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THERMAL PROTECTIVE PROPERTIES OF THERMOSETTING GLASS-FABRICS LAMINATES WITH HIGH-MELTING POWDER FILLERS

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ABSTRACT

The present work investigates the ablative and thermal properties of phenol formaldehyde glass-fabrics laminates filled with mixtures of corundum Al_2O_3 and carbon C powders. The laminates specimens of dimensions 10x25x35 mm were treated with hot combustion gases having a temperature of more than 2800ºC. The carbonization of the thermosetting matrix was observed. Statistical methods for planning experiments were used, and the effect of components on the average rate of ablation, the maximum back side temperature of specimen and the average mass waste under intensive heat flow after 30 s of treatment with hot combustion gases was established.

Keywords: ablative shields and coats, thermosetting glass laminates, high-melting fillers.

INTRODUCTION

The use of modified plastics as ablative materials protecting against excessive temperature increase was connected with the middle of XX century, directly with arms industry as well as aeronautical, rocket and space techniques (Soutis, 2005). These materials can also be used in the design of passive fire-proof protections for large cubature supporting elements in building structures (NIST NCSTAR 1, 2005), communication tunnels (Ono, 2006) and for the protection of data stored in electronic, optical and magnetic carriers (Kucharczyk, 2007). Despite many years of experience with ablative materials, the relationship between the phases type and composition with ablative properties, within the context of others operational properties of the composites used as thermal protection shields, remains still not evaluated qualitatively and quantitatively (Bahramian, 2013; Kucharczyk, 2007; Soutis, 2005).

RESULTS AND CONCLUSIONS

The following materials (input variables x_i) have been used to prepare the specimens of thermosetting glass laminates with powder fillers: two kinds of phenol formaldehyde resins (liquid and adhesive resin) for matrix; glass-fabric (250 g/m^2) as fibre reinforcement; as well as powder fillers, corundum Al_2O_3 with grains of 2 to 5μm with the minimal contents of aluminium oxide of 99.5% (95% α Al_2O_3) and fine grain carbon powder C of 5 μm and purity of 98%.The so-called "ablative gun" (Song, 2003) of our own construction (Kucharczyk, 2007) has been used for the classical ablative properties tests. The specimens (10x25x35 mm cubes) were treated of oxy-acetylene mixture of hot combustion gases having a temperature of more than 2800ºC during 30 seconds. The registration of the back side temperature (t_s) of specimen have been performed. Furthermore, the average rate of ablation (v_a) and the average ablation mass waste of laminates (U_a) has been also evaluated. There are three output variables, components of the response function (Table 1).

Table 1 - The results of ablation (thermal protective) tests

Parameter		Number of test							
		1	2	3	4	5	6	7	8
Matrix (x_1) [%]		24	30	24	30	24	30	24	30
Fibreglass fabric (x_2) [%]		18	18	25	25	13	13	19	19
Powder fillers (x_2) [%]	Al_2O_3	11,6	10,4	10,2	9,0	50,4	45,6	45,6	40,8
	C	46,4	41,6	40,8	36,0	12,6	11,4	11,4	10,2
v_a [μm/s]		121	158	125	128	130	166	157	172
$t_{s\ max}$ [ºC]		56,8	50,1	40,7	37,7	57,3	41,0	50,7	60,6
U_a [%]		10,8	11,0	9,6	8,3	6,9	5,9	6,7	7,3

The evaluation of ablative thermal protection properties of thermosetting glass laminates were carried out on the basis on a first order 2^3 statistical experimental research program. The regression coefficients of all function components have been calculated. The statistical analysis of the tests results allowed the determination of the threshold relevance of the regression coefficients b_i and estimation of their effect on the thermal protection properties. Moreover, the variance $s(\overline{y})$, error of regression coefficients $s(b_i)$ and their level of statistical significance b_{sign} have been determined on the basis of t-Student distribution. (Table 2) (Montgomery, 2009).

Table 2 - Statistics of coefficients the equations of the response variable

Function y_i	b_0	b_1	b_2	b_3	b_{12}	b_{13}	b_{23}	b_{123}	$s(y)$	$s(b_i)$	b_{sign}
v_a [μm/s]	144,5	11,4	-	11,5	-6,9	-	7,5	-	6,9	2,4	5,6
$t_{s\ max}$ [ºC]	49,3	-2,02	-1,93	3,06	3,74	-	5,19	2,82	2,41	0,85	1,96
U_a [%]	8,29	-0,17	-0,34	-1,61	-	0,09	0,63	0,39	0,19	0,07	0,16
Equations	$y_i(x_1, x_2, x_3) = (b_0 + b_1x_1 + b_2x_2 + b_3 x_3 + b_{12} x_1x_2 + b_{13} x_1x_3 + b_{23} x_2x_3 + b_{123} x_1x_2x_3) \pm s(\overline{y})$										

The aim of the experiment was to find such a composite whose values of the average ablation rate v_a, the maximum back side temperature t_{s_max} and the average mass waste U_a are the lowest. These conditions have been fairly met by specimen 4 whose phase composition consists of 30% matrix, 25% fibre glass fabric reinforcement, 9% corundum Al_2O_3, and 36% carbon powder *C*.

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