Experimental study of furnace temperature for metallization of polypropylene

Part III. Temperature differences analysis in heating unit set for zinc.

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Abstract: *In the presented paper an experimental study of heating unit for zinc is made. Results from the study are provided. Provided results are discussed and analyzed.*

Keywords: metallization, polypropylene, automation, heating unit, thermography.

1 Introduction

After manufacturing temperature analysis in furnace from Part I, and analysis of temperature differences of heating unit 1 for silver, the next step in this work is to conduct performance tests of heating unit set 2 for zinc.

The objective of this work is the analysis of temperatures and temperature differences of heating unit for zinc during metallization of polypropylene.

2 Technical realization

The experimental study was carried out using the same methodology developed in Part I, which is used in analyzing the temperatures and temperature differences of a heater for silver (1) in Part II.
The survey was carried out in two stages. During the first stage, the heating unit set 2 for melting and evaporation of zinc in pot, is covered with a mask. During the second stage the heating unit set 2 is without mask with an open pot. Data obtained when taking temperatures and temperature differences are processed and plotted in Table 1 for open pot and table 2 covered pot with a mask of heating unit.
Longitudinal thermal images are shown in Fig. 1 a), the graphic representation of the temperature differences are shown in Fig. 1 b). Comparison of temperature differences between the clean pot is shown in Fig. 3 a) and not cleaned (dirty) are shown in Fig. 3 b) a pot with zinc in the heating unit set.

3 Results of the measurements

After the pot the heating unit set is located in a lower position of the furnace unit 1, which causes some difficulty for measuring the temperature. Because of the position of the heating unit set, which is placed in the middle of the furnace and on both sides are positioned other two heating units for silver and aluminum, temperatures are quite high. The assembly of MAM is quite complicated for investigation. This survey was conducted on top with a small angular displacement. Despite the difficulties, the results of the image are plotted in Table 1.
On Table 1 in vertical columns are plotted temperatures: peak, Tmin, Tmax, and temperature differences Tmax-Tmin in column 7. In the horizontal lines 1, 2 and 3 are plotted measured temperatures of longitudinal thermal image Li, i. In lines 4, 5 and 6 are plotted maximum temperatures Tm of areas Ar. 1, Ar. 2, Ar. 3.

Table 1. Temperatures of pot without mask in heating unit set 2.

№	Figure	Graphics	Measured values of temperature differences [TºC]			
			peak	Tmin	Tmax	Tmax -Tmin
1	2	3	4	5	6	7
1	1	Li 1	756,6	698,0	766,9	68,9
2		Li 2	688,6	654,9	762,7	107,8
3		Li 3	704,0	657,6	760,7	56,7
4		Ar 1			719,3	
5		Ar 2			758,5	
6		Ar 3			766,9	

The following experimental study was carried out to heating unit set 2 for zinc (Fig. 2) with mounted mask. Table 1 plots the data for an open pot of zinc in heating unit set 2. In the horizontal lines 1 to 8 data of the temperatures of the thermal image are plotted of a longitudinal line of Li 1 to Li 8 (Fig. 2 a), and fig. 2 b) shows graphically measured temperatures. The horizontal rows from 9 to 16 temperature points are plotted in areas Ar 1 to Ar 8.

The distribution of measured and recorded temperatures and temperature differences are presented in Table 2 as follows: number of figures in column 2; numbers graphics Li, i areas and points in Ar, i placed in column 3; minimum Tmin in column 4, the maximum Tmax in column 5; differences: Tmax and Tmin in column 6; peak graphics - Avg in column 7; difference between minimum Tmin in column 8; maximum Tmax in column 9; differences between Tmax and Tmin from column 6 are given in column 10, and the difference between maximum and minimum Tmax-Tmin of peak Avg from column 7 is presented in column 11.

Table 2. Temperatures of pot with mask in heating unit set 2.

