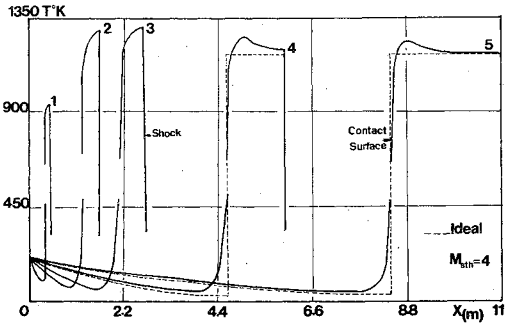

Fig. 3 Example of temperature profiles. 1. $t=550$; 2. $t=1350$; 3. $t=2100$; 4. $t=4350$; 5. $t=800$ μsec.

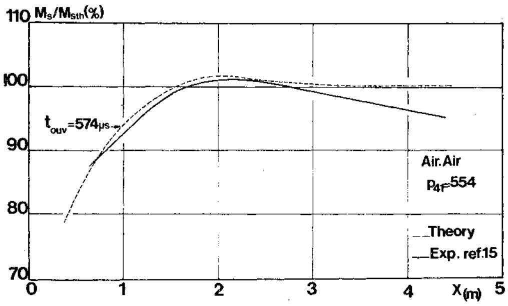

Fig. 4 Comparison of theory and experiments (Ref. 15).

t_{ouv}, but the value of this maximum M_{sm} is not affected. These results are in agreement with experimental data.[3] The influence of p_{41} has also been studied, and it has been shown that the initial acceleration and the abscissa of the maximum increase when p_{41} increases,[2] but the ratio M_{sm}/M_{sth} is only slightly modified. Finally, the lighter the driver gas is (high sound velocity), the more rapidly the ideal value is attained and the smaller the maximum is.

A comparison has been made with the experimental data of Ref. 15, for which viscous effects are small (Fig. 4). Keeping in mind the relative inaccuracy observed for t_{ouv}, which has not been given by the authors, the agreement may be considered as good in the acceleration phase.

Conclusion

The model may be improved by taking into account the following points: Temporal variation of the pressure on either side of the diaphragm, real gas effects, initial three-dimensional dissipative effects, noncentered expansion waves in the high pressure chamber, and turbulent transport phenomena at the contact surface. This model must also take into account boundary-layer effects,[6] so that comparisons with experimental data will be more significant.

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Effect of Electric Field on Composite Solid Propellants

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Introduction

COMPOSITE-SOLID propellants generally contain an oxidizer like ammonium perchlorate (AP). It has been shown recently by this school that the thermal decomposition of the propellant itself and the oxidizer contained in it play a significant role during the combustion.[1,2] The oxidizer (AP) decomposition, as shown by Maycock and Pai Verneker, seems to be controlled by the ionic diffusion process in the low-temperature region.[3] The ionic diffusion process, on the other hand, may further depend upon the nature of the charge-carrying species. For example, in AP it has been shown by conductivity measurements and electric field effects that the perchlorate ion is the charge-carrying species which controls the diffusion process during thermal decomposition.[3-5] Since the oxidizer decomposition seems to be the controlling process during the propellant decomposition, it is worthwhile to examine the effect of the electric field on the propellant decomposition and its subsequent ballistic behavior. The objective of the present Note, therefore, is to examine the effect of prior electric field on the thermal decomposition and burning behavior of the propellant. It may be mentioned here that no studies on the effect of prior electric field treatment on propellant behavior have been reported in the open literature.

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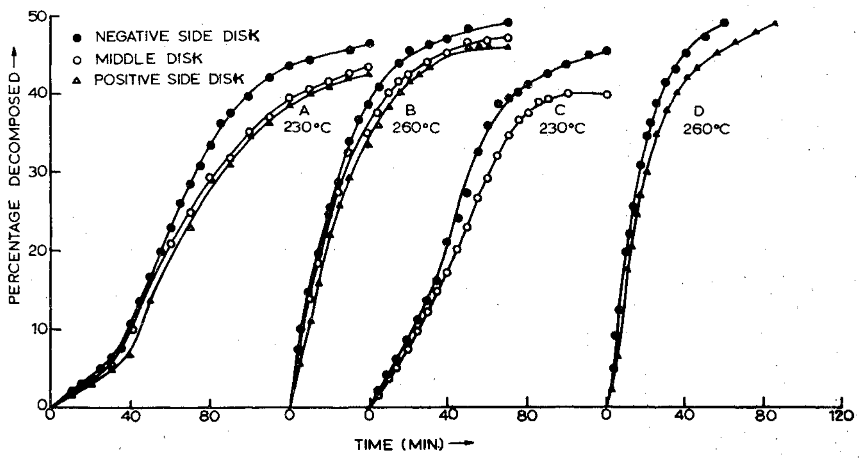

Fig. 1 Percentage decomposed vs time plots of polymethylmethacrylate/AP propellant (mixture ratio = 3; particle size = 40 to 105μ); *A* and *B* plots are for 48 hr preheating at 150°C, and *C* and *D* plots for 96 hr preheating at 150°C. The applied voltage in all the cases was 80 V.

