Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 55
ISSUE 2
December
2012

Quality management in enterprise using Six Sigma method

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Received 19.10.2012; published in revised form 01.12.2012

Industrial management and organisation

ABSTRACT

Purpose: The article includes characteristic of the extrusion moulding as the most popular method of the plastics processing industry. Statistical analysis and a test of explanation of cause of so-called foam collapsing in the chosen productive enterprise were presented. Six Sigma method was used to the problem solution.
Design/methodology/approach: In this paper a detailed plan for implementation of Six Sigma quality management conception in order to eliminate the collapsing effect of polyethylene foam during its cutting was showed. The detailing analysis of the polyethylene foam aging cycle (degassing) was carried out. Next the appropriate measures and procedures to eliminate collapsing foam effect were implementation.
Findings: Six Sigma leads to an effective improvement of the financial results of the enterprise by controlling and planning of a course of work to minimize waste formation and raw materials consumption. These actions make possible a greater customer satisfaction.
Research limitations/implications: In these investigations was established that a decisive influence on the quality of polyethylene foam had the first five days of the seasoning. The proper weather conditions assure obtainment of the product meeting the basic qualitative standards. It was also found that the polyethylene foam rolls which were cut directly after production they were less subject to the process of shrinkage than the rolls cut after several days since the moment of production.
Practical implications: Six Sigma is a well-chosen collection of tools which orientate to the approach to improvement and problems solution in the processes. This results the workings which characterize conscientiousness in the everyday work, maturity in the decision making, responsibility in the tasks realization, consequence in applying suitable tools and effective co-operation in the group. Six Sigma method can be used not only in the production but also in logistics, administration or in services.
Originality/value: In the article the result of the project realization is the introduction of the proper actions and procedures which should bring the improvement of the quality of finished products and financial results of the enterprise.
Keywords: Industrial Management and Organisation; Quality Management; Plastics processing industry; Collapsing effect of polyethylene foam; Six Sigma method implementation

Reference to this paper should be given in the following way:
M. Spilka, M. Sakaluk, A. Kania, Quality management in enterprise using six sigma method, Journal of Achievements in Materials and Manufacturing Engineering 55/2 (2012) 895-901.

1. Introduction

The polyethylene foam is a very good packaging solution for the surfaces which require the special protection. It is light, elastic, resistant to moisture and inactive.

The polyethylene is formed by a method of extrusion moulding consisting in extrusion of plasticized material, mixed with gas through an injection moulding nozzle which forms a ready foam shape.

In the article a statistical analysis and a test of explanation of cause of so-called foam collapsing (collapse of foam cells) in the chosen productive enterprise were presented.

Six Sigma method was used to the problem solution. The precursors of this method, M. Harry and R. Schroeder think that Six Sigma allows to a very effective improvement of the financial results of the enterprise by controlling and planning of a course of work to minimize waste formation and raw materials consumption. This leads to a greater customer satisfaction, also.

Six Sigma is a well-chosen collection of tools which orientate to the approach to improvement and problems solution in the processes [1-3]. This results the workings which characterize conscientiousness in the everyday work, maturity in the decision making, responsibility in the tasks realization, consequence in applying suitable tools and effective co-operation in the group. This method can be used not only in the production but also in logistics, administration or in services [4].

2. Characteristic of Six Sigma method

Six Sigma method is called conception, method or philosophy of the quality management. It is defined as the pro quality initiative which is based on usage of the statistical control methods, experiments planning and improvement tools in the aim of determination of variation causes in the range of all processes which are realize in the organization.

The main aim of Six Sigma conception is connecting of techniques (advanced) for statistical quality control and systematic workers training from all levels of the organization included in workings and processes connected with Six Sigma methodology [1,5,6].

The quality improvement in Six Sigma methodology goes by the starting and realization of projects which lead to quick elimination of the causes of defects occurrence resulting the quality improvement and reduction of costs [7,8].