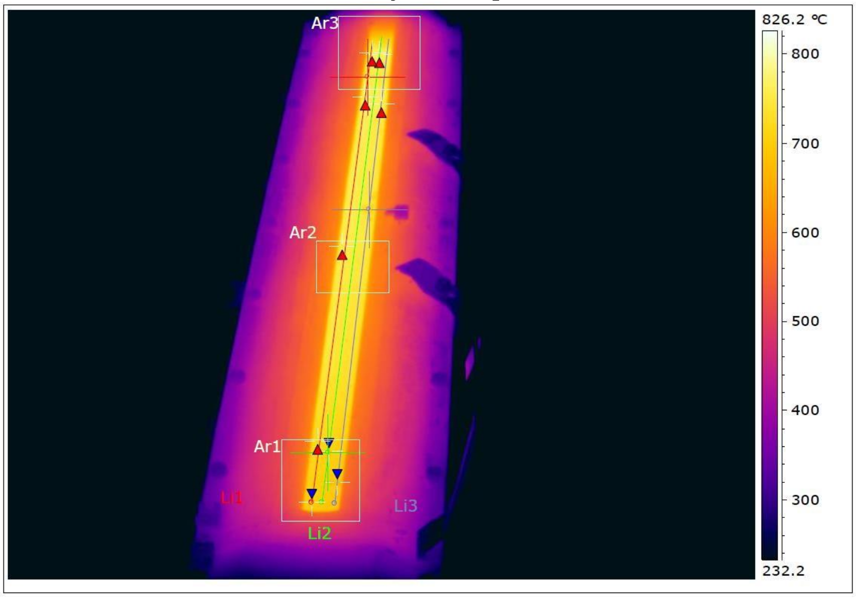
№	Fig	Gra-phics	Measured values of temperature differences [TºC]							
			Tmin	Tmax	Tmax-Tmin	peak Avg	Differences			
							Tmin	Tmax	Tmax-Tmin	Avg Tmax -Tmin
1	2	3	4	5	6	7	8	9	10	11
1	fig 6 a,b	Li 1	**582,9**	**717,9**	**135,0**	688,4	122,3	34,6	95,1	68,9
2		Li 2	612,0	733,3	121,4	**676,0**				
3		Li 3	**705,2**	745,1	**39,9**	734,0				
4		Li 4	645,0	755,2	101,0	712,3				
5		Li 5	700,1	751,0	50,8	734,8				
6		Li 6	658,9	752,4	93,5	723,6				
7		Li 7	660,7	**752,5**	91,8	**744,9**				
8		Li 8	640,8	742,8	101,9	723,4				
9		Ar 1	453,3	719,6	266,3	522,5	Differences			
10		Ar 2	**436,0**	733,1	297,4	510,0	43,0	32,9	40,1	40,7
11		Ar 3	**479,0**	745,1	**266,1**	543,4				
12		Ar 4	469,2	755,2	286,0	545,0				
13		Ar 5	463,3	753,3	290,0	531,5				
14		Ar 6	474,8	752,4	277,6	531,1				
15		Ar 7	446,3	**752,5**	306,2	527,0				
16		Ar 8	439,2	744,7	305,5	504,3				

