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Thermal Analysis of Selected Polymer Materials for Precision Casting Models

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Abstract

Thispaper shows preliminary thermal analysis of 6 polymer materials which are commonly used or can be used as models for precision casting. Thermal analysis was carried out with use of derivatograph and allowed to determine two fundamental properties of examined materials - their phase transition during heating to the temperature of 800°C and mass of dry residue after burning which can be used to evaluate polymer residues remaining in the casting mould cavity. The subject of this paper is related to increasing participation of rapid prototyping methods in casting with use of printed models. Determination of changes in materials, in particular their linear and cubical expansion and analysis of dry residue after burning in casting mould cavity is extremely important for the construction of form crust and surface quality of casting. A problem is to design a polymer-based casting model which allows non-residue burning and simultaneously causes no cracking of ceramic form during heating.

Keywords: Precision casting, Polymers casting patterns, Differential thermal analysis

1. Introduction

Precision casting technology is primarily based on models made of wax compounds. It is a reasonable material for casting models because of its low thermal expansion and non-residue burning. The entire foundry industry in Poland uses wax models however in global scale foamed polystyrene is also common. In recent years a new 3D models printing method was developed to print models made of various materials like polyamide, ABS and wax what creates a new possibility to use printed models in casting [1-7]. It is necessary to determine the suitability of different polymer materials in the casting models application. This paper shows investigation of 5 polymer materials compared to casting wax. Phase transition temperature, the percentage of residues after burning and thermal expansion was determined [8-9].

2. Methods and results

Six materials were chosen for derivatograph thermal analysis: high impact polystyrene (HIPS), foamed polystyrene, co-polymer ABS, printed PA6 polyamide, polymethyl methacrylate (PMMA) and casting wax. Differential thermal analysis and thermogravimetric analysis allow to determine thermal effects during physical or chemical changes. During examination of samples it was possible to determine the DTA curve (material temperature in the function of time)and notice peaks of characteristic - endothermic or exothermic - changes. At the same time the thermogravimetric analysis was carried out which describes the rate of sample mass change in the function of time and set temperature. Temperature rise rate during examination was 5°C/min and the final temperature was 800°C. The following figures show DTA curves (differential thermal analysis) and TG (thermogravimetry - mass loss) (Fig. 1-6).

