18

USE OF WORK STATION PERFORMANCE INDICATOR RATING IN THE MANUFACTURING PROCESSES IMPROVING

18.1 INTRODUCTION

Conveyor belts are used in many areas of industry. Technological and economic reasons have led to the use of fabric made of thermoplastic fibers, polyester and polyamide [20] in the reinforcement of conveyor belts. Conveyor belts with fabric core are used in the mining, energy, food industries as well as metallurgy, agriculture, construction and processing plants of rock and mineral raw materials. They are a component of conveyor belts, characterized by high breaking strength and mechanical damage, as well as abrasion resistance of the running and bearing cover [19, 33]. The properties of the rubber blends used are adapted not only to the electrical and fire safety requirements, resulting from the conditions of the target work environment of the belts, but also from the properties of the material being conveyed. Flame retardant belts are designed for the transport of loose materials in the increased fire risk conditions when working on surfaces. Flame retardant belts are used in the transport of loose materials in underground mining excavations. Oil-resistant belts are mainly used in the food and chemical industries, when transporting oil materials. Low temperature resistant belts are used at temperatures from -45°C to 60°C. Underground methane mines use anti-static belts, while in the unpackaged food products transport food contact belts are used.

18.2 PRESENTATION OF THE RESEARCH SUBJECT

Conbelts S.A. company specializes in the production of conveyor belts with a fabric core based on polyester, polyamide and cotton fibers. The production process of cup to 1400 mm wide types includes [7, 19, 22]:

- manufacture of rubber compound;
- impregnation and coating of fabric with polyvinyl chloride;
- fabrication, i.e., the initial stratification of the spacers;
- vulcanization.

The belt production is performed in a hall of 850 m^2. Rubber blends and blends for the production of PVC belts are manufactured in the Rolling Mill. 32 production employees and 2 shift foremen are involved in the semi-finished products manufacturing process. The result of the process are mainly rubber plates, used in the production of flame retardant belts used in the mining industry. Blends are made on the basis of the company's own recipes or individual customer orders. The quality of the products is ensured by the company's laboratory facilities and a team of qualified R&D staff. The process of weighing and blending the rubber blends is fully automated. The company has an automated line for the production of PVC dry blend and stands dedicated for small components weighing. Constant monitoring of the performed activities ensures repeatability of the blends composition and adherence to the physical and mechanical properties of the produced rubber [33].

At the Fabrication Department, the core of rubber belts and PVC and PWG belts are made. Raw belts are formed by covering the fabric with a blend of PVC or rubber. 36 people participate in the production of raw plates and belts. Fabrication of fabric-rubber conveyor belts to a width of 1400 mm is performed on a technological process occupying approx. 300 m^2. The fabric is subjected to impregnation and thermal procedure in order to improve the adhesion of the rubber and its dimensional stability. The operation involves impregnating the fabric with a binder, removing the solvent and pulling the fabric at a temperature near the melting of the textile substances. As a result of this activity, the rubber adhesion is increased by 2 to 3 times, with a decrease by nearly 50% of elongation in the warp direction and shrinking of the fabric in the direction of the thread from 5 to 25% [15], depending on the type of fibers used and the fabric structure. The impregnated and dimensionally stabilized fabrics are particularly suitable for the production of belts used in high-performance conveyor belts, which carry material at distances from 300 to 2000 m without the need for the station reloading.

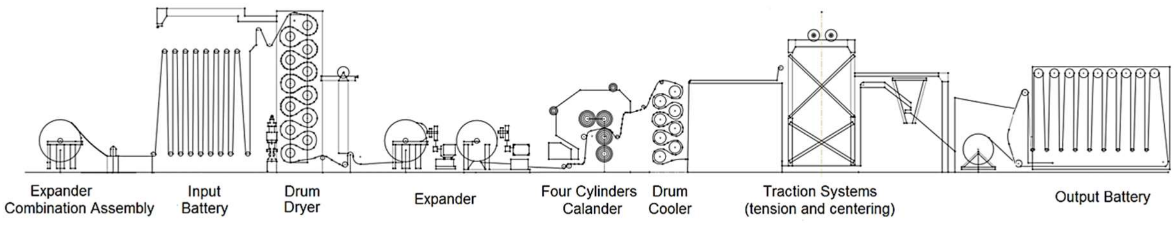

Fig. 1.1 Fabrication station technological line diagram

Source: [22]