4 Analysis of the results

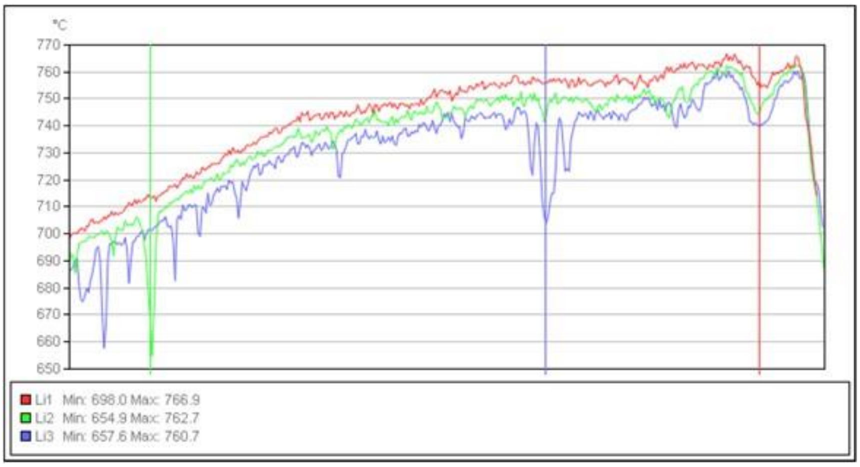
Fig. 1 shows temperatures of the pot of melted zinc, placed in heating unit set 2. Presented longitudinal thermal images of lines Li 1; Li 2; Li 3 of Fig. 1 and graphically represented measured temperature differences Li 1, Li 2 and Li 3 are without mask. They were provided 15-20 min after removing the mask from the heating unit set. Longitudinal thermal image of the line Li 1 is closest to the melting temperature of zinc. It has a maximum Tmax = 766,9º C and minimum Tmin = 698,0º C (Fig. 1 a). In graphically represented measured temperature differences on line Li 1 (Fig. 1 b) a peak is not noticeable. The last peak appears at the end at T = 756,6º C and shortly afterwards fades. Line Li 2 of longitudinal thermal image has a minimum Tmin = 654,9º C and increased by a maximum Tmax = 762,7º C (Fig. 1 a), while a graphical representation of the measured temperature differences, there is a sensitive peak at T = 688,6° C and a second peak into line Li 1 (Fig. 1 b). The last longitudinal thermal image on line Li 3 is the lowest temperature Tmin = 657,6º C and Tmax = 760,7º C. It is farthest from the melted zinc in the pot, placed in heating unit set. At the beginning of the line Li 3 was observed with a pronounced peak. Quite at the end of the three measured temperature differences lines Li 1, Li 2 and Li 3 merges without the presence of peak. Temperature differences in the minimum range are within 43,1° C and at maximum range within the range of T = 6,2º C.

From Fig. 1 a) for longitudinal thermal image easily can be detected the sludges, dark spots, shadows and points. These sludges are obtained before initiation of a new cycle.

At the thermal image longitudinal lines Li1, Li 2 and Li 3 small areas Ar 1, Ar 2 and Ar 3 are marked. In these small areas the maximum temperatures are colored red. In addition, they can be seen sludges of metal oxides with dark spots and dots. In Ar 1 area was measured a maximum temperature Tmax = 719,3º C, line Li 1 has two dark dots, line Li 2 has a dark point and line Li 3 has also dark point. Area Ar 2 was measured with a maximum temperature Tmax = 758,5º C in which only on line Li has a dark point. Measured maximum temperature of area Ar 3 is Tmax = 766,9º C and lines Li 1 and Li 3 are marked by a dark point.



a) Thermal image



b) Graphics

Fig. 1. Temperatures in pot of zinc without mask.

On Fig. 1 a) the right part of the heating unit set is noticed a large pots, caused by sludges in graphically represented measured temperature differences shown on Fig. 1. b) of area Ar 1 are noticed 5 dark points, and only in the end there is a single relatively small peak at the until, while areas Ar 2 and Ar 3 are noticed two dark points, and also has a large and tangible broad peaks. The differences in maximum temperatures is 47,6º C.

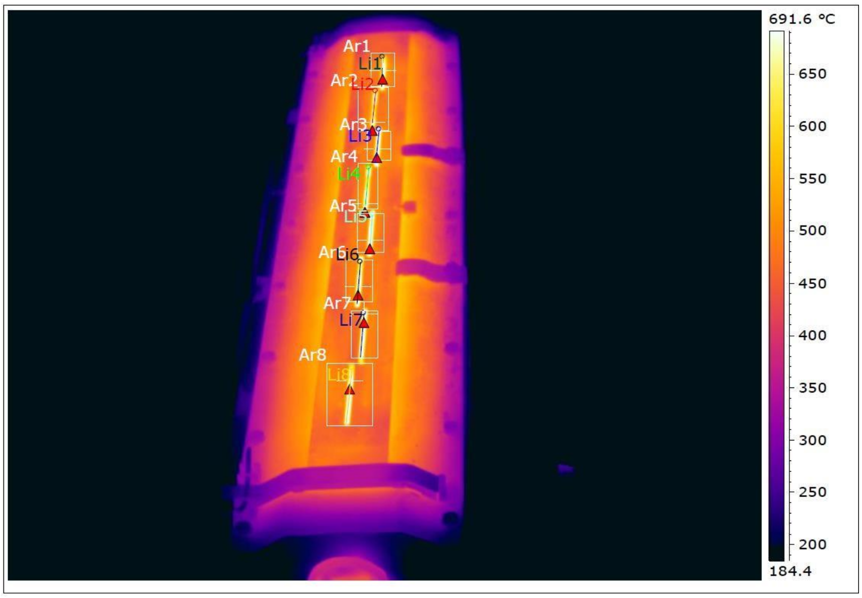
Experimental studies of pot for zinc, placed in a heating unit set with mounted mask are comducted 15-20min before the pot with zinc without mask. A mask with "H6" windows is used for ensuring the application of metallization of polypropylene with dimensions of roll: diameter D = 540mm, width b = 920 mm, a length of the tape polypropylene l = 27000m and thickness δ = 6 μm.