The methods using in Six Sigma were not established once. They are still disclose, develop and improve [8]. To the basic determinants of this method one should actually number [9,10]:

1. Similarly, as in case of TQM and many other modern management trends, the most essential is concentration on customer. The key to the aim realization is a full, exhausting recognition and understanding of needs and expectations of customers including their dynamic character.
2. Second problem relates to the procedural concentration of management and the process improvement. According to Six Sigma conception procedural approach to the all areas of the enterprise is the basic success factor. The conviction of the management that the processes improvement is not the unnecessary process, but the method of building of superiority in the range of giving the effects for customers is the key change.
3. The next fundamental assumption is direction of the management process on collected data and facts. The first problem subject to precise verification at Six Sigma implementation is determination which from applied measures are the key for evaluation of enterprise functioning. The identification of measures allows to data introduction and analyses making based on which one should recognize the most important variables being in further stages the object of the optimization.
4. The fourth significant element of Six Sigma is the co-operation deprived of boundaries. The aim of Six Sigma is increasing of possibility of co-operation through the workers training in the range of a role they create in the system and also recognition and making possible the measurement of correlation of workings in all stages of processes. Six Sigma creates the managerial personnel guaranteeing the true team work.
5. The pro-active management is the next component of Six Sigma conception. It indicates the necessity of determination of aims by the managerial personnel and evaluation of accomplished progresses, determination of priorities and concentration on preventive processes. The pro-active attitude is a word of creativity and introduction of visible changes. This conception defines tools and practices control which make possible the conversion of reactive customs - the dynamic style of the management, pro-active, characterizing quick taking actions.
6. The last element contains two, apparently conflicting, recommendations: direction on perfection achievement and tolerance for mistakes. It is known, that the workers who see the possibility of improvement of the services quality, reduction of costs of usage of new possibilities, etc. they will be fear for consequences of making a mistake and they never take a risk. The stagnation, which can be the first symptom of the organization agony is the result of such attitude.

Summarizing six critical elements of Six Sigma one can notice, that the aims indicated in this method result the continuous pressure directed on achieving a greater perfection [2]. It does not exclude the possibility of appearance of sporadic complications [10].

Six Sigma method can be defined as five-stages DMAIC model. Its name derives from the first letters of English words defining the next stages of project: define, measure, analyze, improve, control. This model is based on well-known assumptions for good organized cycle of the enterprise business, in the form of "Japanese" Deming's circle, PDCA Shewhart's cycle or Kaizen method [11-14].

The next stages of DMAIC model (procedure in case of appearance of defects of the key processes in the enterprise) are following [12,15]:

1. Define. Definition of the basic aims, necessary actions improving processes and allowing to achievement a higher sigma level in the definite area of the enterprise functioning. The determination of connected with this problems and definition of the critical characteristic for quality, costs and its influence on the process.
2. Measure. The precise measuring of the key processes in the selected area, establishment and verification of the system of the precise measurement of these processes, and determination of no accepted actions/defects. The initial selection of the large number of the numerical data necessary to analyzing with usage of well-known tools and statistical methods.

3. Analyse. The statistical analysis of data and results including the possibilities of documentation of the actual way of action of the analysed key processes. Finding of the factors influencing on defined critical characteristic for quality, costs and defects cause.
4. Improve. Taking of proper procedural actions and usage of a new, creative methods of eliminating of defined defects in the aim of bringing the products to desirable values and achievement of standard results.
5. Control. Monitoring and controlling of accepted solutions of a new system and attained results, and assurance of these solutions constancy.

3. Production process of polyethylene foam in the enterprise

Polyethylene foam produced in the analysed enterprise can be divided into three main groups: protective polyethylene foam, construction polyethylene foam and technical polyethylene foam. The first group includes the foam with thicknesses 0.8-1.5 mm, width 1.25-2 m and density 20-19 kg/m^3. The next group is construction foam with thicknesses 2-6 mm and density 18-17 kg/m^3. The foams in the range 2-3 mm are produced with width of protective foams while the foams 4 mm; 5 mm and 6 mm with 1.25 m width only. The last group consists of technical foams with thicknesses 8-15.5 mm, width 1.3 m and density 23-35 kg/m^3.

Each of above mentioned foams can have any colour and antistatic properties also, moreover the protective and construction foams can be produced with different densities. The length and width of the foam rolls are an individual matter of the customer. The maximum length is limited by technical possibilities of winding machine, while the maximum width is limited by diameter of the put mouthpiece/nozzle.