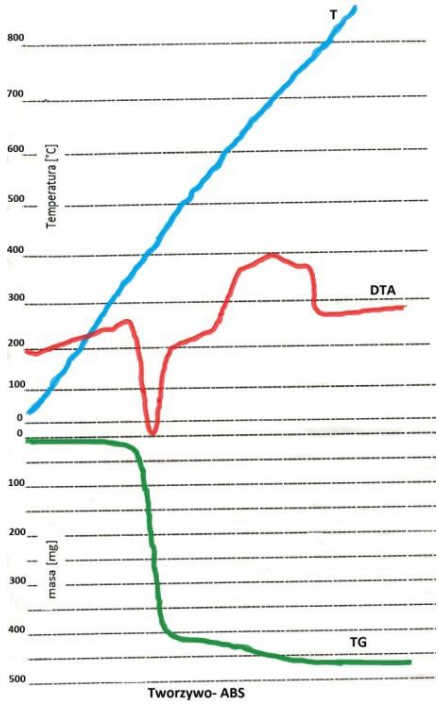

Fig. 1. DTA and TG graphs of examined polymer material ABS

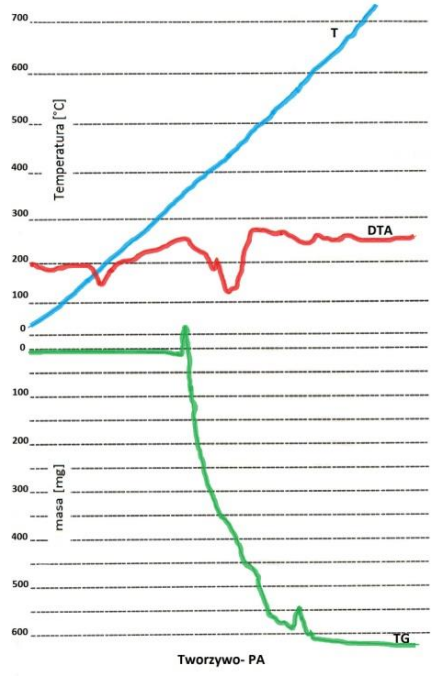

Fig. 2. DTA and TG graphs of examined polymer material PA

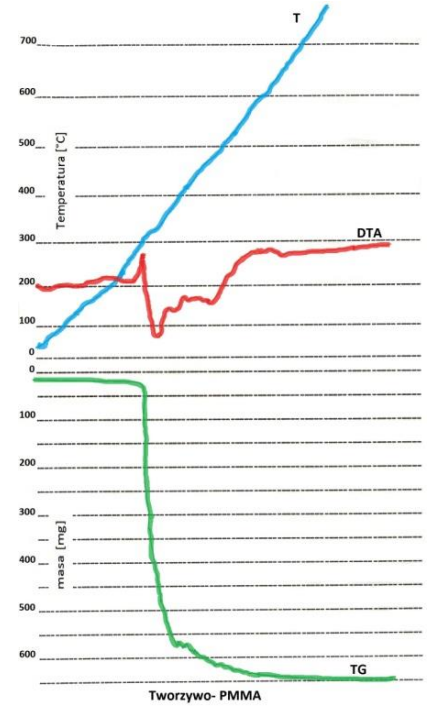

Fig. 3. DTA and TG graphs of examined polymer material PMMA

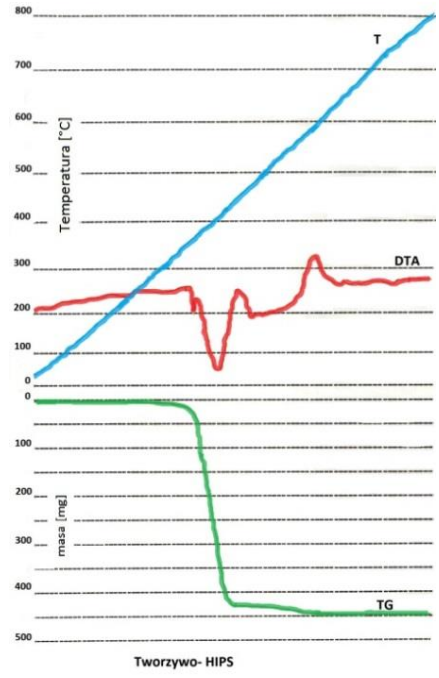

Fig. 4. DTA and TG graphs of examined polymer material HIPS

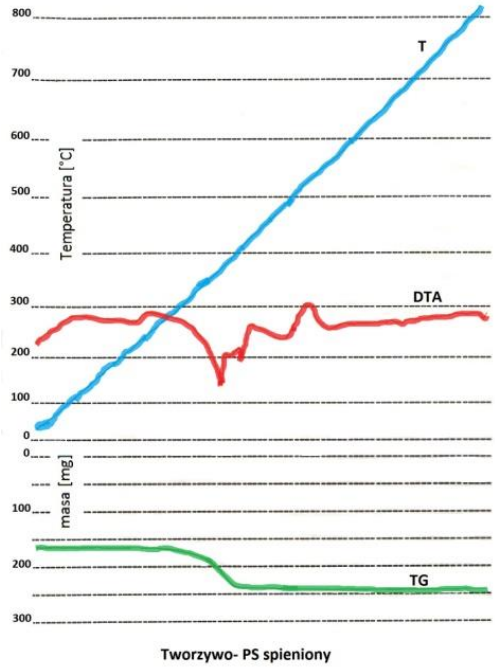

Fig. 5. DTA and TG graphs of examined polymer material foamed PS .

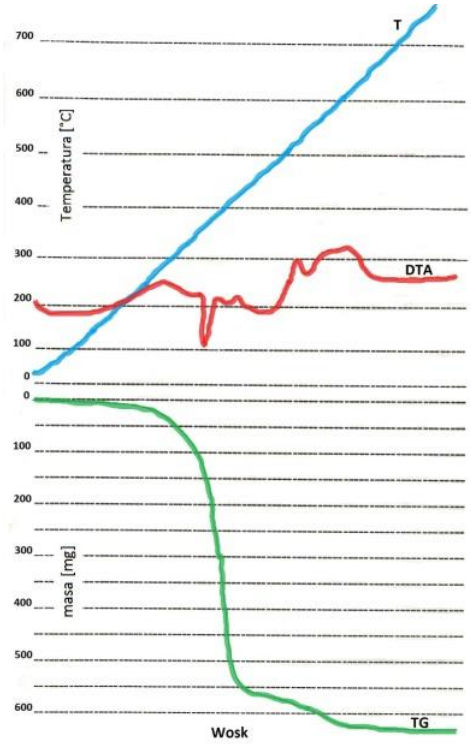

Fig. 6. DTA and TG graphs of examined polymer material wax

Moreover quantitative observations using stereoscopic microscope of residues after burning of polymer materials were made what is shown in Fig. 7.

