DYNAMIC MECHANICAL ANALYSIS OF NITROCELLULOSE-PLASTICIZER-MIXTURES

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Abstract

The glass transition temperature (T_g) of gun propellants is a critical parameter determining their behaviour at low temperatures. It marks the transition from the entropy elastic state to the energy elastic state and thus should be as low as possible. Determination of this transition is typically done by Differential Scanning Calorimetry (DSC) but can be problematic for low plasticizer contents. To overcome this shortcoming Dynamic Mechanical Analysis (DMA) was applied to binder-plasticizer-mixtures containing nitrocellulose and a dinitrodiazaalkane mixture (DNDA-57) and N-ethyl-N-(2-nitroxyethyl)nitramine (ethyl-NENA), respectively. The measurements were carried out in torsion mode with a frequency of 1 Hz.

The decomposition of the measured curve into exponentially modified gauss functions (EMG) reveals multiple processes at temperatures between -80 and 140°C (fig. 1). Both binder-plasticizer-systems exhibit 3 maxima of the loss factor of which each corresponds to a glass transition of a distinct part of the specimen, e.g. chain ends. The kind of plasticizer used mainly affects the first peak at low temperatures with ethyl-NENA being the plasticizer which leads to a lower glass transition temperature. The first maximum in the loss factor seems to be the glass transition that is also detected by DSC. There is only a small difference in the T_g values of DSC and DMA for both binder-plasticizer-systems. Despite the second peak being the most pronounced one it cannot be detected by DSC.

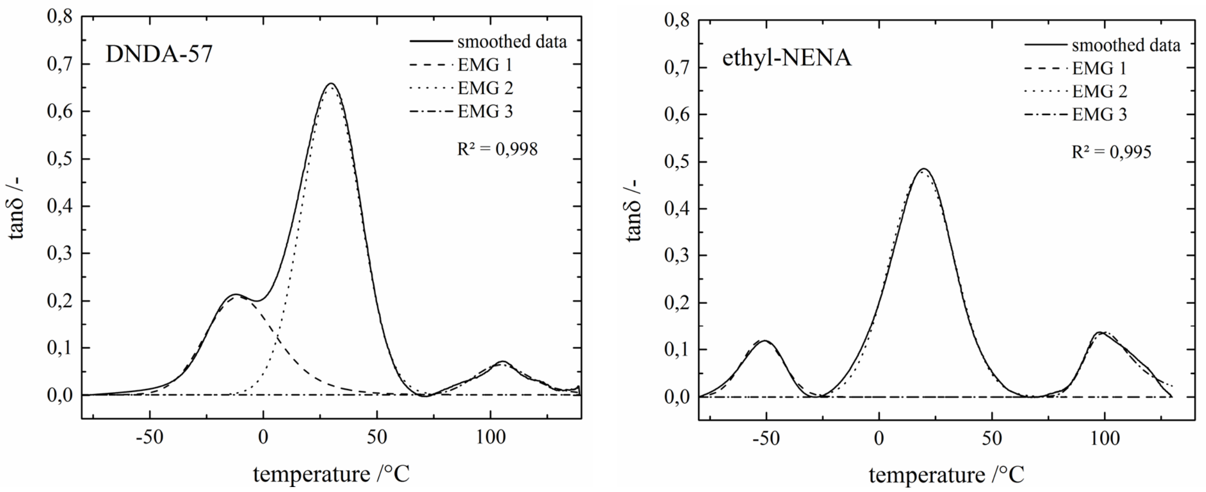

Fig. 1: Loss factor tanδ and exponentially modified gauss functions of binder-plasticizer mixtures with nitrocellulose and DNDA-57 (left) and ethyl-NENA (right), respectively. The mass fraction of plasticizer in the mixtures equals 0.5.

For both systems a decrease in the plasticizer content leads to a peak shift to higher temperatures (fig. 2) as the free volume is reduced and the segmental motion stops at higher temperatures. We assume that the first peak in the mixtures with 50 wt% plasticizer shifts to a temperature of about 60°C for ethyl-NENA and 67°C for DNDA-57 while the second and third are overlapping to a peak at around 100°C.

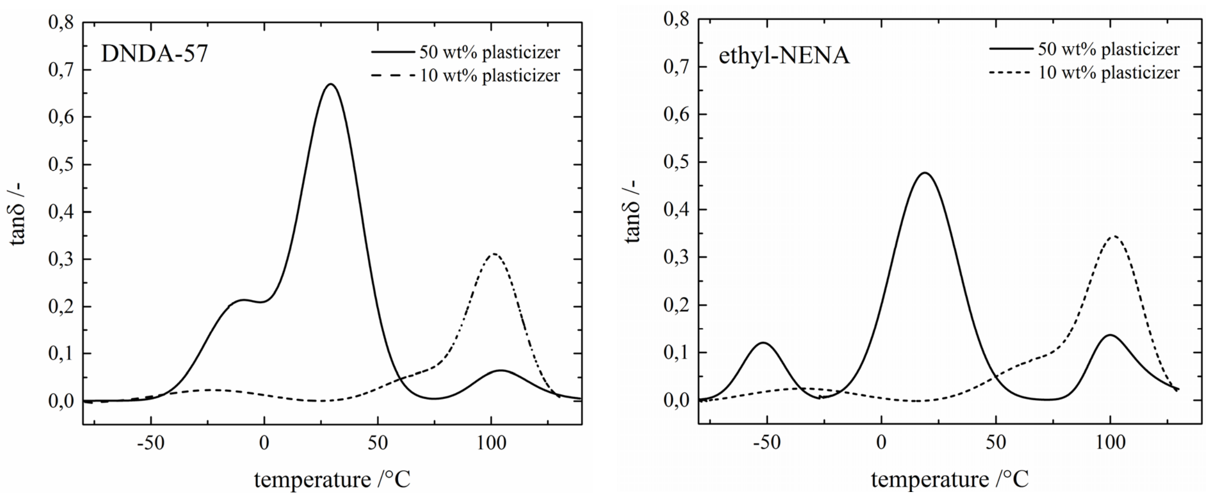

Fig 2: Modelled loss factor tanδ consisting of 3 exponentially modified gauss functions for nitrocellulose-plasticizer-mixtures containing different amounts of DNDA-57 (left) and ethyl-NENA (right), respectively.

As the observed behaviour of nitrocellulose-containing mixtures seems to be very complex these investigations have to be extended to other types of nitrocellulose and plasticizers to gain a deeper understanding of the underlying processes.