The foam production can begin after obtainment in the machines of the appropriate temperature such as 150-180°C. The temperature 180°C is required in a dosage zone of material in which takes place a pre-plasticising of plastic. The other zones of the extruder including the head are warmed to the temperature about 150°C. Preheating process of the extruders takes 6 hours approximately. After obtaining the above mentioned temperature the extruder is starting, dosage of polyethylene and additives are started. Polyethylene dosed into the extruder melts under the influence of the high temperature. Liquid polyethylene is transported toward the side of the mouthpieces of the head by the screw or screws located inside the extruder.

Temperature of the mass in the production process is on the level 100-110°C. To extruders in which is a liquid polyethylene injected the gas (isobutene) under high pressure. After precise mixing of the gas with liquid polyethylene obtained the homologous mixture which gets outside through the small slit in the head called the mouthpiece. It rapidly expanded and foam is formed. Between the extruder and the head is located a device called a sieve changer. Its main objective is purification of the foaming material of any kind of contamination as well as formation of required pressure in the extruder by using special sieves with mesh density dependent on the thickness of the foam produced. At the moment of the foam extrusion from the mouthpiece the majority of gas input is released from the foam.

This process takes place in tunnels of the production technological lines which are heavily ventilated. The gas and air mixture formed in the production tunnel is extracted and placed by the emitter to the atmosphere. A little quantity of gas remains in the foam. After squeezing from the head the foam is stretched for a special device called a mandrel on which takes place the cooling water of the foam and blowing by air.

Under the mandrel is rotating knife which cuts the foam on the ribbon. After cutting, the foam is transported in the production tunnel in the direction of the horizontal production winder which winds the foam ribbon in the finished product which is the foam roller. Then the control of thickness and width of the roller is carried out. Next the visually and tactile estimation according to the quality are carried out.

The next process is a seasoning of the polyethylene foam, which takes place at the designated area equipped in ventilation. During seasoning, butane contained in the foam gets out from cells of the foam and its place is taken by air. This process takes place as a result of influence of the special additives. The gas released during seasoning is exported by the emitter to the atmosphere. After 24 hours the polyethylene foam roll is packed in the bags and transported by conveyor belt to the store as a finished product.

4. Course of Six Sigma project in the analysed company

Six Sigma project was carried out in order to eliminate the problem of uncontrolled shrinkage of the polyethylene foam as a result of the cut, negatively influencing on the quality of the product. According to Six Sigma concept, the project consists of five stages (Define - phase of problem definition and scope of project, Measure - phase of reliable data collecting, Analyse - phase of data analysis and validation of hypotheses, Improve - phase of finding of the most effective solutions and their implementation, Control - monitoring and closure phase of project).

Stage I - Define

In the project was established a list of factors which can influence on the foam contraction process (Table 1) and the schedule of data collection was elaborated.

As a result of the further analysis of factors decided that foam density and foam degassing were excluded from the project, due to the lowest number of received points.

According to the schedule, produced a batch of polyethylene foam rolls with different parameters, which were placed in a designated area of a store, and after 3 days they were cut to the 0.5 m width.

Stage II - Measure

Then, measurements of length and weight of each cut roll, the ambient temperature and humidity for the next eight days of the project realization were taken.

The first batch - 6 rolls of the foam about dimensions 3.0 mm × 0.5 m × 175 m were subjected to seasoning in the following ambient conditions: air humidity 21-56% and temperature 14.1-20.6°C. The changes of the polyethylene foam parameters are shown in Figures 1, 2.

Table 1.
Selected factors influencing on shrinkage process of the polyethylene foam

(1-small, 3-medium, 5-large)	Influence on result	Change facility	No influence on Lead Time	Low costs	∑	Measurement method
Pressure on sieves before the changer	3	5	5	3/5	16/18	Readings on machine
Foam density	3	1	5	1	10	Weight/cubage scaler
Material temperature (changer)	3	3	5	5	16	Readings on machine
Ambient temperature (tunnel, winding machine, store)	5	1	5	1	12	Thermometer
Ambient humidity (tunnel, winding machine, store)	3	1	5	1/3	10/12	Hygrometer
Foam degassing	1	1	1	1	4	Rolls weight/ concentration meter
Pressure on winding machine forks	3	5	5	5	18	Winding machine monitor

