Engineering Notes

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Assessment of the Thermal Decomposition and Combustion Behavior of Double-Base Propellants

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A KNOWLEDGE of the role of condensed phase reactions vis-à-vis gas phase reactions in the combustion of a propellant is essential in formulating models for combustion. The salient features of the role of condensed phase reactions in the combustion of solid composite propellants have recently been reviewed by Kishore.[1] Briefly, in the case of polystyrene (PS)/ammonium perchlorate (AP) propellants it was inferred from the earlier studies that condensed phase reactions contribute significantly to the total combustion process at ambient pressure.[1]

In the present investigation a double-base propellant (DBP) having the following composition (wt.%) was used: NC 57.5%; NG 26.5%; DNT/TNT 6.0%; dibutylphthalate 6.0%; 2-n DpA 1.5%; and inorganic salts 3.5%. Although much information on the combustion aspects of DBP is available, their thermal decomposition and the condensed phase reactions have not received much attention.

The differential thermogravimetric (DTG) trace of DBP, as shown in Fig. 1, reveals the following:

1) In stage I nitroglycerine (NG) leaves the propellant on heating by diffusion, characterized by an activation energy (E) of 14 kcal mole^{-1} in the temperature range 120-190°C.[2] Ayres and Bens[3] have observed endothermic vaporization during differential thermal studies of NG. The residue or undecomposed material at this stage is depleted in NG and is enriched in nitrocellulose (NC) as compared to the starting composition of the propellant. The above observations also get support from the DSC thermogram of NG (Fig. 1).

2) Stage II consists of an endothermic dissociation (190-205°C) of the trapped NG which could not diffuse out of the polymeric matrix at lower temperature. This can be seen as the second endotherm in the DSC thermogram of NG (Fig. 1). Ayers and Bens[3] have reported partial decomposition of NG during differential thermal analysis and gas evolution profile measurements.

3) Stage III consists of an exothermic decomposition of NC in the temperature range 205-215°C. This is also supported by the DSC thermogram of NC, as shown in Fig. 1.

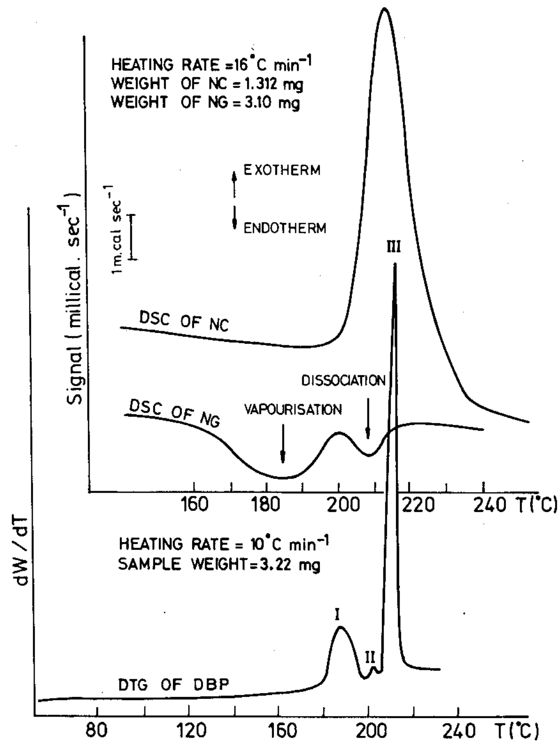

Fig. 1 DTG trace of DBP and DSC traces of NC and NG.

The combustion process of the DBP is characterized by the chemical analysis of the sliver residue (obtained from motor firings), which reveals that the burning surface gets depleted in NC and therefore becomes richer in NG compared to the starting composition of the propellant grain.

One can therefore infer that the NG vaporization rate is much faster compared to the NC decomposition rate during the thermal decomposition of the DBP, but during combustion it is just the opposite. This suggests that combustion and decomposition processes are dissimilar in DBP. From DSC results[4] and from calorimetric value determination[4] it was observed that the condensed phase heat release (during decomposition) is about 1/20th the heat produced during burning (calorimetric value). This suggests that condensed phase reactions have an almost negligible effect during the combustion of DBP, unlike the composite propellants where the condensed phase reaction's contribution is quite significant.[1] Kirby and Suh[5] have also observed that the condensed phase contribution is minor in DBP combustion.

References

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