

## Experimental study of furnace temperature for metallization of polypropylene

### Part II. Temperature differences analysis in heating unit for silver metallization of polypropylene

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**Abstract:** *In the presented paper an experimental study of heating unit is made. Results of the study are provided. The results from the study are investigated and analyzed.*

**Keywords:** metallization, polypropylene, automation, thermography.

### 1 Introduction

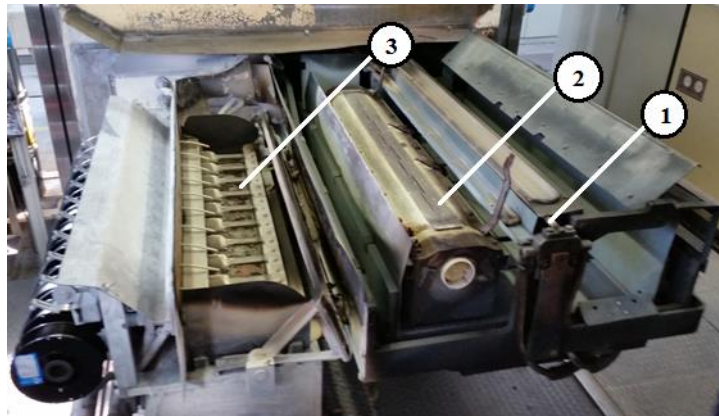
The technical implementation methodology from Part I was used for investigation of the temperatures in furnace for metallization of polypropylene in automatic metalizing machine.

The object of this work is the analysis of the temperature differences in heating unit for melting and vaporization of silver during metallization of polypropylene.

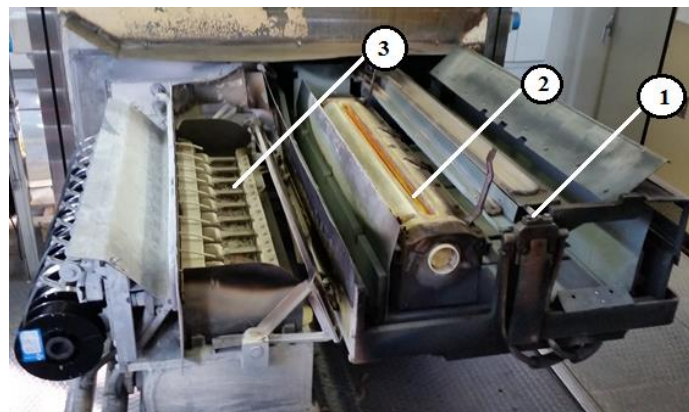
## 2 Technical realization

Experimental study is carried out on basis of the methodology presented in Part I. Using a thermal infrared camera FLIR P640 the temperature differences were measured.

The study was performed immediately after depressurization of the vacuum chamber (module 2) and sequential withdrawal movement to the starting position of the module 3 and then to the module 1. Figure 1 shows the construction of the furnace and location of heating bodies, diaphragms for covering their cooling pipes, components and propulsion systems, masks and other elements of the module 1.



a) Heating unit for zinc with mask (2)



b) Heating unit for zinc without mask (2)

**Fig. 1.** Furnace with heating units of module 1: 1 – silver heater, 2 – zinc heater, 3 – aluminum bathtub.

The measured temperatures of the heating body 1 for melting and evaporation of silver are sequentially captured, shown in Fig. 2, Fig. 3 and Fig. 4.

### 3 Results of the measurements

The obtained results from the methodology used for experimental studies (Part I) and data from the measurements of temperatures and temperature differences are filled in Table 1 of a heater 1 for silver.

Hence the entire heater unit 1 is very long, it is necessary to capture three longitudinal thermal images in order to obtain detailed pictures. The images are shown in Fig. 2. a), Fig. 3. a) and Fig. 4. a). To each image, a corresponding graph of measured temperatures is shown in Fig. 2. b), Fig. 3. b) and Fig. 4. b).