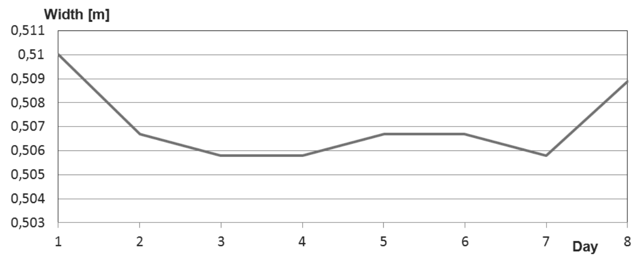

Fig. 1. Change of foam roll width during 8-day of seasoning cycle

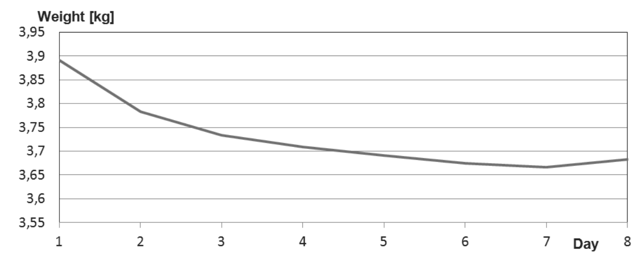

Fig. 2. Change of foam roll weight during 8-day of seasoning cycle

The second batch - 6 rolls of foam with dimensions 0.8 mm × 0.5 m × 700 m were subjected to seasoning in the following ambient conditions: air humidity 25-47% and temperature 15-21.7°C. The changes of the polyethylene foam parameters are shown in Figures 3, 4.

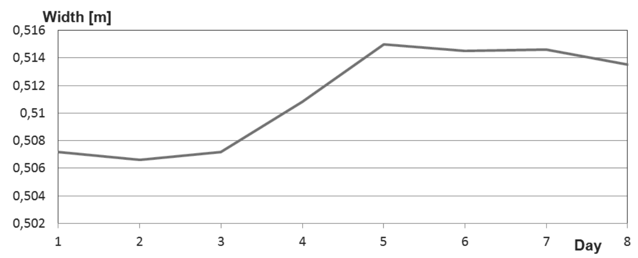

Fig. 3. Change of foam roll width during 8-day of seasoning cycle

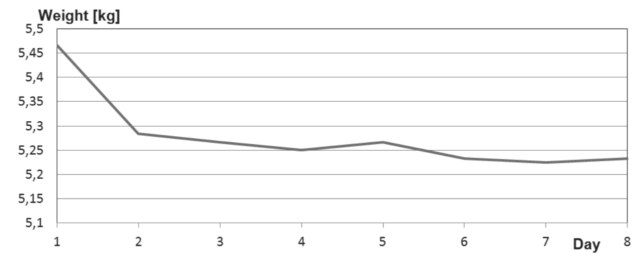

Fig. 4. Change of foam roll weight during 8-day of seasoning cycle

The third batch - 6 rolls of foam with dimensions 5.0 mm × 0.5 m × 100 m were subjected to seasoning in the following ambient conditions: air humidity 25-42% and temperature 15-19.6°C. The changes of the polyethylene foam parameters are shown in Figures 5, 6.

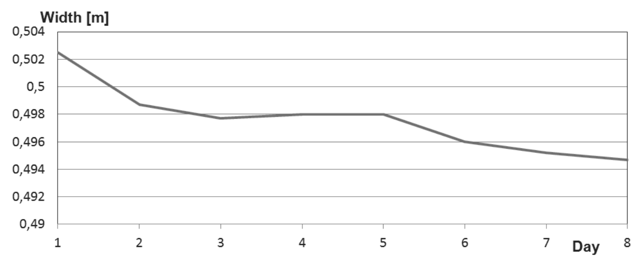

Fig. 5. Change of foam roll width during 8-day of seasoning cycle

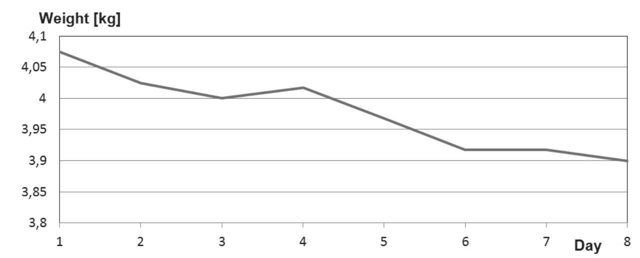

Fig. 6. Change of foam roll weight during 8-day of seasoning cycle

Another batch - 9 rolls of foam with dimensions 0.8 mm × 0.5 m × 700 m were subjected to seasoning in the following ambient conditions: air humidity 19.7-43.6% and temperature 16-24°C. The changes of the polyethylene foam parameters are shown in Figures 7, 8.

