QUALIFICATION PROGRAM OF BRAZILIAN CATALYSTS FOR SATELLITE THRUSTERS: TEST AND RESULTS

Serra Jr, Aguinaldo M, agnaldo@lcp.inpe.br
Salles, Carlos E Rolfsen, salles@lcp.inpe.br
INPE – Instituto Nacional de Pesquisas Espaciais
LCP – Lab. Assoc. de Combustão e Propulsão
Rod Pres Dutra, km40 – Cachoeira Paulista - SP

Rodrigues, José Augusto J.
INPE – Instituto Nacional de Pesquisas Espaciais

Cruz, Gilberto Marques da

Abstract. *Monopropellant thrusters are widely used for maneuvers and orbit correction in micro and small size satellites. For hydrazine decomposition, the most used catalysts are, today, furnished by few companies, which are the only providers in world. This is, in fact, very dangerous to a spatial program. Catalysts obtention is getting more and more difficult. Knowledge for their fabrication is necessary for whom wants to have a spatial program.The National Institute for Spatial research (INPE) is finishing a developing program for brazilian catalysts for monopropellant, hydrazine satellites thrusters. The qualification tests run at Tests Bench with Altitude Simulation plant, in Cachoeira Paulista, SP. This paper intents to present tests and their results with one type of brazilian catalysts, as part of its qualification tests. Results are compared with Shell 405, a long time used catalyst in all spatial programs out Brazil. All test were made with the same thruster, in the same apparatus, with the same propellant batch. The thruster had a bolted decomposition chamber, which allows experiments with a large number of different types of catalysts in the same conditions. Obtained results are very satisfactory, when compared with the widely used Shell 405*
Keywords*: catalyst, satellites thrusters, hydrazine, thrust qualification*

1. INTRODUCTION

Low thrust propulsive subsystems (up to 400 N) are widely used in positioning and repositioning satellite maneuvers. After the launching, these subsystems are the only responsible for positioning satellites in its correct orbit, in a correct attitude. Along of satellite mission, these thrusters make all orbit and attitude correction, to allow a full satellite mission. Almost all on board propulsive subsystems use monopropellant hydrazine thrusters. Thrust is furnished by hydrazine decomposition: passing by a suitable catalytic bed where hydrazine is decomposed and transformed in a hot gaseous amount of various chemical products. These gases are accelerated in a nozzle, and produce thrust. Hydrazine decomposition occurs by means of the catalyst.

Brazilian catalysts are in development at the Brazilian Institute for Space Research (INPE). Development and qualification of the whole propulsive subsystem take place at INPE's plant in Cachoeira Paulista, SP. The program includes design, development, evaluation and qualification of various low thrust satellite monopropellant thrusters.

The INPE's Catalyst Group is responsible for development and production of the catalyst while Test Bench with Altitude Simulation is responsible for the tests during development and, later, for tests of qualification. The main objective is to verify if the Brazilian catalyst is as efficient as the S405, an Ir/Al_2O_3 based, long time used in satellites in worldwide commercial applications.

In this work, some results are presented obtained in comparative tests performed with Brazilian catalyst LCP-33R and the American S405, both Ir/Al_2O_3 based. All tests were performed in the same conditions: same apparatus, thrusters, durations, start temperatures and others.

2. CATALYST PREPARATION

Main steps in Brazilian catalyst preparations are:

- I- Alumina obtaining: precursor aluminum hydroxide precipitation, hydrothermal treatment in the presence of a ligature compound, molding, spheroidization and thermal treatment.
- II- Catalyst obtaining: multiple impregnations of the alumina with a Iridium solution. Iridium is the active phase of the catalyst.

3. TESTES AND RESULTS

All tests were made in the same 5 N thruster. This thruster had a suitable bolted catalytic chamber, which allows the utilizations of various catalysts. Both catalysts, S405 and Brazilian LCP-33R, performed the same campaign of tests, in the same environment conditions, with the same apparatus. All tests run at INPE's Spatial Center (CES), in Cachoeira Paulista, São Paulo. CES was built to give support to development and qualification of all thrusters used in Brazilian Spatial Programs.

