БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES

ПРОБЛЕМИ НА ТЕХНИЧЕСКАТА КИБЕРНЕТИКА И РОБОТИКАТА, **67**
PROBLEMS OF ENGINEERING CYBERNETICS AND ROBOTICS, **67**

София • 2016 • Sofia

Experimental study of furnace temperature for metallization of polypropylene

Part I. Production temperature analysis of a furnace for metallization of polypropylene and establishment of methodology for experimental study.

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Abstract: *In the presented paper analysis of metallization of polypropylene is made. Attention is paid to polypropylene films. An automatic metallizing machine is investigated, methodology for experimental study is established.*

Keywords: metallization, polypropylene, automation

1 Introduction

The improvement of the capacitors technology is driven by the increasing electrification of the modern world. A quick switch to hybrid and pure electric

technologies is required to improve the low voltage capacitors, so necessary for automatic production of electro-efficient and compact portable appliances in the areas of communications, medicine, power electronics etc.
The capacitors are widely used in forming a newly established industry which is supposed to satisfy the constantly growing desire for energy saving and finding alternative energy sources. This industry includes the development and production of wind turbines, solar systems, and hybrid systems.
Increased requirements towards the parameters and the quality of the capacitors, given the expanding field of application, the need for reduction of their cost, and hence the final price because of increased competition in the sector are factors that make the topic of technology particularly relevant in this type of production.
The object of this work is to make a production temperature analysis of a furnace for metallization of polypropylene and to propose a methodology for experimental research.

2 Metallization of polypropylene

Even after its opening in 1876 the main capacitor technologies are constantly improving. At present, the fight for market share is based on impregnated polymer films (high voltage and low current), metallized polypropylene films, ceramic materials and electrolytes.
Polypropylene along with PET is suitable for capacitors operating at low voltage with a thickness less than 3μm.
The following materials are used for metallization of polypropylene films: Silver - Ag, Zinc – Zn, and aluminum - Al. The metallization itself is carried out at evaporation temperatures of the above mentioned metals in a vacuum installation. [1, 2, 3, 7, 8, 9]. Typical for these metals are their good dielectric properties, good ductility and elasticity, as well as low pressure and good adhesion.
The metallization of polypropylene is carried out on special automatic metalizing machines (MAM), which require a periodical experimental study of the operating temperatures to guarantee the uniform distribution of the three metal components.

3 Automatic metalizing machine

Fig. 1 shows the structure of the automatic metalizing machine (MAM). It consists of four main modules. Module 1 is the power unit. It comprises power supply, hydraulic and pneumatic equipment, vacuum pumps, cooling and part of the control system.
Module 2 is a vacuum chamber, and Module 3 is a drive unit. The latter is equipped with gearboxes, driven by electric motors, compensating, leading, winding and other shafts. Module 4 is a console. It is equipped with a monitor, computer, and programs which provide the technological metalizing process.
Fig. 2 shows the locations of the modules 1 and 3 inside the module 2. At the section A-A is shown the position of parts of the module 1 into the vacuum

chamber as follows: a heating body 1.1; aperture 1.3; a heating set 1.4; aperture 1.5; heating unit - ceramic tile 1.6; aluminum wire supply unit 1.7; pulley 1.8.

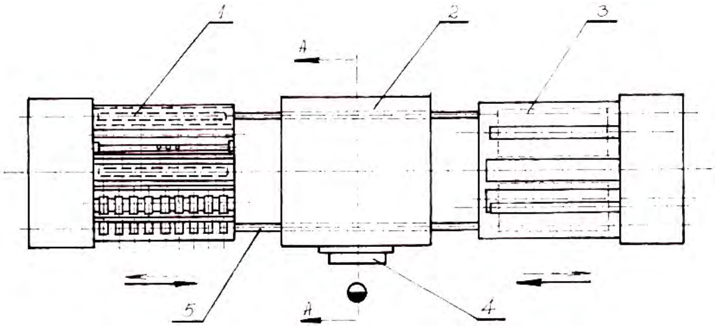

Fig. 1. Structure of automatic metalizing machine.