Table 1 Effect of electric field on the thermal decomposition and burning properties of polymethylmethacrylate/AP (75%) propellant[a]

Time of heating, hr	Thermal decomposition rate, % min^{-1}						Burning rate, cm/sec		
	Positive side disk at 230°C	Middle disk at 230°C	Negative side disk at 230°C	Positive side disk at 260°C	Middle disk at 260°C	Negative side disk at 260°C	Positive side disk	Middle disk	Negative side disk
48	0.342	0.357	0.492	0.666	0.696	0.810	0.12	0.12	0.13
96	0.429	...	0.612	1.110	...	1.380	0.16	...	0.21

[a] Temperature = 150°C + 1°C, voltage = 80 V.

Experimental

Polymethylmethacrylate/AP (75%) propellant was made in a way similar to that of polystyrene/AP propellant and the details of the method are described elsewhere.[6] The assembly for observing the effect of the electric field was quite simple. Three identical circular disks of the propellant, 50 mm in diameter and 3-mm thick, were put close to each other, like a sandwich, between two stainless-steel electrodes held tightly together by means of stainless-steel springs. The whole electrode assembly was inserted horizontally into an enclosed tubular furnace (maintained at a temperature of 150 ± 1°C) such that electrode leads were protruded out of the furnace through a small axial hole. The electrodes were connected to an 80V dc power supply. After a certain heating period, the electrode assembly was taken out, and the three propellant pieces were removed with the aid of a sharp blade. It was observed that the negative side pellet was darker in color compared to that of positive side. Strips about 10-mm wide were cut from each propellant disk for the measurements of the burning rate and thermal decomposition studies. Burning rate measurements were done at ambient pressure in air.[6] Burning rate data are given in Table 1.

Thermal decomposition (Isothermal TG) studies were carried out on a home-made assembly as described elsewhere.[7] The system was slightly modified in the following way. A long perforated TG tube was used to avoid the deposition of sublimate on the quartz spring and hook. The distance between the furnace and the spring was kept at about 45 cm. The propellant samples of definite shape and size (vol/surface = 0.0512 cm and weight 50 mg) were used in all the runs. TG studies were done at 230°C and 260°C, and the percentage change in weight loss as a function of time was recorded. TG thermograms are shown in Fig. 1. Thermal decomposition rate was calculated from the time taken for the decomposition to take place from 10% to 40%. The results are given in Table 1.

Results and Discussion

Data presented in Table 1 very clearly show that thermal decomposition rate and the burning rate both follow the following pattern:

$$\text{Negative} > \text{Neutral} > \text{Positive}$$

The results also show that the thermal decomposition rate and burning rate both increase with time of keeping the sample under the electric field. Visual observation of the color (darker on negative side compared to that of positive) also supports the quantitative observations presented in Table 1. This suggests that the electric field changes the thermal decomposition characteristics which, on the other hand, are responsible for the change in burning rate.

Experiments using applied voltages of 40, 60, 100, and 150 V also were tried. The general pattern up to 80 V is the same as mentioned in Table 1. For voltages less than 80, it took several days to observe any significant change between the disk at the two electrodes. On the other hand, when the voltage was increased to more than 80 V, the disks became wet. The exact reason for this behavior is still under investigation. The wet disks showed an acidic behavior. This could be due to some sort of electrolysis.

Although the exact nature of the practical application of such a phenomenon is difficult to speculate at this stage, it seems possible that the propellant ballistic behavior could be changed in an already processed propellant which otherwise is not possible by any other means. Second, the same propellant may have low and high burning regions, and the burning behavior could be similar to that observed in liquid propellants by changing the propellant flow rate.

Acknowledgment

Thanks are due to G. Prasad of our group for carrying out the TG runs.

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L^* Oscillations and a Pressure-Frequency Correlation for Solid Rocket Propellants

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IN the early 1960's experimenters[1,2] working with metallized double base propellants, reported a correlation between the mean pressure $\bar{p}$ and the frequency F, at which (L^*) oscillations occurred in solid propellant rocket motors or in special devices such as T burners and L^* burners. Combining their data, one finds that for 0.1 MPa (0 psig) $<\bar{p}<1.5$ MPa (200 psig) there is a more or less linear relation between the mean pressure and the frequency at which the oscillations take place. Price[3] points out that the mechanism that controls the frequency of L^* oscillations is not well understood and that the $\bar{p}-F$ correlation is not as distinct for composite propellants as for double base propellants. On the other hand, Strand,[4] working with metallized and nonmetallized composite propellants presents $\bar{p}-F$ correlations over a small interval, approximately 0.4 MPa (60 psi).