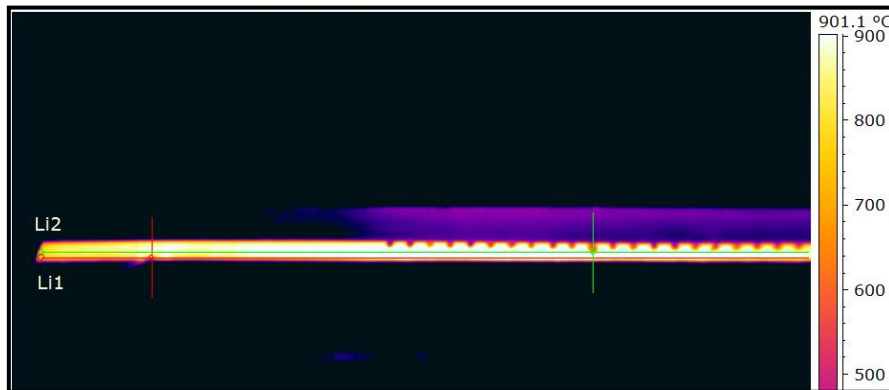
Vertical columns 4, 5 and 6 show the reported temperatures values: peak, Tmin, Tmax. Tmax-Tmin. The temperature difference averages (Avg) are presented in column 7 and 8. Horizontal rows 1 to 7 show measured temperatures of longitudinal thermal image of lines Li, i.

**Table 1.** Temperatures of heating unit 1.

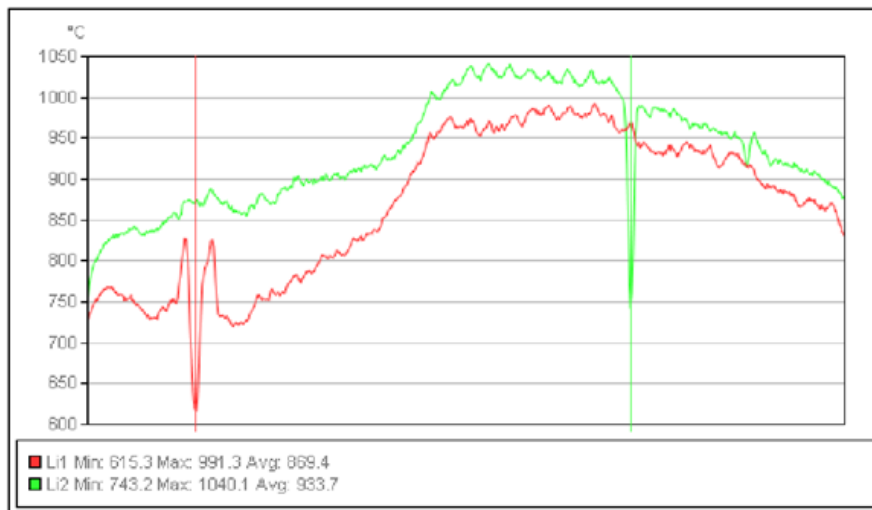
№	Figure	Graphics	Measured values of temperature differences [T°C]				
			peak	Tmin	Tmax	Tmax -Tmin	Avg
1	2	3	4	5	6	7	8
1	2 b	Li 1	615,3	615,3	991,3	376,6	869,4
2		Li 2	743,2	743,2	1040,1	296,9	933,7
3	3 b	Li 1	901,1	715,7	901,1	185,4	799,1
4		Li 2	854,6	791,7	955,8	164,1	890,2
5		Li 3	609,9	604,5	934,6	326,7	861,0
6	4 b	Li 1		559,4	985,2	425,8	879,4
7		Li 2	662,0	544,0	972,8	428,8	870,7

### 4 Analysis of the results

Fig. 2 a) represents the longitudinal thermal images of: Li 1 line. The line is more remote from the center of the heating unit 1, while line Li2 is almost in the center of the heating unit 1. This is evident in the presented graphical measured temperature differences (Fig. 2 b). In this section, the outlines are dark yellow. In mid-length of line Li 1 the temperature reaches 991,3° C. The peak of line Li 2 is 743.2° C and peak of Li 1 is 615.3 ° C. This is due to sludge, which is obtained by vapor and burns of metal in the furnace as well as from drops of silver over the heating unit 1. It is obvious that the temperature along the heater unit is variable, it is not constant. At the beginning of the heating unit it is lower, because it is closer to the cooling installation, to the protected part of the furnace and aperture.