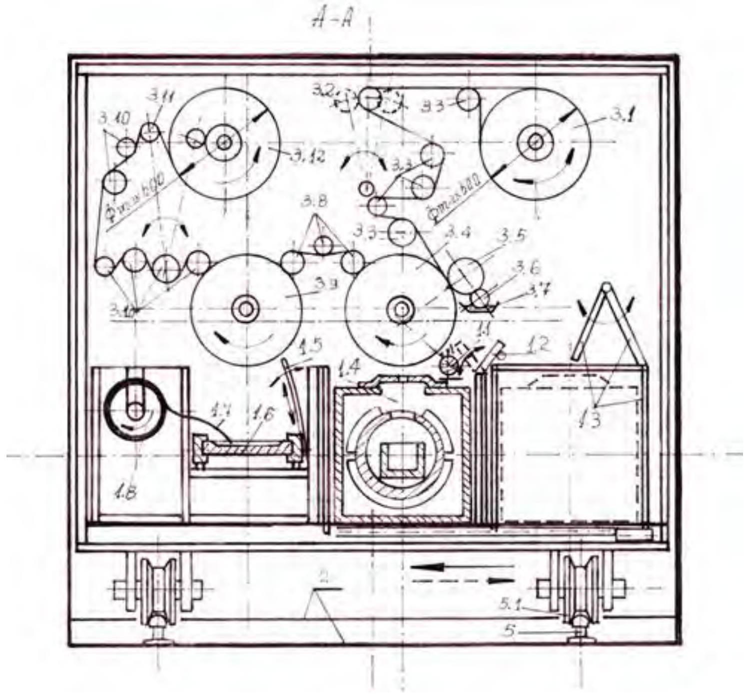

Fig. 2. Locations of the modules 1 and 3 inside the module 2.

Module 3, which is the drive unit, comprises gearboxes driven by servomotors as well as the following elements: unwinding shaft 3.1 which supports the roll of polypropylene; compensating shaft 3.2; leading shafts 3.3; leading drum 3.4; rollers 3.5; feed rollers 3.6; oil basin 3.7; pressing leading shafts 3.8; leading drum 3.9; leading shafts 3.10; clamping shaft 3.11; winding shaft 3.12.

Setting Modules 1, 2 and 3.

The normal process flow requires certain settings. First the power supply unit - module 1 is switched on, followed by the heating units 1.1, 1.4, and 1.7. The next step is to load module 3 - motor unit. The polypropylene roll is mounted on the shaft 3.1. Than starts the process of unwinding the polypropylene according to the following scheme: compensating shaft 3.2, leading shaft 3.3, leading drum 3.4, pressing leading shafts 3.8, leading drum 3.9, leading shafts 3.10, clamping shaft 3.11, and a final attachment at the shaft 3.12, observing strictly the direction of transport.

The next step is setting the width of the metalized polypropylene film, corresponding to the width of a standard capacitor. This involves the use of rollers, covered by oil type "FOMBLIN", and rolling on the polypropylene film. The oil prevents deposition of metal, and thus the wide polypropylene tape is divided into several narrower bands which are already metalized.

Next is the preparation for loading the heating bodies with silver (Ag), zinc (Zn) and aluminum (Al).

Fig. 3 shows the three heating units. The heater body 1.1 is made of nickel-chrome alloy (fig.3 a) and has the following dimensions: d = 13mm and L = 1400mm. 63 holes with a diameter of 6 mm and depth of 5mm are drilled in 1.1 and are being consecutively loaded from a piece of silver with a diameter of about 2mm and then covered with aperture 1.2.