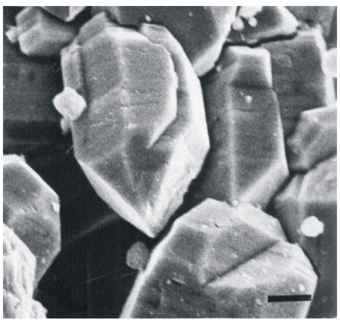
Each one of the catalysts were submitted to 39 (thirty nine) shots in various duration, start temperatures end fuel injection pressures. Table 1 shows a short description of all these shots. The total amount of time in tests is twice the necessary lifetime of a geo stationary satellite thruster. In Table 1, *Hot Start* indicates a pre heating to 120ºC, and *Cold Start* means a start with a temperature between 23 and 24ºC in catalytic chamber; *Test* is the sequential number of shot in the same campaign; *P* is the absolute pressure of fuel injection, in bar; t_{on} and t_{off} are the time in milliseconds, in pulsed shots, in which the fuel valves stay close or open during pulsed shots; *Pulses* is the number of pulses in pulsed shots.

Table 1. Description of shots for each one of the thruster campaign.

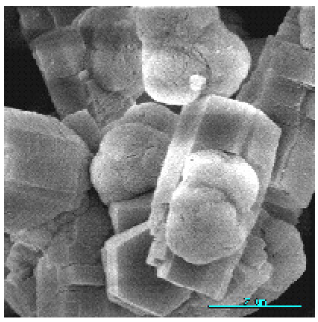
HOT START				
Test	**P (bar)**	**Pulses**	**t_{on} (ms)[a]**	**t_{off} (ms)[b]**
1	5,60	1	10 000	-
2	5,60	1	100 000	-
3	5,60	100	500	500
4	5,60	100	200	800
5	5,60	100	100	900
6	5,60	100	50	950
7	12,00	1	100 000	-
8	12,10	100	500	500
9	12,10	100	200	800
10	12,10	100	100	900
11	12,10	100	50	950
12	22,00	1	100 000	-
13	22,10	100	2 00	800
14	22,10	1	2 000 000	-
15	5,60	1	10 000	-
16	5,60	1	2 000 000	-
17	5,60	2000	500	500
18	5,60	2000	100	900
19	5,60	2000	50	950
20	12,00	1	2 000 000	-

HOT START (Cont.)				
Test	**P (bar)**	**Pulses**	**t_{on} (ms)[a]**	**t_{off} (ms)[b]**
21	12,00	1	10 000	-
22	12,00	2000	500	500
23	12,10	2000	200	800
24	12,10	2000	100	900
25	12,20	1	200 000	-
26	22,00	2000	500	500
27	22,10	2000	200	800
28	22,10	2000	100	900
29	22,10	100	500	500
30	22,10	100	200	800
31	22,10	100	50	950
COLD START				
32	5,50	10	50	950[b]
33	5,50	10	100	900[b]
34	12,10	10	50	950[c]
35	12,10	10	500	500
36	12,10	1	100 000	-
37	22,00	1	100 000	-
38	22,10	100	20	980
39	5,50	1	100 000	-

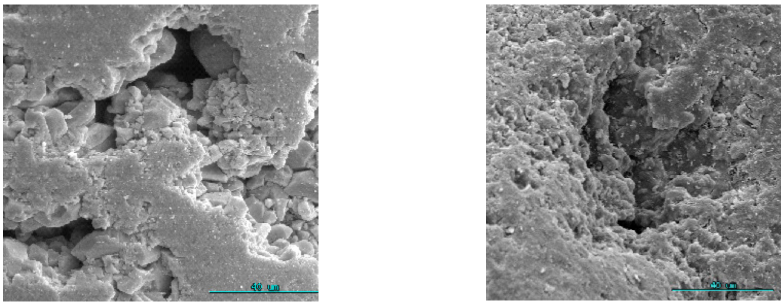
Microscopic photos (Fig. 1) take from both analyzed catalysts show their similarity. The high grade of crystallizes form observed in both catalysts guaranties a high grade porosity, which is one essential characteristic as it provides fast gases and heat release when hydrazine is decomposed in the catalytic bed.



