Foamed Propellants: Insights in the Foaming Process

Geschäumte Treibladungen: Einblicke in den Schäumungsvorgang

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Abstract

Foamed propellants are based on crystalline explosives like nitramines bonded in inert or energetic polymers. Due to their porous structures they show high burning rates in comparison to conventional gun propellants based on nitrocellulose.
Energy content and material characteristics such as burning behaviour can be varied by using different energetic fillers, energetic polymers and porous structures.
Therefore the foaming process has a great influence on the material properties and quality of the foamed propellants.
This paper outlines results received by various measurements using a specific laboratory equipment to characterise the foaming process. Parameters as rise height and rise profile are the classic methods. Additional informations can be derived measuring the temperature of the exothermic crosslinking reaction, the rise pressure and the dielectric polarisation during foam formation.

Kurzfassung

Geschäumte Treibladungen bestehen aus kristallinen Explosivstoffen wie Nitraminen, die in einer inerten oder energetischen Polymermatrix eingebunden sind. Im Vergleich zu konventionellen Treibladungspulvern auf Nitrocellulose-Basis zeigen sie aufgrund ihrer porösen Struktur hohe Abbrandgeschwindigkeiten.

Der Energieinhalt und die Materialeigenschaften sowie das Abbrandverhalten der geschäumten Treibladungen können in weiten Bereichen sowohl durch Auswahl der energetischen Füllstoffe und der energetischen Polymere als auch durch Einstellung von verschiedenen Porositäten variiert werden.

Der Schäumungsprozess besitzt einen großen Einfluss auf die Materialeigenschaften und die Qualität der geschäumten Treibladungen.
Die folgenden Ausführungen zeigen Untersuchungen des Schäumungsvorganges mit einem speziellen Schaumqualifizierungsgerät. Die Bestimmung von Steighöhe und Steigprofil sind klassische Methoden bei der Charakterisierung von Schäumen. Zusätzliche Informationen können aus dem Temperaturverlauf der exothermen Vernetzungsreaktion, dem Schäumungsdruck und der Änderung der dielektrischen Polarisation während des Schäumungsvorganges gewonnen werden.

Introduction

The properties of foamed propellants can be modified to a wide extent by the selection of ingredients as well as by the porous structure. Typical application areas are caseless ammunition and combustible cartridges [1-9]. Due to the chosen manufacturing procedure - the reaction injection moulding - it is possible to achieve complex geometries [10]. As well it is possible to produce modular or layered charges of different porosity and also composition. The foaming process is decisive for the quality of foamed propellants. Therefore it is necessary to have close insights in this process.

Experimental

The classic method for characterising foams is to determine the rise height or height profile by recording expansion of a foam sample in a cup as a change of height. The starting and the rise time are determined from the height curve. Although these terms have not been standardised the starting time is generally accepted to be the start of the reaction between the mixed components after metering. The rise time is the time which elapses until maximum expansion is occurred. Ultrasonic sensors are suitable for measuring the rise height.
The exothermic crosslinking reaction causes the rising temperature in the foam sample. Thin thermocouples are a good solution to measure the temperature of foam because they have a low heat capacity and are easy to handle.
Pressure builds up in the foam after the components have set. The forming network of stable cell walls prevents the foam from further expanding and the blowing agent from

escaping. The rise pressure is measured in a special expansion vessel into which the reaction foam are poured. The expanding foam stresses the bottom of the expansion volume. That is where the pressure force is measured. The force sensor is protected by a PE film to avoid contamination.

Dielectric polarisation is a new measuring parameter in the field of foam qualification. Chain formation precedes the crosslinking reaction that ultimately suppresses all dipole mobility during curing. For repeatable measurements of the dielectric polarisation, the foam must be in contact with the polarisation sensor. This is ensured by an arrangement in which the polarisation sensor is located in the bottom section of the expansion vessel. The dielectric polarisation is measured as the increase in capacity relative to the empty vessel. This can be used to assess the setting times of foams. Another application for this system is to measure the influence of catalytic effects [11].

Results

The following figures show the results obtained by the investigation of a polyurethane foam. First the polymer system was investigated without fillers or other ingredients. Than the influence of water, blowing agent or an inert filler added to the basic system was tested. The addition of water as well as blowing agent yields an uniform increase of the rise height during the foam formation (Fig.1).