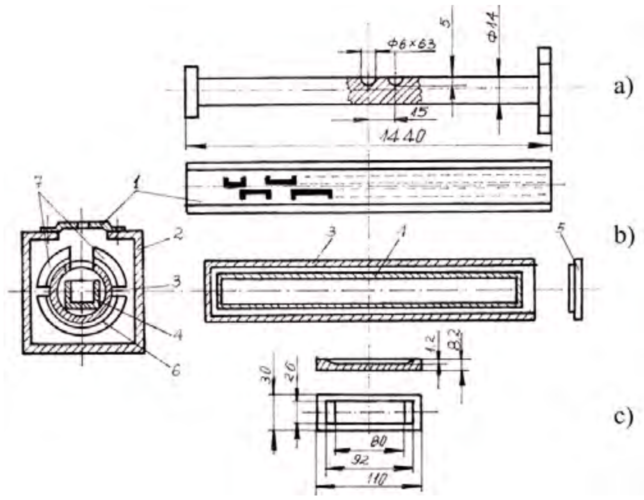

Fig. 3. Heating body unit for silver (Ag), zinc (Zn) and aluminum (Al).

The next heating unit 1.4 is designed to melt the zinc. It consists of a metal box 2, in which the following elements are integrated: the metal tube 3 tightly covered with three heating units 6 and 7. In the gap between the heaters and the metal box an insulating material is inserted. After the vessel 4 is being loaded with a zinc rod, it is inserted into the metal tube 3 and then sealed by the cap 5. The metal tube has a longitudinal gap with a cross section corresponding to the gap of the vessel 2, required for the evaporation of the zinc. On top of the metal box 2 is fixed mask 1 (fig.3 b). The mask in the middle are cut open lengthwise specialized meeting the standard condenser widths longitudinal holes at the beginning and end are issued small side lateral openings. The masks are eight in number and are designated as follows H25; H34; N37,5; H50; H55; N75; N100 and N110.

The last heating unit is ceramic tile 1.6, fed with aluminum wire 1.7. The ceramic tile is moved through the roll 1.8 which is driven by a servomotor (Figure 3 c). It has dimensions of 30mm x 110mm and thickness δ = 8,2 mm. The aluminum is melted in a gap on the tile with dimensions 26mm x 92mm x1.2mm. After carrying out 14 to 18 metallization cycles, ceramic tiles are replaced with new ones.
After loading and setting all the modules, the operator moves the module 1 in the vacuum chamber (module 2) by means of rollers 5.1, running on rails 5, until it triggers the limit switches. Then the same operation is performed by module 3.
Module 2 is equipped with six vacuum pumps, working in two sets. Each of the sets comprises two rotor pumps and one diffusion pump.

Working process

From the control panel (Module 4), the operator successively switches the following modules on:
1. The two groups of vacuum pumps;
2. Drivers of the polypropylene tape at a speed V = 4m / min;
3. Temperature increase of the heating bodies 1.1, 1.4, and 1.6;
4. Intensive cooling.

The attainment of a vacuum in the range of $2.3.10^{-4}$ mili bar, takes 22min. During this time, the evaporation temperatures of each metal have reached the following values: silver - 1030ºC; zinc - 715ºC; aluminum - 608ºC.
After realizing the requirements of all factors on the metallization technology, the speed of the polypropylene tape is increased up to 800 – 1200 m/min. At this point apertures 1.2, 1.3, and 1.5 are being simultaneously opened. The heating unit 1.4 is moved to a cell which has already evaporated zinc. It is possible now in the vacuum environment to obtain an adhesion on the surface of the polypropylene and application of the vaporized metal is launched in the following sequence: silver, zinc and aluminum.
The average time for metallization is 27min. The process itself requires a constant monitoring, although it is fully automated. If some problem occurs, an operator intervenes. Upon completion of the process, the heating bodies power supply must be suspended, the reduction of their temperature is accelerated by water cooling, the vacuum pumps are stopped, the movement of the already metalized polypropylene film is also ceased, module 2 is unsealed, and the eject mechanisms for module 3, module 1, and module 2 are triggered. At the end the already metalized film is removed from the winding shaft 3.12.

