Notes

Observations on the Effects of Materials on Card Gap Test Results

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THE dependence of the card gap value for a propellant on the container material has been previously reported.[1] The data reported here on nitromethane (NM) and a mixture of tetranitromethane (TNM) and acetonitrile (AN) confirm this dependence and, moreover, uncover certain effects that could be interpreted in terms of specific chemical or catalytic activity.

This card gap test is a standard test in the rocket industry used to determine the relative sensitivities of propellants to hydrodynamic shock.[2] It is capable of good reproducibility if one conforms to the conditions specified for the test. However, if the conditions are varied, then marked changes in the card gap value for a given propellant are possible.[1] The simplicity and reproducibility of the test and its sensitivity to experimental conditions suggested that it could be useful in obtaining qualitative or semiquantitative information on the effects of certain variables on the initiation and detonation processes of monopropellants. It was therefore decided to use this method to study two monopropellants. The variable of greatest interest was the propellant container material. In addition to varying container materials, small quantities of several solids were added to the monopropellants to assess the presence or absence of particular chemical or catalytic effects.

The basic experimental procedure was that of the JANAF Panel on Liquid Propellant Test Methods.[2] The propellants were reagent grade NM and a mixture of TNM (99 + % by weight) and reagent grade AN in the ratio of 2 moles of AN to 1 mole of TNM.

The container materials investigated were Teflon-coated steel (the standard container material), stainless steel 304, aluminum (T-3003), Pyrex glass, and Lucite. These materials were selected because of large differences in their chemical and mechanical properties. The dimensions of the cups prepared from these materials were very close to the dimensions of the standard cup. In some tests, small quantities of a variety of different solids, usually in the form of spheres (less than 1 cm^3 volume, equivalent to 7 to 10 in number), were added to the test containers. The card gap value was located to ± 5 cards, since only gross changes as a function of the variables were sought.

The card gap values of NM in the standard Teflon-coated steel, stainless steel, aluminum, Pyrex glass, and Lucite cups were 15–20, 20–30, 20–30, < 5, and < 5, respectively. The addition of solids (carbon steel, aluminum, glass, sand, and stones) to NM in the stainless steel and aluminum cups raised the card gap value by at least 10 cards to between 40 and 50.

The card gap values for TNM-AN in the standard Teflon-coated steel cup, stainless steel, and aluminum were 75, 95–100, and 180–200, respectively. Carbon steel, glass, and aluminum were added to TNM-AN contained in the stainless steel cup and resulted in an increase of card gap value from 95–100 to 145–165, 110–120, and to > 230, respectively.

In considering the effects of variations in container material and added solids on the card gap value of NM, no effect that can be uniquely attributed to the chemical nature of the material in contact with the NM can be discerned. The added solids tend to raise the card gap value, probably as a result of the enhancement of "hot-spot" formation in the detonation initiation process,[3] but all of the added solids are about equally effective. The card gap values of NM in the nonmetallic containers were considerably less than those in the metallic containers. The reasons for this are not precisely known at this time, nor can the fairly small differences between the card gap value of NM contained in Teflon-coated steel, and stainless steel or aluminum be explained. The tests are not sufficiently quantitative to justify a correlation with variations in chemical, physical, or mechanical properties of the materials in question.

The studies with TNM-AN were more limited than those with NM in that no nonmetallic containers were studied. Also, because TNM-AN is considerably more sensitive than NM, caution must be exercised in the interpretation of the results, since it has been shown that the initiating pressure pulse passing through a stack of cards falls off exponentially with increasing number of cards.[4] This notwithstanding, it appears that the marked effect of aluminum, whether it is in contact with TNM-AN as the container material or as an additive, in increasing the card gap value is evidence of some specific chemical or catalytic effect on the initiation process.

References

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Influence of Conduction on Spacecraft Skin Temperatures

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Nomenclature

A = area of shell
k = thermal conductivity of shell material
r = radius of shell
t = shell thickness
T = absolute temperature

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