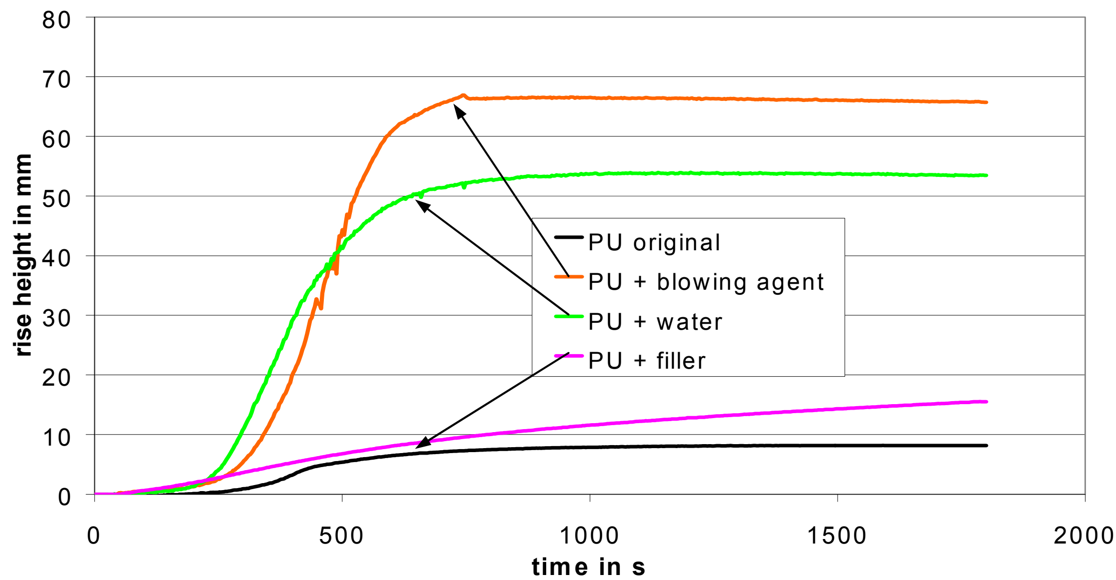

Figure 1: Rise profiles of different polyurethane systems during foam formation

The temperature curve of the foaming process is in principle comparable for the original polyurethane system as well as for the system with blowing agent. Therefore the blowing agent added has only a limited heat of evaporation and withdraws only a limited energy from the system during the foaming process. The addition of water yields a temperature rise during foam formation caused by the exothermic chemical reaction between isocyanate and water. The addition of a filler (69 weight%) changes dramatically the temperature curve compared to the original polyurethane system due to its high heat capacity (Fig.2).

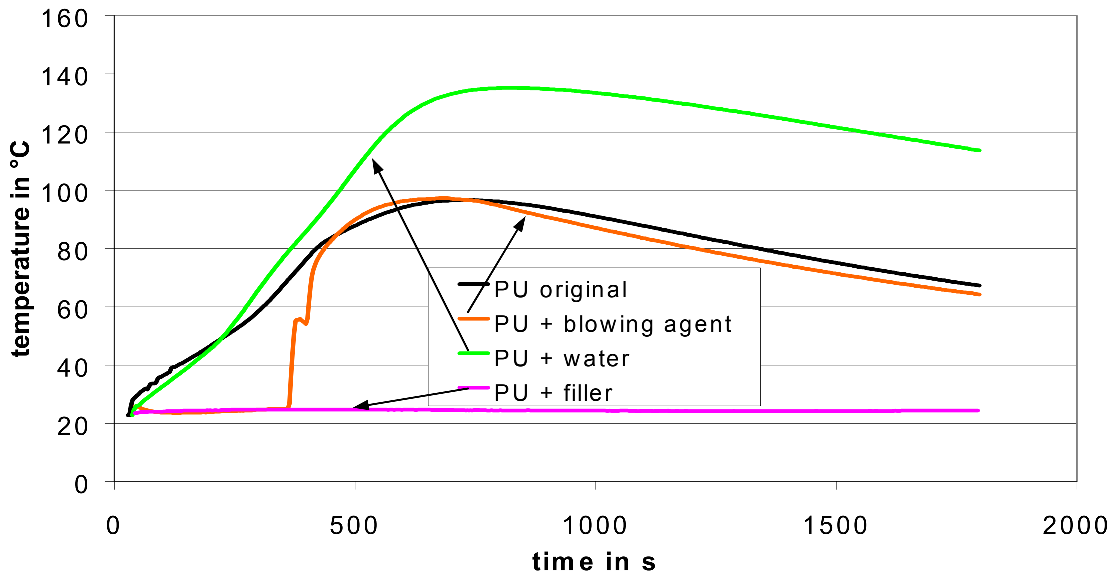

Figure 2: Temperature profiles of different polyurethane systems during foam formation