Fig. 2a shows the measured temperatures of thermal longitudinally image lines from Li 1 to Li 8 graphically represents measured temperature differences of lines Li 1 to Li 8 (Fig. 2b) and the temperatures of the peaks from Avg 1 to Avg 8, and also longitudinal thermal images marked with small areas from Ar 1 to Ar 8. All filmed measured temperatures are shown in table 2.

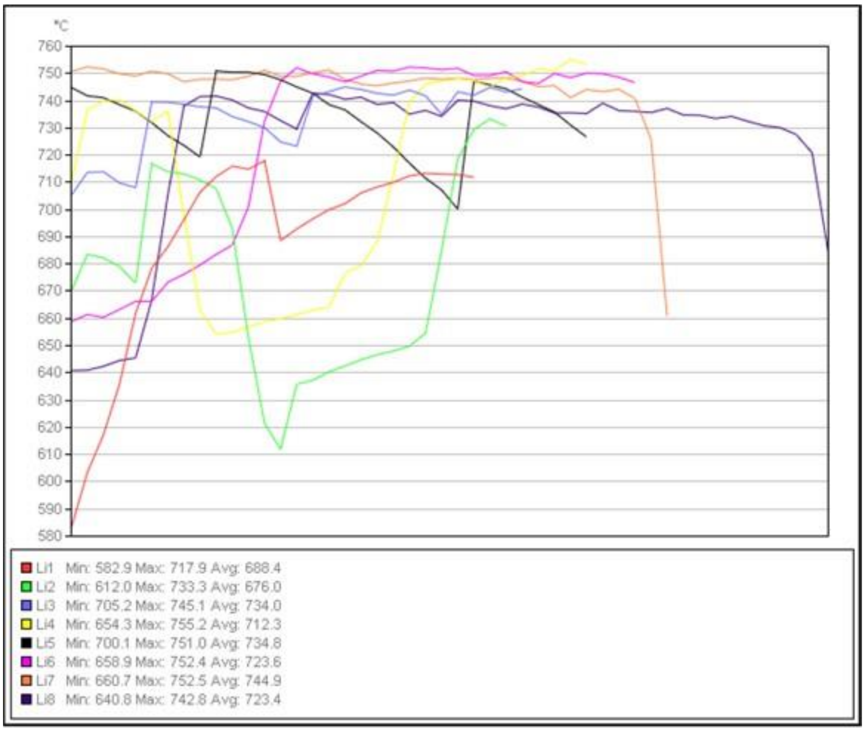
The obtained result differences in minimum temperatures, measured on the lines Li 1 to Li 8 are Tmin = 122,3º C, the maximum temperatures are Tmax = 34,6º C, while differences in temperature Tmax - Tmin = 95,1ºC. The differences are very well graphically represented in temperature lines Li 1 to Li 8. These curly graphs are shown in Fig. 2 b). Differences in the peaks are in quite widely range from Avg = 68,9ºC of the areas.

The smallest differences are in line Li 3 with temperatures Tmin = 705,2º C, Tmax = 745,1º C, Tmax - Tmin = 39,9º C and peak T = 734,0º C. The biggest differences are noticed in the lines Li 1, Li 2, Li 4 and Li 8, which are above 100° C.

The produced differences by the longitudinal measured temperatures marked with small areas Ar 1 to Ar 8 are with minimum temperatures Tmin = 43º C, at the maximum is Tmax = 32,9º C and for Tmax - Tmin = 40,1º C peaks areas.