Cleaning of the MAM

The necessary total time for quality cleaning of the MAM after the metallization is an important factor. The completion of the whole production process requires the following basic operations: preparation for loading with raw materials; installation and adjustment of the mask; switching power supply on; launch of the heating units; loading the heating units with silver, zinc, aluminum; loading polypropylene and adjustment of module 3; adjusting the rollers, which apply FOMBLIN oil on

the polypropylene film; moving the module 1 and then module 3 towards the vacuum chamber(module 2); locking the three modules 1, 2 and 3.
The necessary time to complete the production process is structured as follows:

- selection and setting of a control program - 75min;
- time to reach the necessary vacuum - 22min;
- metallization of polypropylene - 27min;
- cooling down the furnace, release, and removal of the metalized polypropylene roll - 2-3 hours.

The necessary machine service time is structured in the following way:

- technological process accomplishment – 40%;
- cleaning – 60%.

A subject of a thorough cleaning are:

- the furnace of module 1, especially the heating units, the apertures, and the cooling units;
- the whole inner side of the vacuum chamber;
- all the shafts, drums, rollers, and inner surfaces of module 3.

Cleaning the machine is very important when trying to achieve a good quality of the metalized polypropylene.

4 Establishment of a methodology for the survey

The methodology is consistent with the process and the operations that are performed during metalizing polypropylene in an automatic metallization machine. The experimental study of the heating units temperatures and the temperature changes take place in the "furnace" of MAM in operating conditions.

1. The object of study is an adjustable metalizing machine for polypropylene films.
2. Determination of factors, parameters and their correlations, affecting the quality of the metalized polypropylene films.
3. Purpose of the study: examination of the relationships of the factors, influencing the temperature attained by heating units in the furnace of MAM in metalizing polypropylene films.
4. Conditions and apparatus used to carry out experimental research.

Experimental studies were carried out in the metallization workshop on a MAM type TIRO 970 - 4L1SBSO ANN AP RILE 1990 METALLATOREMOC Nome CAMS: MET1 situated in the town of Kyustendil, and equipment of IICT BAS including:

1. Thermal infrared camera FLIR P640 with the following specifications:
   - infrared detector - 640x480;
   - thermal sensitivity - 0,06ºC;
   - picture in picture (thermal + normal image)
   - wireless control via WLAN;
   - laser for precise orientation;
   - temperature range of -40 ºC to 120 ºC; 0 ºC to 500 ºC; 300 to 2000 ºC;

2. Digital Camera OLYMPUS Stylus SP820 40x optical zoom, 22,4mm wide-angle view and a 14 megapixel CMOS sensor.
3. Resistance measuring device used to measure the resistance of the film (the different paths of the film) on a distance L = 500mm with a measurement range from 7,1 Ω to 8,2 Ω.
4. Eight standard masks for standard capacitor widths - H25; H34; N37,5; H50; H55; N75; N100 and N110.
5. Caliper with vernier accuracy 0,02mm.
6. Indicator with an accuracy of 0,02mm.

Conclusion

A profile of the process for metalizing a polypropylene film is made, which is applicable to the manufacturing of film capacitors. The paper also analyzes the structure of an automatic metallization machine, its power settings, workflow, and quality of cleaning at the end of the working cycle. An analysis of the heating units which are mounted in the metalizing furnace is carried out and a methodology is proposed for conducting research and assessment of the relationships of the factors, influencing the temperature attained by these heating units.

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Acknowledgments
The research work reported in the paper is partly supported by the projects funded by the Young Scientists Grants, reg. No 96/2016

Экспериментальное исследование температуры печи для металлизации полипропилена

Част I. Температурный анализ металлизации полипропилена и установление методики экспериментального исследования.

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Тодор Нешков, Любен Клочков

Резюме

В представленной работе производится анализ металлизации полипропилена. Особое внимание уделено полипропиленовых пленок. Исследована автоматическая машина металлизации, установлена методика экспериментального исследования.