Analysis of graphs and residues after burning led to identification of characteristic values (Table 1,2). From DTA graphs in combination with TG analysis it was possible todetermine approximate values of the beginning of burning temperature (breakdown temperature) and the beginning and the end of carbon residues decomposition temperature (CRDTB and CRDTE).

Table 1.
Polymer sample weightbefore and after the test using derivatograph

Material	Sample weight [g]	Residue [g]	Percentage of residue mass [%]
PMMA	0,6287	0,0003	0,048
ABS	0,459	0,0015	0,33
PA	0,633	0,0024	0,38
HIPS	0,445	0,0032	0,72
Foamed PS	0,0746	0,0002	0,27
wax	0,6337	0,0005	0,08

Table 2.
Experimental characteristic temperatures of examined materials

Material	$T_{melting}$[˚C]	$_{breakdown}$[˚ C]	T_{CRDTB}[˚C]	T_{CRDTE}[˚C]	Rc [mm/ m/ ^{0}C]
PMMA	160	~300	~340	~600	0,065
ABS	120	~350	~450	~688	0,1
PA	220	~350	~480	~610	0,05
HIPS	160	~330	~425	~590	-
Foamed PS	160	~330	-	-	0,07
Wax	78	~360	~405	~610	-

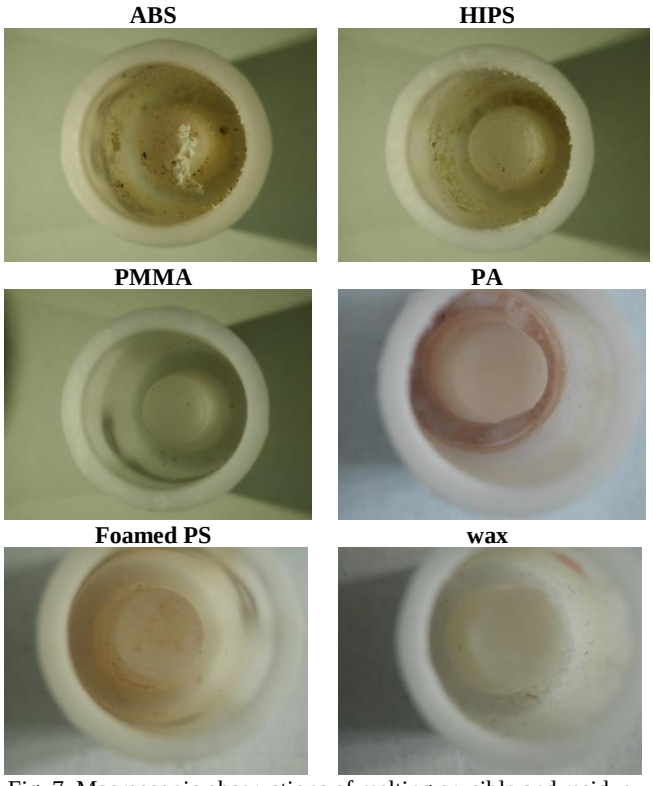

Fig. 7. Macroscopic observations of melting crucible and residue after burning of examined polymer materials

4. Discussion and summary

Conducted preliminary investigations on behavior of selected polymer materials during burning allowed to determine such characteristics as dry residue and the breakdown temperature of residual carbon. It was also possible to specify a general relation, very important in the aspect of casting, according to which the material was subjected to change. It has been found that all materials above the temperature of 300°C decompose which is indicated by a loss of mass (TG graph) and appearance of endothermic peak which points on delivering certain amount of energy required to break the monomer bonds. The next step is a charring process that occurs in the range of temperatures 350-600°C for all examined materials. In practice decomposition of polymer leaves carbon black on the walls of ceramic form, which is stable at the temperatures above. Over the temperature of 600°C oxidizing of carbon residues to CO and CO_2 carbon oxides occurs, which is related to exothermic peak in DTA graph which is probably caused by further oxidation (burning) of CO into CO_2. After analysis of dry residue mass percentage after burning of polymer materials, according to table 1, it can be concluded that PMMA (99,95%) is characterized by the best burn rate.

Acknowledgements

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