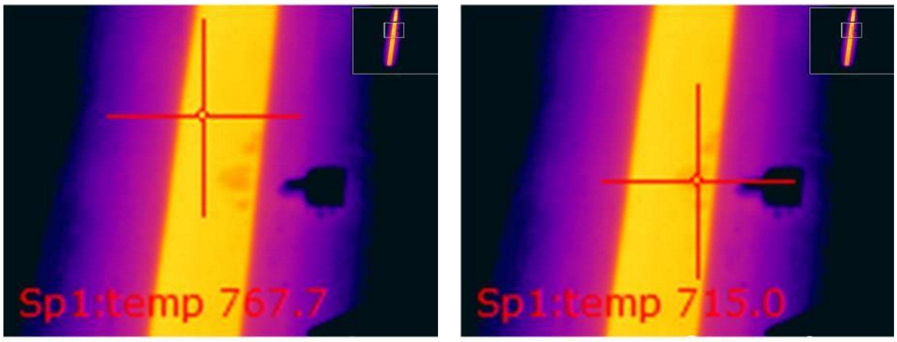
a) Thermal image



b) Graphics

Fig. 2. Temperatures in pot of zinc with mask.

It is noticeable that the differences are smaller than the above presented for measurements, but the differences between the maximum and minimum are significant. The smallest difference was in Ar 3, T = 266,1º C, while Ar 7 is T = 306,2º C.
The results from thermal longitudinally measured temperatures marked with small areas from Ar 1 to Ar 8 have the following differences: at minimum temperatures Tmin = 43,0º C, the maximum temperatures are Tmax = 32,9º C and for Tmax - Tmin = 40,1° C, and the differences of the peaks are in the range of approximately Avg = 40.7° C
The obtained differences of the experimentally investigated pot with zinc temperatures of heating unit set 1.4 with mask and unmasked are quite large and varied, despite of the minimum distance between them of about 50mm. But of course the resultant difference in measured temperatures indicated with a mask and without mask of the heating unit set varies, depending on the differences in the timing of measuring. The resulting difference of the temperatures captured due to the variation in time obtained by removing the mask.
It is necessary to pay attention to the operation of the furnace as a whole, heating units and especially the mask, with regard to what problems can occur in these rapid increases of high temperatures and then rapidly cooling of about 2-3 h. The mask is made of sheet material and a precise profile holes which change their size, shape, deformation and etc. On the surface of heating units, covering panels, masks, used pots, cooling pipes and all elements of Modules 1, 2 and 3 of MAM, are noticed very serious sludges, and for that reason should be performed clean after each work cycle.
Sludges occur also on the pot. Those sludges interfere with uniform evaporation of material by changing the differences. A comparison is shown between a clean pot (Fig. 3 a) and dirty in Fig. 3. b). The difference is 52,7ºC.



a) Clean b) Not clean

Fig. 3. Pot temperature differences.

Therefore it is necessary a methodology to be established for cleaning at certain period of time and capturing the temperature of the heating units not only with thermal infrared camera, but with noncontact thermometers.

Conclusion.

The proposed experimental study has examined the problem of temperature differences in heating unit set for melting and evaporation of zinc in metallized polypropylene in MAM. The experimental study was analyzed using a thermal infrared camera FLIR P640, held on developed methodology in Part I and captured immediately after depressurization module 2. The captured, measured and obtained data of temperatures and temperature differences are processed, synthesized and plotted in Table 1 and 2. The captured thermal images are analyzed by longitudinal lines Li, i and peaks. Areas Ar, also averages Avg, of a heater unit set without pot mask and with pot mask type "H6" for zinc. It is recommended after each cycle, the surfaces of heating units, masks, pot covering panels, cooling units and all elements of the modules 1, 2 and 3 MAM after leakage have very serious sludges not only silver, zinc and aluminum, but and the evaporation of metal and polypropylene in metallizing process. Comparisons were made between clean and dirty pot (Fig. 3) w

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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 III. Температурный диференциальный анализ блока нагрева для цинка

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Резюме

В представленной работе проведено экспериментальное исследование блока нагрева для цинка. Результаты исследования представлены. Предоставленные результаты обсуждаются и анализируются.