S405 (5000 times)



LCP-33R support (5000 times)



S 405 (1000X) LCP-33R (1000X)

Figure 1. Electronic microscope images taken from LCP-33R, its support and S405 catalyst.

Figures 2 show similarity between LCP-33R and S405 in porous distribution

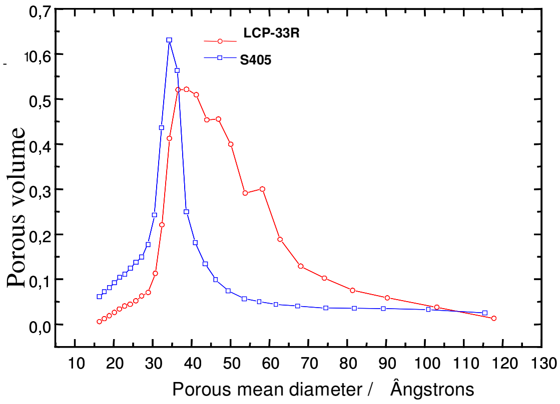


Figure 2 – Porous distribution of catalysts

Some tests performed at Test Bench with Altitude Simulation are presented at Fig. 3 and 4 below. Main parameters to be evaluated are thrust, pressure in catalytic chamber and overall temperature.

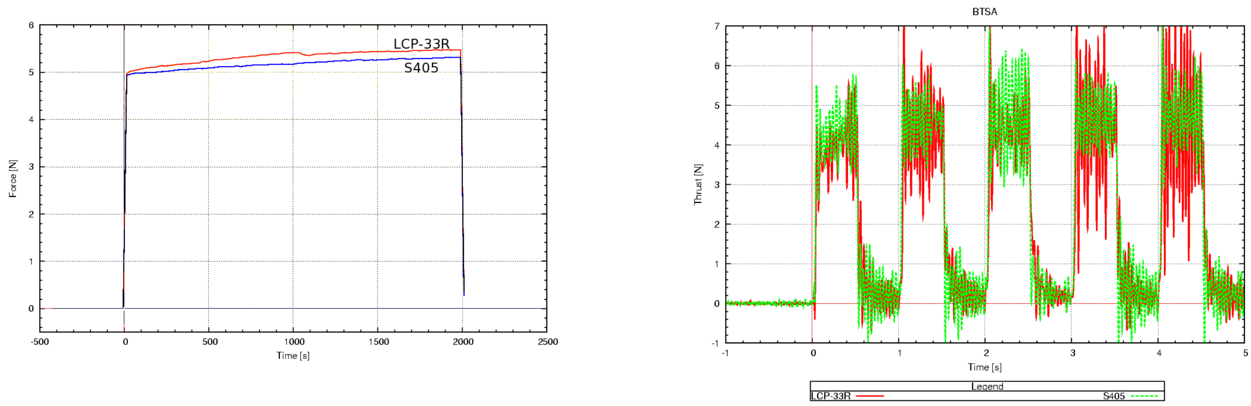


Figure 3 – Measured thrust in a continuous and in a pulsed (first 5 pulses), 2000 seconds duration shots There is no notable difference in both catalyst performance.

