Characterisation of Resin-Modified HTPBs for use in Composite Propellant formulations

Introduction

Composite propellants consist of solid filler particles suspended in a polymeric matrix. In order to achieve maximum performance the amount of solid filler is increased resulting in a viscous suspension. Such high viscosities present processing challenges during manufacture, as such other ingredients such as plasticisers are used as processing aids to lower the mix viscosity and make manufacture of such propellants easier.

Processing aids, often have no other purpose than to make the manufacture of certain formulations easier, they do not contribute to the energetic output of propellant systems and may themselves cause other issues that may need to be addressed, such as migration through the propellant grain in the case of plasticisers. Other additives, such as bonding agents are added to propellant formulations to increase the adhesion between the binder and the filler in order to enhance the mechanical properties and, for the most part, prevent cracking and deformation of the propellant grain during storage and use.

In composite propellant formulations, the most common polymer chosen is hydroxyl-terminated polybutadiene (HTPB) for its excellent mechanical properties over a broad temperature range as well as its potential for high solids loading. Once cured, HTPB provides an intricate polymeric solid matrix in which solid particles may be suspended.

Tackifying resins have been commonly utilised in the adhesive industry, but rarely, if ever, in propellants. This work utilises tackifying resins to modify HTPB creating a number of resin-blends and use these resin-modified HTPBs to produce composite propellant formulations. Functionally the resins are used to increase adhesion between the binder and the filler; potentially allowing formulators to remove common processing aids such as bonding agents and plasticisers. This paper focuses on the characterisation of these blends.

Initial Characterisation – Differential Scanning Calorimetry

HTPB is commonly chosen in composite propellant formulations for its excellent mechanical properties over a broad temperature range (-70 – 100°). As this work focuses on resin-modified HTPBs the initial work was to utilise DSC to ascertain the Glass Transition Temperatures of the pre-prepared resin blends, and directly compare them to pure HTPB.

	Structural notes	Literature Tg (pure) (°C)	DSC Tg (pure) (°C)	Tg (blend) (°C) (average)	Shift (°C)
HTPB	-	-76	-80.2*	N/A	N/A
E5380	DCPD (C9 derivative)	36	32.6	-74.3	+5.9
E5690	DCPD (C9), adjusted with aromatics	44	37.2	-74.0	+6.2
E2173	Piperylene (C5 derivative)	-	*	-74.8	+5.4
E1102	Piperylene adjusted with aromatics	51	46.4*	-77.0	+3.2

Upon modification of the HTPB with 4 different tackifying resins (a range of DCPD and Piperylene derivatives) the data shows a 3-6°C shift in the glass transition temperature, compared to the experimental value obtained for pure HTPB using the same experimental procedure. This indicates that while there is a slight shift to a higher temperature, however it is not significant and therefore would not initially indicate a substantial concern, however more would should be continued in order to comment further on the mechanical properties of such formulations.

