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DEVELOPMENT OF ADHESIVE FOR BONDING THE THERMAL PROTECTIVE COATING AND LOAD-BEARING CASING OF THE MAIN SOLID ROCKET MOTOR

When rocket hardware is developed special attention is paid to improvement of materials and components used for the products. At present the 51-K-35 adhesive is used to bond the interior thermal protective coating (ITPC) and load-bearing casing (LBC) of the main engine (ME) to produce a main solid rocket motor (SRM). Formulation and procedure for applying the 51-K-35 adhesive was developed in Russia and patented. Development of the adhesive composition to bond thermal protective coating and load-bearing casing of the main solid rocket motor is a subject of great interest. [dx.doi.org/10.29010/085.8]

Keywords: *main solid rocket motor; load-bearing casing; interior thermal protective coating; adhesive.*

Introduction

Due to cessation of the 51-K-35 adhesive delivery, the task was assigned to develop a domestic adhesive for bonding ITPC and the load-bearing casing of the main engine on the basis of the environmentally friendly components available in Ukraine in order to minimize the dependence on import components supply and to produce main solid rocket motors within the time limit without threat of technology breach.

In accordance with the task assigned, the adhesive shall comply with the following technological requirements:

1. Ultimate peeling strength of adhesive bond: polymer composite material of the load-bearing casing based on carbon fiber impregnated with rubber binder shall be not less than 0.196 MPa;

2. Ultimate pull strength of adhesive bond: cured rubber with uncured rubber mixture, after thermal treating is not less than 1.176 MPa;

3. Ultimate pull strength of adhesive bond: LBC material with 1001 rubber, after thermal treating is not less than 1.176 MPa;

4. The adhesive shall be water-resistant;

5. Operational temperature for adhesive bond shall be: from 60 °C below zero to 100 °C above zero;

6. Adhesive shall be efficient and preserve its properties after long-term thermal treating (for 25 days at temperature 70-80 °C)

In accordance with Yuzhnoye SDO statement of work, SE UNIKTI DINTEM developed and supplied the test butch of adhesive to bond the interior thermal protective coating and the load-bearing casing of the main solid rocket motor.

That is why the aim of the work is to test the strength provided to the bond of the interior thermal protective coating and the SRM load-bearing casing and to determine:

1. Ultimate strength of uniform separation of the adhesive bond: LBC material + adhesive + TPC (not less than 1.176 MPa;);

2. Ultimate strength of uniform separation of the adhesive bond: rubber + adhesive + TPC (not less than 1.176 MPa;);

3. Ultimate strength of bond peeling: LBC material + adhesive + TPC (not less than 2 H/cm);

4. Ultimate strength of bond peeling: rubber + adhesive + TPC (not less than 2 H/cm).

To check the efficiency of the developed adhesive, a program was developed to produce plates with different composition for subsequent testing in order to confirm the required properties of the adhesive bond. In accordance with the developed program of Yuzhnoye SDO, the plates were manufactured to study the provision of strength in the bond of the interior thermal protective coating and the SRM load-bearing casing.

To produce the plates the following materials were used:

- "calendered rubber mixture 1001" TU U 22.1-00152135-146:2016, 1 mm in thickness;
- highly elastic polyamide sheet (ПВП-У) TU U 13.9-16287311-162:2016 ;
- adhesive DV-05-01 TU U 22.1-00152135-152:2018
- pre-preg based on:
- epoxy matrix system Araldite LY 1135-1 A/Aradur 917 CH/Accelerator 960-1 Huntsman (Huntsman binder), or
- epoxy binder ЭДТ-10 that consists of modified epoxy resin КДА-2 TU 6-05-13-80-76 and hardener triethanolamine titanate ТЭАТ-1 TU 6-09-11-2129-93,

and one of the following carbon fibers:

– carbon fiber Tenax-E IMS65 E23 24K 830 tex (China);

– carbon fiber Tenax-E IMS65 E23 24K 830 tex;

– carbon fiber TC 36P-12K.

The tests were conducted on samples cured in accordance with the procedure for producing main solid rocket motors as well as on samples cured with additional thermal treatment (TT) at temperature 75 °C for 14 hours.

Test results are given in tables 1 and 2

Test results for adhesive bonds given in table 1 indicate that the best performance of the ultimate pull strength when separating TPC from LBC was shown by a plate from carbon-filled plastic based on carbon fiber Tenax-E IMS65 E23 24 K 830 tex, impregnated with binder ЭДТ-10 (plates №№ 21, 22) and equals 2.43 – 2.47 MPa while the statement of work requirement is > 1.176 MPa, as well as by a from carbon-filled plastic based on carbon fiber TC 36P-12K impregnated with binder ЭДТ-10 (plate № 15) with ultimate pull strength of 2.806 MPa.