Other experimenters[5,6] in the early 1970's did not attempt to correlate the frequency of L^* oscillations to mean pressure. They used only composite propellants, such as JPL 540, A-13 and variations thereof. During recent experiments[7] with double base ARP propellant in two L^* burners of different size,[8] a well-defined relation was observed between the frequency and the mean pressure at which the oscillations took place. All experiments exhausted in the atmosphere (about 0.1 MPa), and the L^* varies between 0.25 and 1.75 m. ARP composition is as follows: cellulose nitrate (12.6%N) 49.9%, glycerol tri-nitrate 36.4%, triacetin 8%, additives 5.7%. Experimental results are shown in Fig. 1. We note the following:

1) There are two regions in which L^* oscillations occurred for ARP propellant: a low-pressure, high-frequency region (0.15 MPa$<\bar{p}<$0.7 MPa and 40 sec$^{-1}<F<$100 sec^{-1}), and a medium-pressure, low-frequency region (1.25 MPa$<\bar{p}<$4 MPa and 10 sec$^{-1}<F<$50 sec^{-1}). To the author's knowledge, the existence of two regions has not been reported before, and since no L^* oscillations were observed for 0.7 MPa$<\bar{p}<$1.25 MPa, it is not clear whether the regions are connected or not.

2) The medium pressure range in which a linear $\bar{p}-F$ correlation was observed is much larger than previously reported for L^* oscillations.

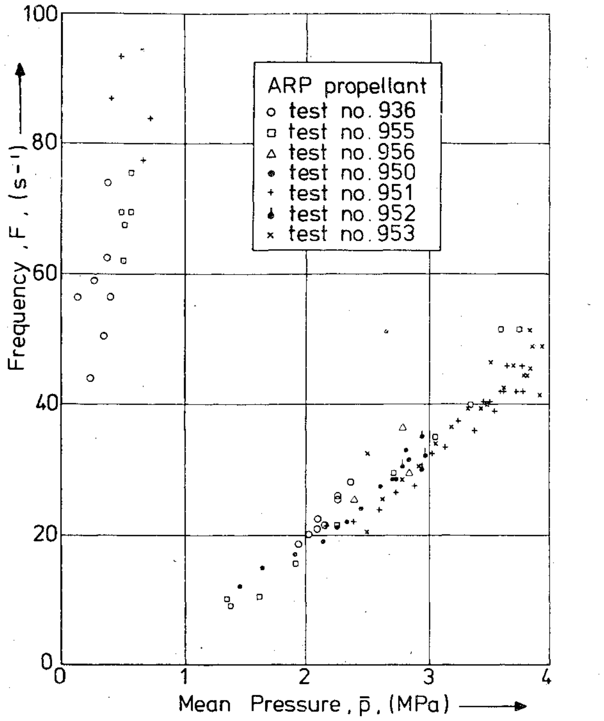

Fig. 1 Regions of linear mean pressure frequency relationship for L^* oscillations in 5-cm (open plotting symbols) and 10-cm L^* burners. (0.25 m$<L^*<$1.75 m.)

Figure 1 discriminates in the plotting symbols between the results of experiments carried out in L^* burners with 5 cm and with 10 cm i.d. Tests 936, 955, and 956 (open plotting symbols) were conducted in the 5-cm L^* burner, the other tests (closed plotting symbols) in the 10-cm L^* burner, and the $\bar{p}-F$ correlation is independent of the size of the L^* burner. Low-pressure, high-frequency oscillations are predominantly found in the 5-cm L^* burner tests, but test 951, conducted in the 10-cm L^* burner, is equally compatible with the other low-pressure, high-frequency data.

Earlier data by Eisel et al.[2] indicate for the L^* burner data, $dF/d\bar{p}\approx 4\times 10^{-6}$ m·sec·kg^{-1}. The medium-pressure, low-frequency data of Fig. 1 indicate $dF/d\bar{p}\approx 15\times 10^{-6}$ m·sec·kg^{-1}, which is of the same order of magnitude. However, the slope of the low-pressure, high-frequency data of Fig. 1 is much larger with $dF/d\bar{p}\approx 88\times 10^{-6}$ m·sec·kg^{-1}.

To determine whether composite propellants also yield a significant $\bar{p}-F$ correlation, older data[5,6] were reconsidered. Schöyer,[5] using A-13 propellant provided by the Naval Weapons Center, China Lake, presents tables listing $\bar{p}$ and the angular frequency ω. No $\bar{p}-F$ correlation could be traced from these data. Kumar and McNamara,[6] using CIT-2, Ã-13, CIT-3, and CIT-4 propellants, produced at JPL, present $\bar{p}$, but the frequency F must be deduced from other data.

No $\bar{p}-F$ correlation could be traced for CIT-2 propellant. The experiments with Ã-13 propellant yield a clear correlation, as is shown in Fig. 2. Around $\bar{p}=0.4$ MPa the frequency is at a minimum and the figure suggests that the right branch of the curve may continue as a medium-pressure, low-frequency correlation, while the left branch may become the low-pressure, high-frequency correlation. A correlation

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