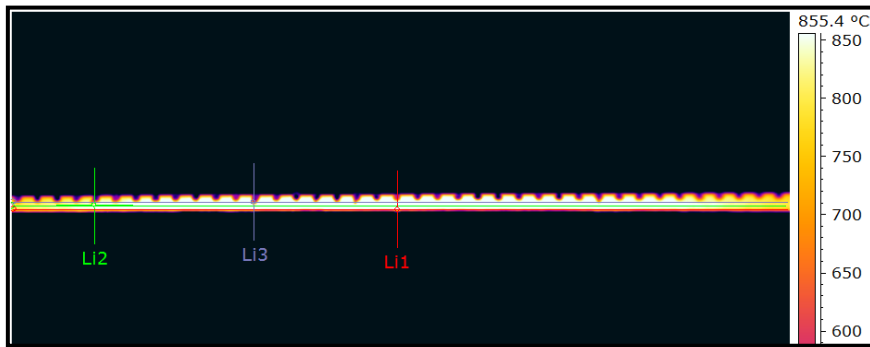
a) Thermal image



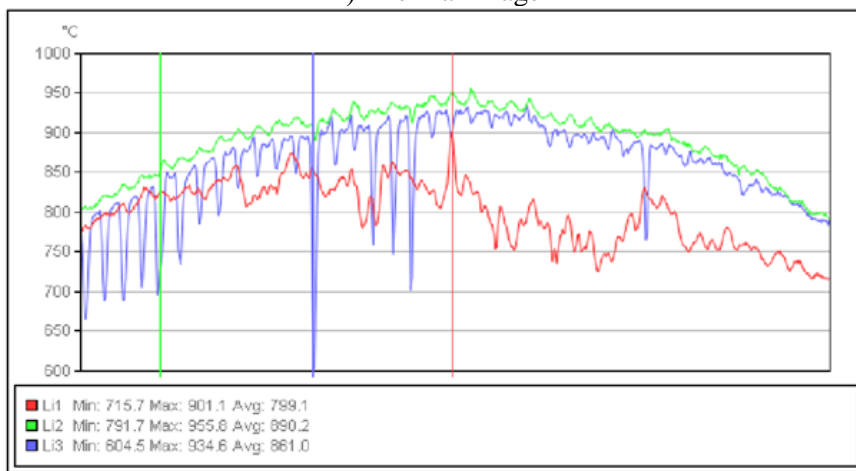
b) Graphics

**Fig. 2.** Captured temperatures at the start point of heater unit 1.

Fig. 3 a) shows a thermal image of longitudinal lines Li, i and plotted temperature differences which are more similar (Fig. 3 b). Fig. 3 shows almost the entire length of the heating unit 1. Temperature peak on line Li 1 is  $T_{max} = 901,1^{\circ} \text{C}$ . In the middle of the graph there is a distance of the two other lines Li 2 and Li3. The line Li 2 -  $T_{max} = 955,8^{\circ} \text{C}$ , there is a small peak at the beginning in  $T_{min} = 854,6^{\circ} \text{C}$ , indicating that the temperature of the silver has begun to melt into the keel of the heating unit 1. The line Li 3 is located between the lines Li 1 and Li 2, shown in Fig 3 a) of the longitudinal thermal image. The plotted measured temperature differences (Fig. 3 b). Initially a uniform peak can be observed, which fades after the medium, it becomes smooth and merges with the line Li 2. At both ends of the heating body, the yellow color is darker, while in the middle of the investigated object is much lighter. Here again is available a sludge of silver drops in heating unit 1.