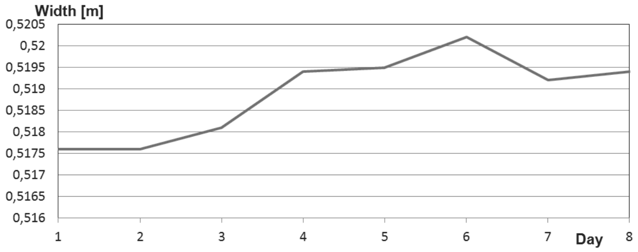

Fig. 7. Change of foam roll width during 8-day of seasoning cycle

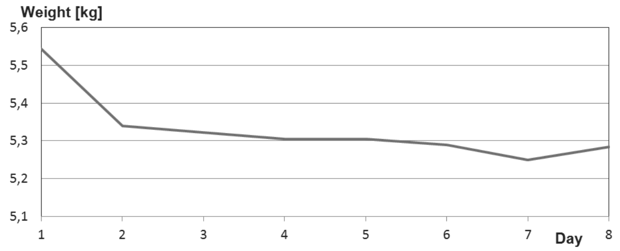

Fig. 8. Change of foam roll weight during 8-day of seasoning cycle

The last batch - 9 rolls of foam with dimensions 1.0 mm × 0.5 m × 500 m were subjected to seasoning in the following ambient conditions: air humidity 31-42% and temperature 15.8-22.8°C. The changes of the polyethylene foam parameters are shown in Figures 9, 10.

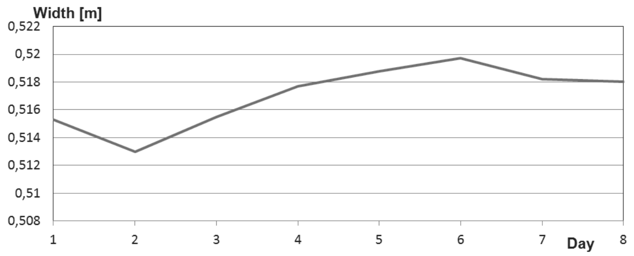

Fig. 9. Change of foam roll width during 8-day of seasoning cycle

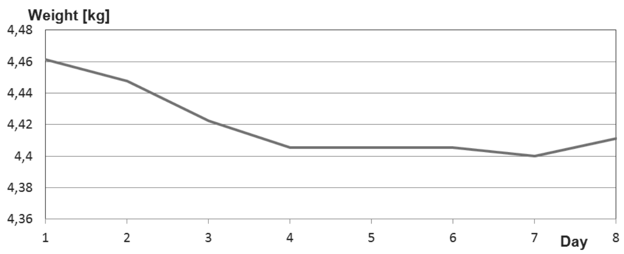

Fig. 10. Change of foam roll weight during 8-day of seasoning cycle

After completion of data collection chosen rolls from each batch were cut in order to measure thickness and width of the foam. The measurements of the rolls length were also carried out. It was found that in each case the foam which was near the sleeve characterized a lower quality than the foam on the outside of the roll.

Stage III - Analyse

The analyse of all collected data allowed to submit the following proposals:

- the course of the foam collapsing process is similar in all the foams of different sizes;
- in case of the protective foams there occurs increase of width of external layers of the polyethylene foam with following days of seasoning. Then the foam width stabilized and the quality of the foam is not significantly deteriorated. In case of layers being inside the roller and near the sleeve, there follows a rapid deterioration of the foam quality (it becomes soft) and there is a large loss of width. The foam from these places do not meet the standards of quality and dimensional tolerances;
- in case of the construction foams there occurs a gradual reduction of width of the polyethylene foam both the outer layers, central layers and layers being directly near the sleeve, with following days of seasoning. The layers inside the rollers as well as those near the sleeve are characterized by loss of quality. The loss of width, as well as the deterioration of quality, do not give the bases for considering these rolls as the products which don't meet the quality standards and dimensional tolerances in the analysed enterprise in force;
- both the protective and construction foams during the first few days of seasoning there occur the weight reduction of the rollers, and then the rollers weight is stabilizing;
- thickness of the foam in both groups is gradually decreased with the following layers of the foam inside the rolls;
- length of the foam rollers in both groups changed, while in case of the construction foam the length of rolls increased whereas the length of the protective foam roller decreased.