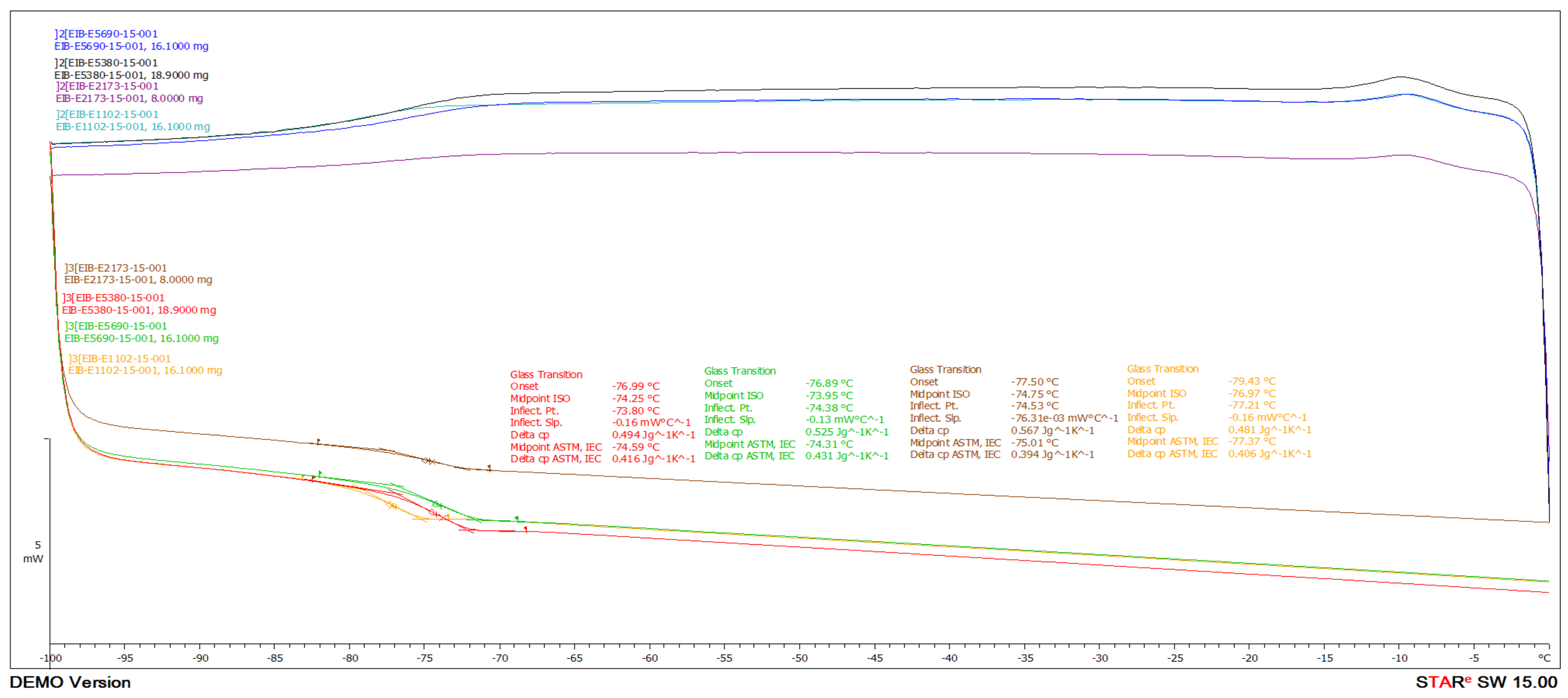
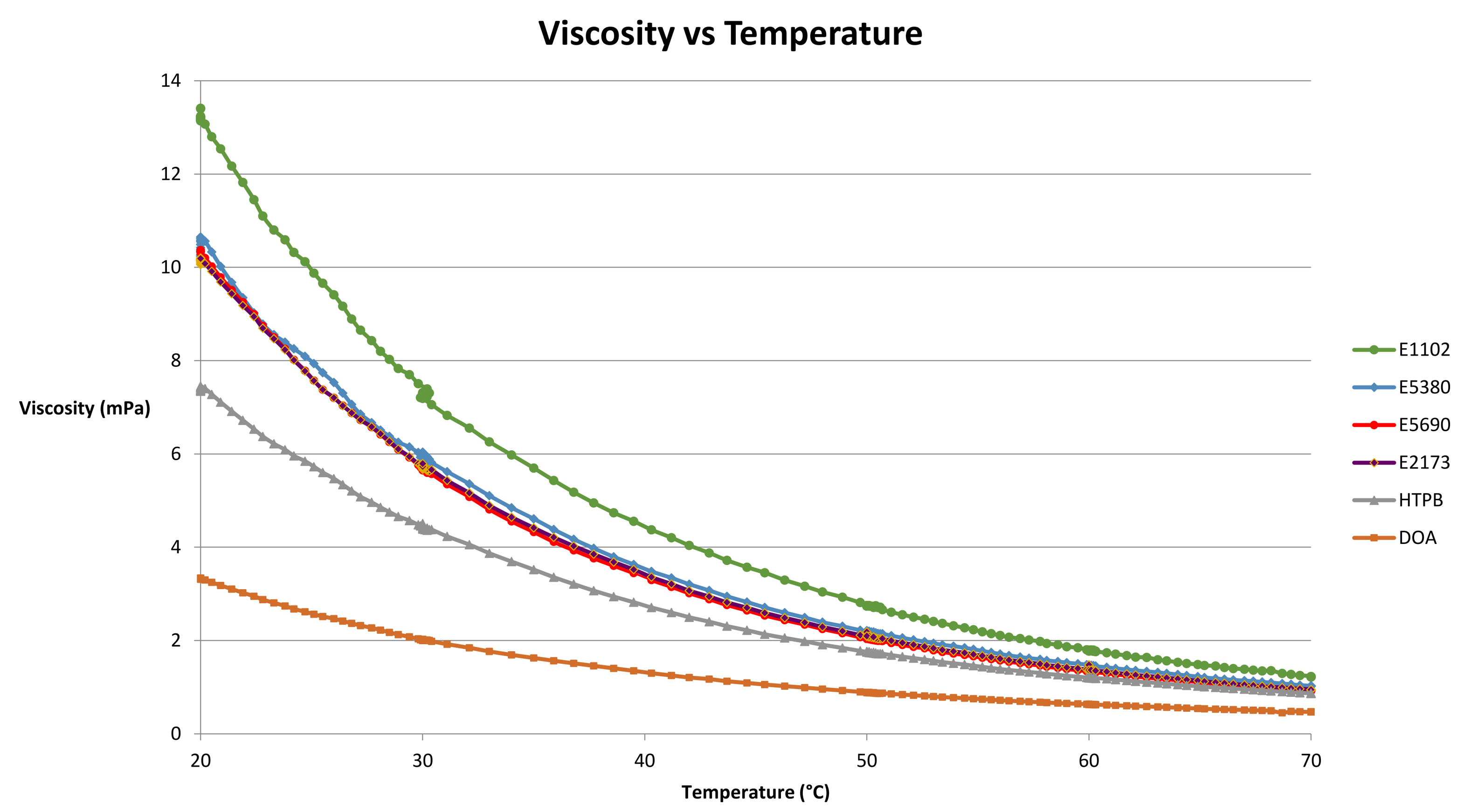


Figure 1. A comparison of the glass transition temperatures of 4 different resin-modified HTPBs using DSC at 5°C/min.

Rheological Characterisation – affect on processability

Ease of processability in composite propellant formulations is related to the viscosity of the final mix, and this is intrinsically linked with the viscosity of the binder itself and the interactions between the binder and the filler. As this work focuses on utilising tackifying resins to potentially increase the adhesion between the binder and the filler and therefore act as a bonding agent, we have focused on rheological characterisation to assess how modifying the HTPBs affects the viscosity of binder and therefore comment on the potential effects on processability.



For a range of 15% blends, compared with pure HTPB and a HTPB-DOA blend for comparison, at lower temperatures there is a significant increase in the viscosity of the binder on addition of the resin. However, at higher temperatures, especially those in the mixing temperature range (50-70°C) the difference in binder viscosity is significantly lower, indicating, initially, that addition of the resin would not adversely affect propellant formulation manufacture.

Further work is required to fully ascertain the affect of resin-modification of HTPBs in terms of rheological and mechanical effects, such findings will be reported on in future.

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