workstations, resulting a minimum value of 0,013 which corresponds to a production rate of 700 pairs/8h.

Taking into consideration the way the conveyor belt is set up, load equilibration of working places is proposed where possible, and for a series of operations N_{ai} a rounding of N_{ci} is used for workers in training or skillful workers. In this case, for the same production rate for which a minimum degree of load per working place was obtained, the number of working places was reduced from 40 to 36 workers. A higher value of work efficiency was obtained by load equilibration of working places.

The choice considered optimal for a daily production is that of 700pairs/8h resulting in a work productivity of 19.44 pairs/worker·8h compared to the initial productivity of 17.5 pairs/worker ·8h. An improvement of work productivity and an optimization of the resources usage was obtained. Future research can be orientated towards analyzing production efficiency of more varied styles of shoe.

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