Tension of the fabric is achieved by placing the bale along the axle on the expander in the self-closing heads (Fig. 18.1). The combination of fabrics coming from different bales is performed on the combination assembly press. It is performed in approx. 3 minutes. The assembly should withstand a pull of 5000 N. Through the tractive system, the fabric is passed to the input battery. The average speed of travel is approx. 40 m/min. Removal of moisture from the material is made using a twelvedrum dryer, steamed at 130°C. The tension of the fabric is regulated by a hydraulic cylinder during drying. Then the fabric is subjected to friction in the slit of the four cylinders calander. The rubber coating is applied by rubbing the plastic material. Ribbons of non vulcanized rubber blends, heated to 80°C, are transported from the rolling mill to the calender, using a belt conveyor. Friction adjustment is achieved by the independent drive of each roller. Reduction of the temperature of the manufactured belts to the range between 16 and 25°C is made on the drum cooler.

The final product (Fig. 18.2) is produced by vulcanization. Rubber belts and PWG belts are subjected to high temperatures (up to 200°C) on a mechanical vulcanizing press. The press plate has a size of 250x350x30 mm and the maximum pressure of the device is 4 kg/cm^2 (60 PSI). PVC belts are gelled. As a result of the performed operations, the products obtain the parameters that guarantee the protection of rim against the moisture and dust penetration. In the Vulcanization Department 35 direct production employees and 3 foremen are employed.

Fig. 18.2 Bales of transport belts with fabric cores

Source: [6], Fig.: Jarosław Galusek

The maintenance of the company's machinery is ensured by the Maintenance Department staff. They are responsible for the steam condenser systems and steam technology connections reviews organization; monitoring the measuring systems operation; operating, configuring and maintaining equipment and controls; and repairing technical equipment of the company. 44 employees are employed in the Maintenance Department, including 3 foremen [22].

18.3 RESEARCHES

18.3.1 Identification of the performance limiting factors

The OEE indicator was used to evaluate the productivity of the up to 1400 mm wide conveyor belt. Overall Equipment Effectiveness) [24, 29, 34, 36, 38]. In the research it was assumed that the cycle time necessary to produce 100 lm of the belt core with a thickness of 4 + 3 mm was 110 min. It was assumed that the work is a three-shift work. Sometimes the difference between the work time and the total downtime was called the duration of the operation. The coefficient of availability, expressed as a percentage, was defined as the quotient of the operation duration of until the station is operational. The quotient of product of the product quantity and the normalized cycle time, up to the duration of the operation was called the utilization factor [%]. The coefficient of quality [%] was assumed to be the quotient of the difference between the number of products and the number of defects arising during one shift in the given quantity of products. Total efficiency [%] was defined as the product of the availability, use, and quality coefficients.

Table 18.1 Workstation performance of the up to 1400 mm [mm] conveyor belt production process

Item	Parameter name	IU	Name of workstation			
			Rubber compound manufacturing	Fabric coating	Fabrication	Vulcanization
1.	Shift duration	min	480	480	480	480
2.	Workstation operation duration	min	435	460	460	460
3.	Scheduled break duration	min	45	20	20	20
4.	Scheduled downtime duration	min	15	5	15	15
5.	Unplanned downtime duration	min	15	20	50	10
6.	Total downtime duration	min	30	25	65	25
7.	Operation duration	min	405	435	395	435
8	Product quantity	kg	480	700	350	700
9.	Defects amount	kg	40	4	35	35
10.	Normal cycle duration	min	48	60	110	55
11.	**Availability Factor**	%	**93.10**	**94.57**	**85.87**	**94.57**
12.	**Use Rate**	%	**94.81**	**96.55**	**97.47**	**88.51**
13.	**Product Quality Factor**	%	**91.67**	**99.43**	**90.00**	**95.00**
14.	**Workstation Total Productivity**	%	**80.92**	**90.78**	**75.33**	**79,51**

Source: Own study based on [6, 37]

The lowest overall performance was recorded for the Fabrication Workstation (Tab. 18.1). Kepner's method - Tregoe [12, 17] was used to identify the workstation performance limiting factors. Analysis of the manufacturing process at the fabrication station of the up to 1400 mm wide conveyor belts production process was based on a film material showing the operator's work. Interpretation of the record made it possible to distinguish between procedures and activities and to determine their duration. The evaluation was conducted by a team consisting of Fabrication Department Manager, machine operator, OSH officer, Maintenance Department

Representative and an external expert. Due to the number and type of defects and the employee's speed of response to undesirable events, special attention was paid to the calander retrofitting. This is caused by a change in the width of the belt produced and includes the positioning of the three pairs of cutters (Fig. 18.3). The first and second pair of cutters are on the calender rollers while the third pair is located on the tensioning roller.

