Control Characteristics of a Gel Propellant Throtteable Rocket Motor

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Abstract submitted to the
5th European Conference for Aeronautica and Space Sciences
Munich, Germany, 1 – 5 –July 2013

Established in the year 2000 by the German authorities, Bayern-Chemie and national Institutes, the national gel propellant team [Bayern-Chemie, Fraunhofer Institut für Chemische Technologie (ICT) & Deutsches Luft- und Raumfahrtzentrum (DLR)] started to develop the technology needed to build a rocket motor burning gelled propellants. The research and development activities were guided by a suitable principal concept for a gelled propellant rocket motor (GRM).

Based on theoretical considerations (regarding functional aspects) and experimental pre-tests (regarding propellant gelatinization and spraying) a motor system was pre-selected. The identified requirements were proven in December 2009 by two successful demonstration flights [1, 2].

The achieved Know-how on motor level, structured in feeding and injection system, burning chamber and gelled rocket propellant (GRP) has been extended in a systematic and application oriented way so that the goal of an effective control of the thrust by throttling the fuel mass flow rate (FMFR) is now realistic. This paper describes the advances in the development of the model and controller of the GRM, as an adequate model of the system is essential in order to optimize the controller performance. In Figure 1 a simplified scheme of the GRM can be seen. The gas generator (GG) chamber generates the necessary pressure to inject the GRP into the combustion chamber. The GG is activated through pyrotechnics, followed by initiation of the GRM ignition, which means that the system is not under pressure until that moment. The control valve and injector system regulate the FMFR.

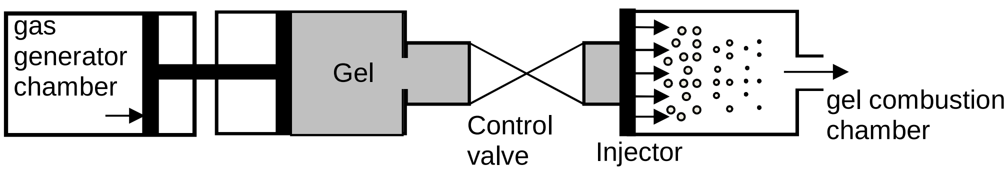

Figure 1 – scheme of the gel motor

A series of trials were performed in order to determine the GRP with the best control characteristics and performance. A brief description of three trials is shown in Table 1. Figure 2 shows a comparison between the three trials in terms of FMFR and achieved gas generator pressure (2a) and thrust (2b). For control purposes, it is essential to have a monotonic relationship between those two parameters for as large an interval as possible. It can be clearly seen that GRP-001 presents poor control characteristics without any benefits in term of added thrust compared to GRP-006 (Figure 2b).