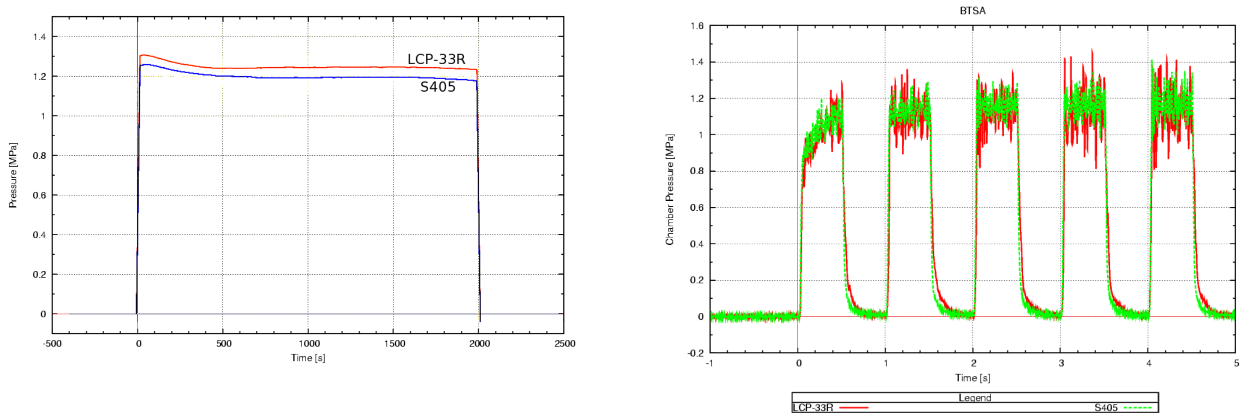


Figure 4 – Measured catalyst chamber in a continuous and a pulsed shots (first 5 pulses), 2000 seconds duration. In both situations, there are no significant differences between catalysts performance.

Figure 5 shows temperature in decomposition catalytic chamber for the same shots above.

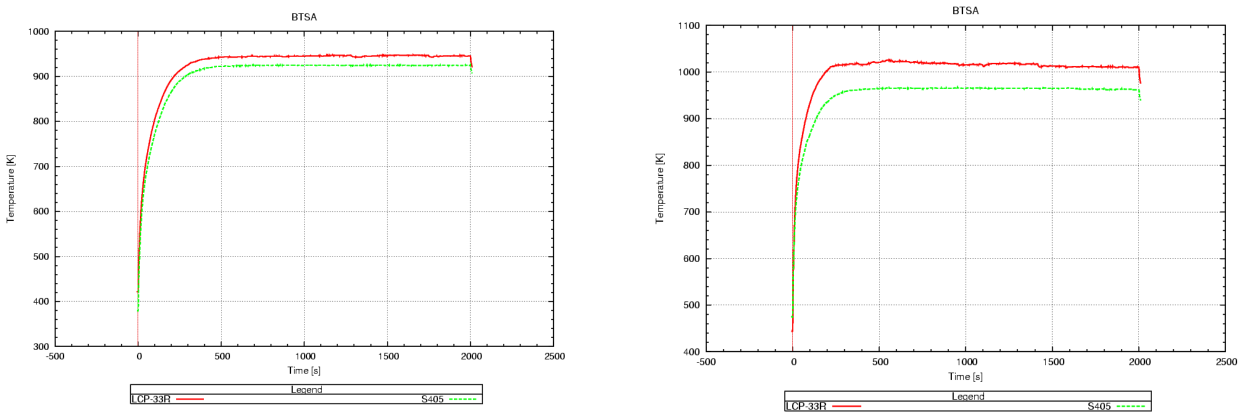


Figure 5 – Temperature in catalytic chamber, in a continuous (left) and a pulsed (right) shots.

Table 2 shows some parameters others than above obtained in others shot for both catalysts.

Test #	Catalyst	$P_{chamber}$ (MP_a)	Thrust (N)	T_{end} (K)
14	S405	1,2	5	960
	LCP-33R	1,25	5	1010
16	S405	0,375	1,4	850
	LCP-33R	0,35	1,2	880
17	S405	0,375	1,5	830
	LCP-33R	0,375	1,3	830
26	S405	1,15	5	920
	LCP-33R	1,15	5	940

Table 2. Some performance evaluation parameters obtained in others shots.

4- CONCLUSIONS

All tests results and chemical and physical characterization showed that Brazilian catalyst LCP-33R and the more utilized worldwide, the commercial S405, present same structural characteristics and performance as a catalytic. The Brazilian one shows physical properties, sometimes, greater than the S405. Utilization of Brazilian LCP-33R is possible in any propulsive subsystem in any satellites of Brazilian Space Program.

5. REFERENCES

Oberlander, R.K. Aluminas for Catalyst – Their Preparation and Properties. Applied Industrial Catalysis v.3, p.63,Academic Press, New York, 1984.

Sayer, C.F.; Southern, G.R. The Comparative Testing of the Shell 405, CNESRO-1 e RPE-72/1 Hidrazine Decomposition Catalyst. P.1-7, AIAA 73-1266, 1973.

Rodrigues, J.A.J. Relatórios Reservados. CENPES – Petrobrás / INPE.

Zacharias, M.A. Relatórios Reservados. IME / INPE.

6. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.