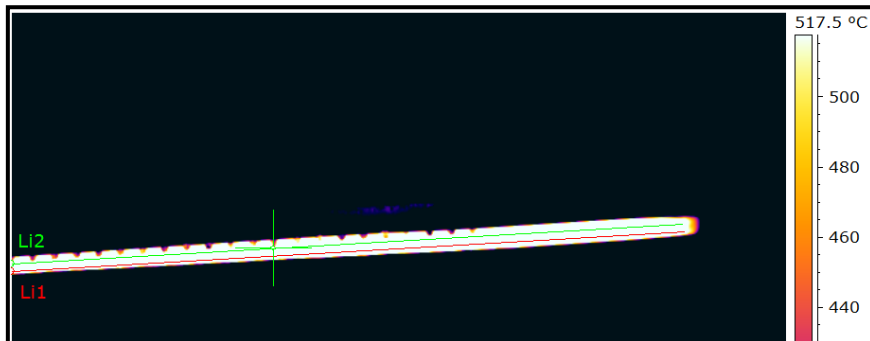
a) Thermal image



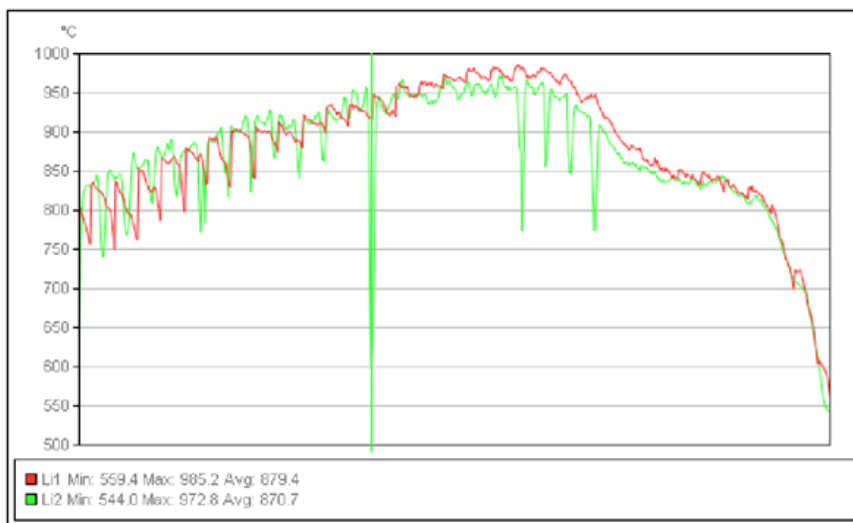
b) Graphics

**Fig. 3.** Captured temperatures in the middle point of heater unit 1.

The last fig. 4 shows longitudinal thermal images of the lines Li 1 and Li 2. At the beginning a small peak is observed (Fig. 4 b). In the middle of the line Li 2, the peak is  $T = 544^{\circ}\text{C}$ , after this point, it fades. After that the two lines Li 1 and Li 2 are fading and merge. This capture is implemented at the other end of the heating unit 1, which has a light yellow color, and finally converges to white.



a) Thermal image



b) Graphics

**Fig. 4.** Captured temperatures at the end point of heater unit 1.

## Conclusion

The proposed experimental study of temperatures in furnace of MAM metallization polypropylene is based on measurement of the values of temperature differences of a heater unit 1 for melting and evaporation of silver, and realized by using a thermal infrared camera FLIR P640. Captured temperature differences are realized immediately after depressurization of the vacuum chamber. The experimental study was conducted successively using a methodology (Part I). The obtained data from the captured and measured temperatures and temperature differences are processed, synthesized and plotted in Table 1. An analysis of captured thermal images of longitudinal lines Li, i; - Fig. 2 a), Fig. 3 a) and Fig 4 a). Graphically presented thermal variations of Fig. 2 b), Fig. 3 b) and Fig. 4 b) takes into account the temperature peaks.

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Экспериментальное исследование температуры печи для металлизации полипропилена

Част II. Температурный дифференциальный анализ блока нагрева для металлизации полипропилена

*Николай Стоименов, Любомир Димитров, Димитър Карастоянов,  
Ваня Георгиева, Любен Клочков*

*Резюме*

*В представленной работе проведено экспериментальное исследование блока нагрева. Представлены результаты исследования. Результаты исследования изучены и проанализированы.*