Despite of the lack of conclusive evidence of factors impact like ambient temperature and humidity on the foam collapsing process, it was decided that the stage of data collection will be carried out again. It was established that the measurement will be carried out for protective foam, because the seasoning process causes significant deterioration of their quality. The factors - ambient temperature and humidity will be monitored, and the measurement will be related only to width of the rollers without their weight. In order to obtainment of changing climatic conditions for the given batch, designated on the production plant three zones, in which the foams will be seasoning: "store - centre", which probably characterized the most stable climatic conditions, "store - loading gates", probably the average stable climatic conditions and "store - outside", probably highly unstable climatic conditions. The rollers will be cut immediately after production, to actual production conditions assurance.

Stage II' - Measure

According to the schedule, produced batch of polyethylene foam rollers which was placed in the designated store zones.

On the basis of the collected data the charts were elaborated. On the charts a change of width (Figs. 11, 13, 15) ambient humidity and temperature (Figs. 12, 14, 16) in the next days of the foam seasoning process were presented.

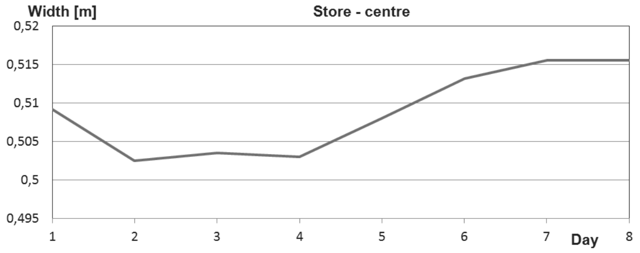

Fig. 11. Change of foam roll width during 8-day of seasoning cycle

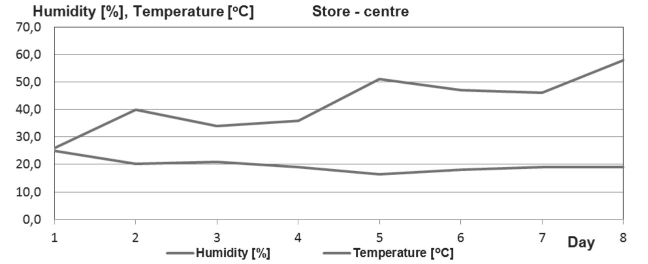

Fig. 12. Change of humidity and ambient temperature during 8-day of seasoning cycle

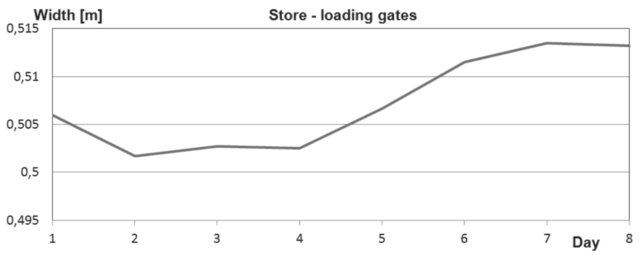

Fig. 13. Change of foam roll width during 8-day of seasoning cycle

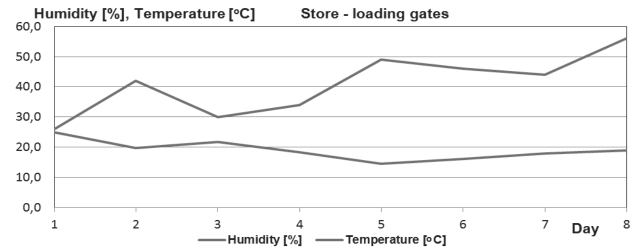

Fig. 14. Change of humidity and ambient temperature during 8-day of seasoning cycle