Table 1: Trial description

Trial	Gel reference
A	GRP-001
B	GRP-002
C	GRP-006

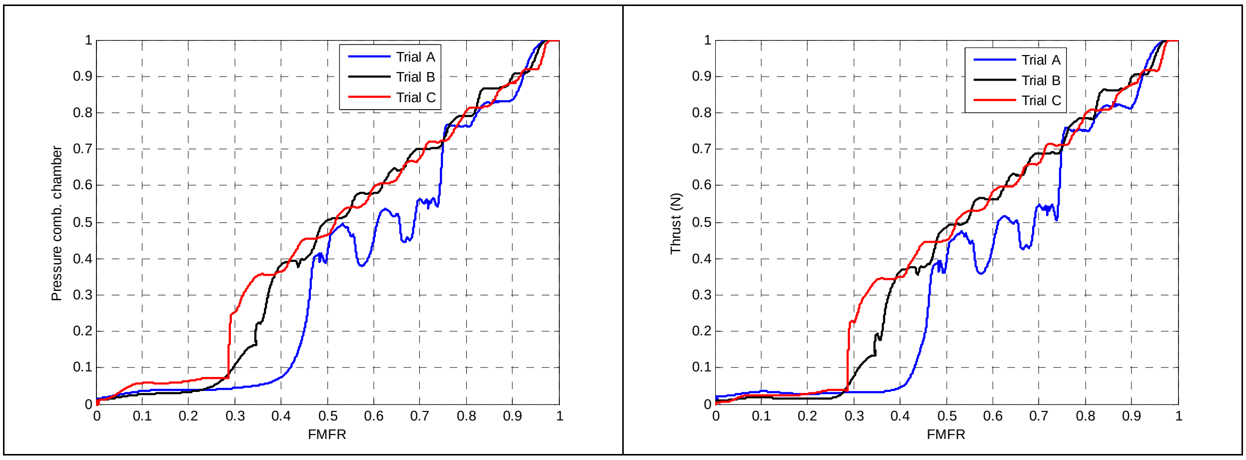

Figure 2a, 2b: FMFR – Pressure combustion chamber (a), FMFR – Thrust combustion chamber (b)

Based on these results, a GRM with GRP-006 was chosen to perform a series of control trials, in order to determine its basic control characteristics. A series of steps of increasing amplitude were given in an open pressure control loop. Enough time was given between steps for the pressure to settle. The trial results, as shown in Figure 3, indicate that the motor performs within the desired parameters, with a response time predominantly determined by the response time of the test control valve (i.e. the FMFR).

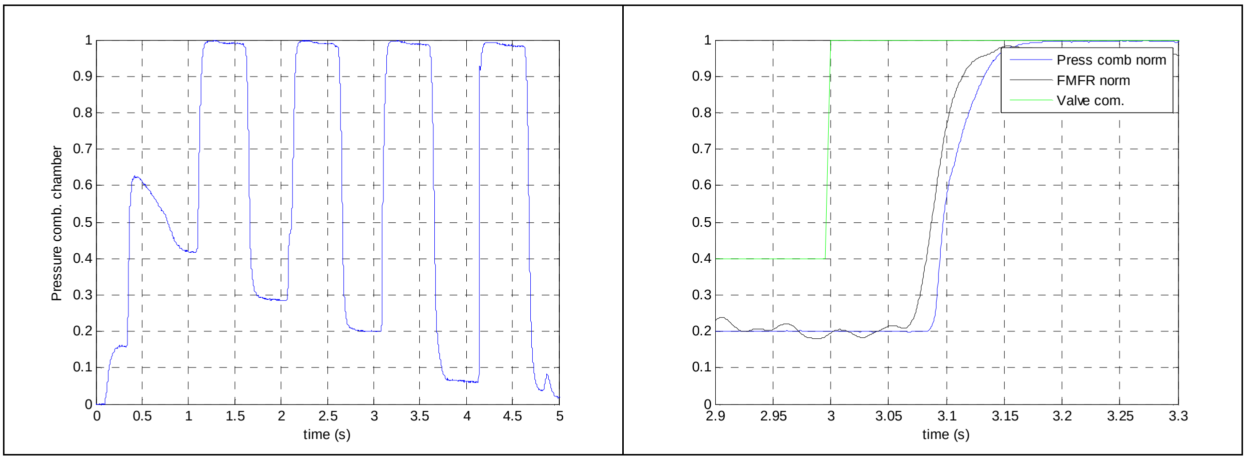

Figure 3a, 3b: Pressure combustion chamber (a), Pressure combustion chamber, FMFR and valve command for step Nr. 3 (b)

Figure 3a shows the normalized achieved pressure for the entire trial, which is composed of 4 steps. The pressure pique at t = 0.4 s indicates the ignition of the motor. The time delay between a FMFR increase and pressure increase in the GG is consistently lower than 5 ms (Figure 3b).

The results achieved with these and other trials indicate that the path forward for the development of the controller pass through an optimization of both the control valve and the injection mechanism. This paper will provide an overview of the work being done in that regard both at Bayern Chemie and at other institutions.

REFERENCES

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