Destruction of samples cut from plates №№ 1, 2, 3, 7, 8 (pre-preg based on carbon fiber Tenax-E IMS65 E23 24 K 830 tex with Huntsman binder) that occurred when testing the carbon-filled plastic at values of ultimate pull strength of less than 1.176MPa, made it impossible to determine the real strength of the rubber-adhesive-pre-preg bond, but there was no destruction of adhesive samples.

After plates №№ 1, 4, 24 were thermally treated at temperature 75 °C for 14 hours the destruction pattern of samples did not change but the bond strength increased significantly (see table 1).

Bond strength in layers was improved when quantity of binder was increased up to 46.41% (plate № 17). Ultimate pull strength when separating TPC from LBC was 0.911 MPa as compared to 0.196 MPa of the similar sample (plate № 1) that contained binder 30_{-3} %.

When highly elastic polyamide fiber (ПВП-У) produced in Ukraine was used for plates № 8, 9 their ultimate pull strength when separating TPC from LBC was 1.451 MPa and 1.037 MPa respectively, while the statement of work requirement is > 1.176 MPa. However, considering the scatter of obtained results and increase in mass and geometrical dimensions of the ME casing it is not advisable to use ПВП-У.

Keeping pre-preg in the cooler (t = 2÷6 °C for 24 hours) led to reduction in its ultimate pull strength (see table 2, plates № 13, 14, 28).

When a layer of resin Araldite LY 1135-1 A was applied on adhesive ДВ-05-01 (see table 2, plate № 15 without being kept in the cooler) ultimate pull strength was 1.588 – 2.333 MPa, that complies with statement of work requirements (>1.176 MPa).

Table 1

Pull tests results for samples

Plate No.	Plate composition	Breaking stress upon uniform separation, MPa						Destruction pattern
		1	2	3	4	5	Mean	
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
"Load-bearing casing" - IMS65+ Huntsman (30%$_{-3}$)								
1	TPC +adhesive +LBC	0.183	0.176	0.181	0.106	0.306	0.196	on carbon-filled plastic
2	TPC +adhesive +LBC (TT)	0.307	0.192	0.144	0.202	-	0.201	on carbon-filled plastic
3	Rubber +adhesive +LBC	0.153	0.067	0.115	0.278	-	0.153	on carbon-filled plastic
4	Rubber +adhesive +LBC (TT)	0.135	0.452	0.480	0.326	0.057	0.028	on carbon-filled plastic
5	TPC +adhesive +ПВП-У +LBC	1.681	1.066	0.864	2.652	1.009	**1.451**	on LBC adhesive bond
6	TPC +ПВП-У+LBC	0.460	1.211	0.355	1.383	1.777	1.037	on LBC adhesive bond
7	TPC +adhesive +binder Huntsman, hardened at t 60°C for an hour +LBC	0.480	0.558	0.529	-	-	0.519	on carbon-filled plastic
8	TPC + binder Huntsman, hardened at t 60°C for an hour +LBC	0.686	0.568	0.539	0.304	0.304	0.441	on carbon-filled plastic
9	TPC +adhesive +adhesive Epoterm-03т+LBC	plate laminated, samples were not cut						
10	TPC +adhesive +2 layers of pre-preg based on ЭДТ-10+8 layers of binder pre-preg on base	plate laminated, samples were not cut						
11	TPC + adhesive +binder ЭДТ-10, hardened at t 60°C for an hour +LBC	plate laminated, samples were not cut						
12	TPC + binder ЭДТ-10, hardened at t 60°C for an hour +LBC	plate laminated, samples were not cut						
13	TPC + adhesive +resin Araldite+LBC (pre-preg kept in the cooler for 24 hours)	0.558	0.686	0.833	0.372	0.402	0.529	on carbon-filled plastic
14	TPC +adhesive +resin Araldite and adhesive (ratio 1:1)+LBC (pre-preg kept in the cooler for 24 hours)	0.392	0.931	1.087	1.755	1.157	0.941	on carbon-filled plastic