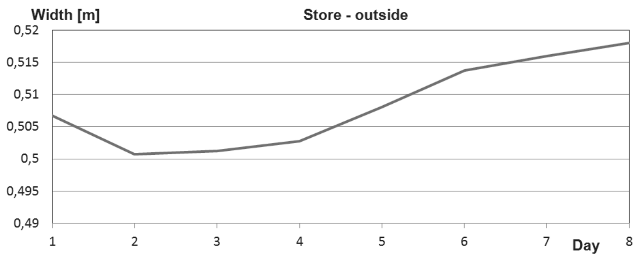

Fig. 15. Change of foam roll width during 8-day of seasoning cycle

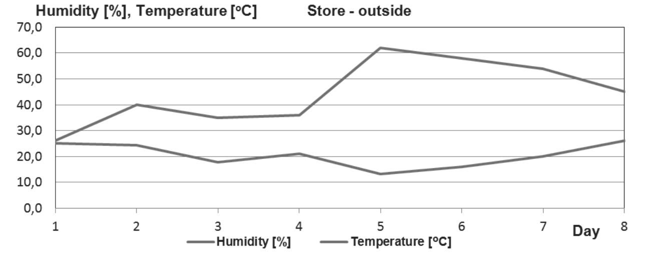

Fig. 16. Change of humidity and ambient temperature during 8-day of seasoning cycle

Stage III' - Analyse

The analyse of all collected data allowed to submit the following conclusions:

- climatic conditions in three designated zones were diverse, what confirmed the measurements of ambient humidity and temperature. The most stable conditions were noted in the "store - centre" zone, average temperature 19°C; average humidity 45%. Then in the "store - loading gates" zone average temperature 15.4°C; average humidity 43%, however the least stable climatic conditions were in the "store - outside" zone, average temperature 19.7°C; average humidity 47%;
- width of the rolls were the least variable in the "store- centre" zone (the difference between the foam outside and the foam near the sleeve was 10 mm). Then in the "store - loading gates" zone (the difference between the foam outside and the foam near the sleeve was 14 mm); however the most variable in the "store - outside" zone (the difference between the foam outside and the foam near the sleeve was 22 mm);
- the best quality of the foam was noted in the "store - centre" zone; worse in the "store - loading gates" zone, while the worst in the "store - outside" zone;
- collected data show that the most important factor influencing on the foam collapsing process is the ambient temperature. The temperature does not have to be high ("store - outside" zone) but stable ("store - centre" zone). The constant temperature assurance which oscillating about 19-20°C it causes reduction of the collapsing effect of the polyethylene foam;
- from the available data it doesn't follow that the factor like ambient humidity has a significant influence on the foam collapsing process. However we can suppose, that similarly as in case of the ambient temperature, the stability of the ambient humidity can influence in the positive way on the foam quality.

Stage IV - Improve

As a result of the analysis of collected conclusions following actions in order to limitation of the collapsing process of the polyethylene foam were undertaken:

- protective foams, if it is possible, they have to be cut directly on a reeler. When the cut is not possible on the reeler directly, the foam has to be immediately cut after it left the reeler;
- in the "store - centre" zone there will be appointed the place in which protective cut foams will be stored only;
- in the "store - centre" zone the thermometers and the hygrometers in order to measurement of actual temperature and humidity will be installed. It was established that the temperature should oscillate about 20°C, and humidity about 40%;

- in the autumn - winter period the “store - centre” zone will be equipped in additional heating devices in order to ensure of the proper temperature. In case of improper humidity in the zone air sprinklers will be installed.

Stage V - Control

The last stage of the project related to monitoring of the seasoning zone of the foam rolls included in Six Sigma project, and the cut rolls, also. It was established that a person from the technology section will control every day the seasoning zone in order to measurement of actual temperature, humidity and quality of the cut foam rolls being there.

5. Conclusions

As a result of the realized project it was established that a decisive influence on the quality of polyethylene foam had the first five days of the seasoning. The proper weather conditions (stable ambient temperature and humidity in the place of storing of the seasoning foam) guarantee obtainment of the product meeting the basic qualitative standards. Moreover, it was found that the polyethylene foam rolls which were cut directly after production they were less subject to the process of shrinkage than the rolls cut after several days since the moment of production.

The result of the project realization is the introduction of the proper actions and procedures which should bring the improvement of the quality of finished products and financial results of the enterprise.

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