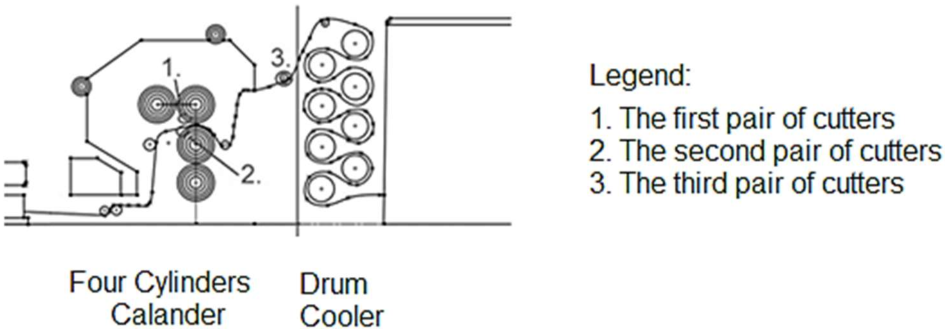

Fig. 18.3 Location of cutters

Source: [9]

Because the retrofitting procedure is always preceded by the placement of a bale along with the axis on the expander of the combining press assembly, the operator is obliged to cross the 37m route (Fig. 18.1). The operator's route runs along the technological line and ends at the level of the four cylinders calander where the fabric is subjected to friction.

18.3.2 Proposal for changes

The results of the research work, including the identification of activities for the four cylinders calander retrofitting and duration of the mentioned activities, are presented in tabular form (Tab. 18.2).

Table 18.2 List of activities for the four cylinders calander retrofitting procedure

Item	Activity	Use	Place	Description	Time
1.	Adjustment 1. pair of cutters	Carrier cover cutting	Calender	Operator transition - 37 [m] route length	27s
				Adjusting the cutter spacing to the required width	1 min 12s
2.	Adjustment 2. pairs of cutters	Running cover cutting	Calender	Adjusting the cutter spacing to the required width	1 min 14s
3.	Adjustment 3. pair of cutters	Trimming the edges of the belt after the friction operation	Tensioning roll	Operator transition - route length 4.3 [m]	12s
				Adjusting the cutter spacing to the required width	1 min 20s

Source: [22]

The preparatory and finishing works include: operator transition resulting from the place of the particular tasks execution, cutter spacing width adjustment, cutters position verification and belt cutting trial series execution. The collected data allowed us to attempt to find a solution that would reduce the retrofitting duration. The SMED (Single Minute Exchange of Dies) method was used for this purpose [1, 3, 25, 26, 28]. Transformation of the selected preparatory and final retrofitting activities from the internal into the external actions was proposed. The transformation covered the position of the first, second and third pair of cutters. Graphical interpretation of changes is presented in Fig. 18.4.

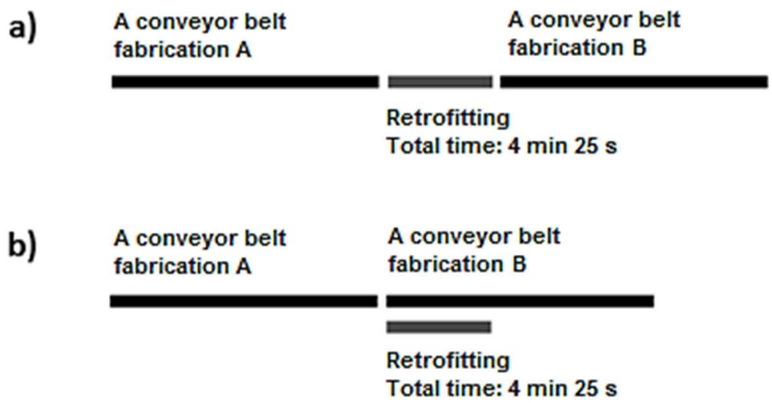

Fig. 18.4 Transforming the internal into external retrofitting
Source: Own study

The search for the reason for cutting the conveyor belt's rim into the appropriate width has led to the activities verifying and validating of the thesis indicating the inadequately adjusted setting of the cutters trimming the bearing and running covers, and the edges of the belt after the friction. As a solution that reduces the impact of the human factor and eliminates mistakes made by operators [2, 4, 10, 15, 27, 31], it was proposed to automate the method of normalizing the cutter spacing according to the requirements determining the expected width of the belt. The need for ongoing production control and the need for rapid elimination of undesirable events related to the belt rims trimming has prompted the proposal to install a monitoring for the fabrication workstation. The expander of the press combination assembly and the four cylinders calander were chosen as the place of observation by means of the installed cameras. Consequently, the application of those activities is expected to increase the productivity of the fabrication workstation.