Table 1

1	2	3	4	5	6	7	8	9
15	TPC +adhesive +resin Araldite+LBC	2.333	1.784	2.128	1.431	1.588	**1.696**	on carbon-filled plastic
16	TPC +adhesive +resin Araldite and adhesive (ratio 1:1)+LBC	Carbon-filled plastic laminated and loosened, samples were not cut						
Produced by reeling on round section mandrel of ∅600 mm								
section I	TPC +adhesive +resin Araldite+LBC	1.559	1.098	1.765	2.157	1.598	**1.496**	on carbon-filled plastic, on technological adhesive
		1.431	1.775	1.284	1.784	0.990	**1.343**	on carbon-filled plastic
section II	TPC +adhesive +resin Araldite and adhesive (ratio 1:1)+LBC	1.245	1.098	1.078	1.421	1.961	**1.274**	on carbon-filled plastic
		0.892	1.068	1.863	0.990	0.912	1.029	on carbon-filled plastic
section III	TPC +adhesive +LBC	0.774	0.686	0.676	0.706	0.637	0.676	on carbon-filled plastic
"Load-bearing casing" - IMS65+ Huntsman (46,41%)								
17	TPC +adhesive +LBC	1.191	0.893	1.124	0.518	0.807	0.912	on carbon-filled plastic
"Load-bearing casing" – TC 36P-12K+ ЭДТ-10 (30%$_{-3}$)								
18	TPC +adhesive +LBC	2.719	2.720	2.902	3.017	2.719	**2.806**	on LBC adhesive bond
"Load-bearing casing" – TC 36P-12K+ Huntsman (30%$_{-3}$)								
19	TPC +adhesive +LBC	0.529	0.404	0.637	0.451	0.745	0.549	on carbon-filled plastic
"Load-bearing casing" - IMS65 (China)+ Huntsman (30%$_{-3}$)								
20	TPC +adhesive +LBC	0.715	0.451	0.549	0.245	0.362	0.451	on carbon-filled plastic
"Load-bearing casing" - IMS65 (China)+ЭДТ-10 (30%$_{-3}$)								
21	TPC +adhesive +LBC	2.216	2.363	2.170	2.824	2.598	**2.432**	on LBC adhesive bond
"Load-bearing casing" - 1M865+ЭДТ-10 (30%$_{-3}$)								
22	TPC +adhesive +LBC	2.245	2.706	2.961	2.745	2.392	**2.520**	on LBC adhesive bond
Uncured rubber + cured rubber								
23	TPC + adhesive + rubber	1.961	2.088	1.912	1.873	1.608	**1.833**	on technological adhesive
Uncured rubber + cured rubber								
24	TPC +adhesive + rubber (TT)	2.324	2.062	2.137	2.235	2.373	**2.128**	on LBC adhesive bond

Table 2

Peeling tests results for samples

Plate No.	Plate composition	Breaking stress upon uniform lamination, σ_p, N/cm					
		1	**2**	**3**	**4**	**5**	**Mean**
25	TPC +adhesive +LBC	plate laminated while samples were cut					
26	TPC +adhesive +rubber	24.03	24.15	26.19	22.79	23.30	**24.09**
27	TPC +adhesive +rubber (TT)	17.30	17.13	19.17	20.17	19.10	**18.57**
"Load-bearing casing" - IMS65+ Huntsman (30%$_{-3}$)							
28	Rubber +adhesive +LBC	1.7	2.4	0.0	0.0	0.0	0.0
13	TPC +adhesive +resin Araldite+LBC	1.87	3.02	1.55	3.08	1.70	**2.24**
14	TPC +adhesive +resin Araldite and adhesive (ratio 1:1)+LBC	2.18	2.35	4.23	1.99	1.97	**2.44**

Conclusions

Adhesive ДВ-05-01 has better basic quality ratings than batch adhesive 51-К-35 TU 1051787-87 and shall fully replace it.

Adhesive ДВ-05-01 was preliminary tested and is recommended for usage in rocket hardware.

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ОТРАБОТКА КЛЕЯ ДЛЯ СОЕДИНЕНИЯ ТЕПЛОЗАЩИТНОГО ПОКРЫТИЯ И СИЛОВОЙ ОБОЛОЧКИ ТВЕРДОТОПЛИВНОГО МАРШЕВОГО ДВИГАТЕЛЯ

При разработке ракетной техники особое внимание уделяется усовершенствованию материалов и компонентов, применяемых в изделиях. В настоящее время при изготовлении твердотопливного маршевого двигателя (РДТТ) для соединения внутреннего теплозащитного покрытия (ВТЗП) и силовой оболочки (СО) корпуса маршевого двигателя (МД) использовался клей марки 51-К-35. Рецептура и технология нанесения клея марки 51-К-35 разработана в России и запатентована. Разработка клеевого состава для соединения теплозащитного покрытия и силовой оболочки твердотопливного маршевого двигателя является актуальной. [dx.doi.org/10.29010/085.8]

Ключевые слова: *твердотопливный маршевый двигатель; силовая оболочка; внутреннее теплозащитное покрытие; клей.*

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