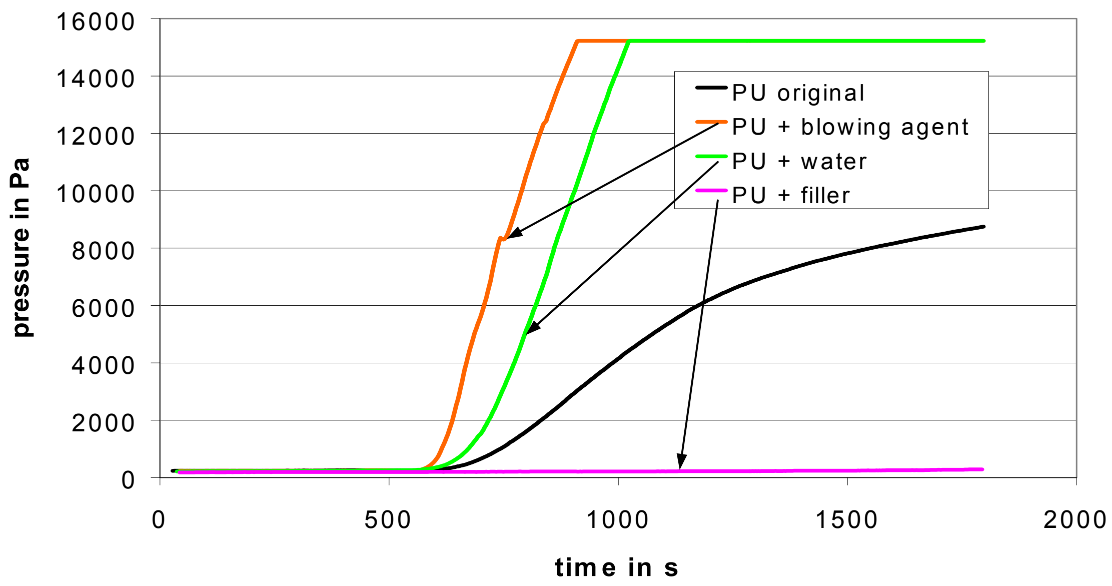

Figure 3: Pressure profiles of different polyurethane systems during foam formation

The addition of water as well as blowing agent to the polyurethane system causes a tremendous increase of pressure in the cell structure during the foam formation, which can even be higher than the recording limits of the test equipment, whereas the addition of filler yields into the formation of a foam body of high mechanical stability being able to absorb the foam pressure without any visible deformation. (Fig.3)
The crosslinking reaction depicting by the curve of the dielectric polarisation is fastest in the original polyurethane system compared to the other measured systems with water, blowing agent or inert filler (Fig.4).

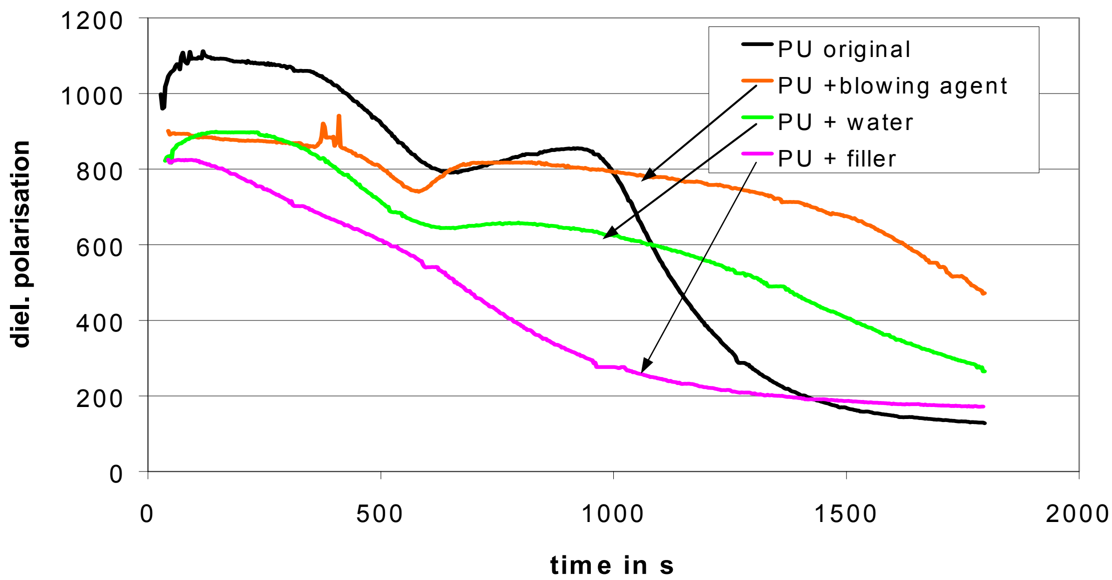

Figure 4: Profiles of dielectric polarisation of different polyurethane systems during foam formation

Conclusions

The described method of foam qualification allows to get insights into the processes during foam formation. Therefore it is possible to check the quality of the foam. Foaming parameters as rise height, temperature curve, foam pressure and dielectric polarisation are measured and can be compared regularly with representative samples. When foam systems with special properties are being developed, measuring the formation parameters accords an insight into the proceeding of the reaction and into the effects of additives, blowing agents, stabilisers and the mixing ratio for the foam formation.

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