Changes in the process of production of up to 1400 mm wide fabric conveyor belts in Conbelts S.A. Company caused the employee training need [8, 16, 31, 32]. The 5S Method [13, 21, 23] was used to develop a framework training program, including a discussion of working conditions and a presentation of how to perform the safety tasks. The training was mainly addressed at the fabrication workstation operators. In order to improve the practical skills of employees and to introduce the newly-recruited employees self-discipline, the training of a workshop character was conducted [11].

18.3.3 Solutions post-implementation evaluation

The above analysis has led to the development and implementation of the following solutions to streamline the production of up to 1400 mm wide conveyor belts:

- transforming the internal into external retrofitting;
- automation of spacing adjustment of cutters located on the calender and tensioning roller;
- installation of the work monitoring on the combination press assembly and the four cylinders calander.

The post-implementation evaluation of the workstation performance allowed for comparison of data sets obtained before and after the changes (Tab. 18.4) and for evaluation of effectiveness of the actions taken [5, 14, 18, 30, 35]. There has been an increase in the quality factor and an increase in the total productivity of the fabrication workstation. The amount of the conveyor belt produced per year, prior to the change, amounted to 252.0 km, and after the implementation of the above described solutions it amounted to 280.8 km. Therefore, the increase in production amounted to approx. 12%.

Table 18.4 Performance of the workstation of fabrication of the fabric conveyor belt up to 1400 mm width, before and after the changes introduction

Item	Parameter name	IU	BEFORE the implementation	POST-implementation changes
1.	Shift duration	min	480	480
2.	Workstation operation duration	min	20	8
3.	Scheduled break duration	min	460	460
4.	Scheduled downtime duration	min	15	15
5.	Unplanned downtime duration	min	50	50
6.	Total downtime duration	min	65	65
7.	Operation duration	min	395	407
8	Product quantity	mb	350	390
9.	Defects amount	mb	35	28
10.	Normal cycle duration	min	110	104
11.	**Availability Factor**	%	**85.87**	**86.23**
12.	**Use Rate**	%	**97.47**	**99.65**
13.	**Product Quality Factor**	%	**90.00**	**92.82**
14.	**Workstation Total Productivity**	%	**75.33**	**79.76**

Source: Own study

18.4 SUMMARY

Improving the performance of the work executed at up to 1400 mm wide conveyor belts fabrication workstation in Conbelts S.A. has been achieved by evaluating the performance of the station works and implementing organizational changes to improve the four cylinders calander retrofitting. The proposed solution of transforming internal into external retrofitting, cutter spacing automated adjustment and production recording monitoring at the combining assembly press expander and calender, enabled less than 12% increase in belt production and a 7 lm reduction in the number of defects created over one shift.

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Abstract: *The study presents the results of the research on improving the productivity of works executed of the up to 1400 mm conveyor belts fabrication workstation in Conbelts S.A. with its registered office in Bytom. Using the OEE indicator, the author conduct a performance evaluation of the work stations of the selected technology line. The results of the research have enabled us to design and implement solutions that eliminate irregularities and streamline the operation at the belt fabrication workstation. The post-implementation performance evaluation confirmed the effectiveness of the solutions taken.*

Key words: *performance, OEE, conveyor belts*

WYKORZYSTANIE WSKAŹNIKOWEJ OCENY WYDAJNOŚCI STANOWISK W DOSKONALENIU PROCESÓW WYTWÓRCZYCH

Streszczenie: *W artykule przedstawiono wyniki badań dotyczących poprawy wydajności prac realizowanych na stanowisku konfekcji taśm przenośnikowych tkaninowych do szerokości 140 mm w przedsiębiorstwie Conbelts S.A. z siedzibą w Bytomiu. Wykorzystując wskaźnik OEE autor wykonał ocenę wydajności stanowisk roboczych wybranego ciągu technologicznego. Uzyskane wyniki badań umożliwiły zaprojektowanie i wdrożenie rozwiązań eliminujących nieprawidłowości oraz usprawnienie działań realizowanych na stanowisku konfekcji taśm. Powdrożeniowa ocena wydajności potwierdziła skuteczności podjętych rozwiązań.*

Słowa kluczowe: *wydajność, OEE, taśmy przenośnikowe*