INVESTIGATION OF QUALITY AND REPRODUCIBILITY OF FOAMED PROPELLANTS

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Abstract

Foamed propellants are based on crystalline explosives bonded in energetic reaction polymers. Due to their porous structures they are distinguished by high burning rates. Energy content and material characteristics can be varied by using different energetic fillers, energetic polymers and porous structures. Foamed propellants can be produced by the reaction injection moulding process (RIM). The properties of the propellants have to show a high reproducibility in order to provide a proper function in the weapon. Therefore a lot of quality studies of propellant charges have been performed.

The evaluation of the quality of foamed propellants manufactured by the reaction injection moulding process by different methods will be presented in this contribution as well as the influence of some processing parameters on the quality of the foamed propellants. Especially, the homogeneity of the propellant will be under consideration. Therefore the propellants were cut into segments of which the density was measured.

1. 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 which can be manipulated by process parameters. Typical application areas of foamed propellants are caseless ammunition and combustible cartridges. Compared to conventional gun munitions with their metallic case the main advantages of caseless ammunitions lie in its low weight and volume. Due to the absence of a protective metallic case there are very stringent requirements regarding the material properties of the foamed propellants. Dimensionally stable and combustible cases with high energy content, high burning rate, low sensitivity and good chemical stability and a good reproducibility of the material properties are needed.

2. Manufacturing process

The basis of the foamed propellants is a reactive binder system filled with octogene (HMX) and other energetic components and some additives. Mainly polyurethanes are used as reactive binder. The polyol component contains an energetic part (e.g. the glycidylazide polymer GAP).

Foamed charges can be produced easily by the reaction injection moulding process. The reaction injection moulding (RIM) is an industrial process for the mass production of a wide variety of plastic parts mainly using polyurethanes. For the manufacturing of foamed propellants a semi-continuous remote controlled production plant in pilot scale was set up and a modified reaction injection moulding process was applied. The principle of the modified reaction injection moulding (RIM) process is shown in figure 1.

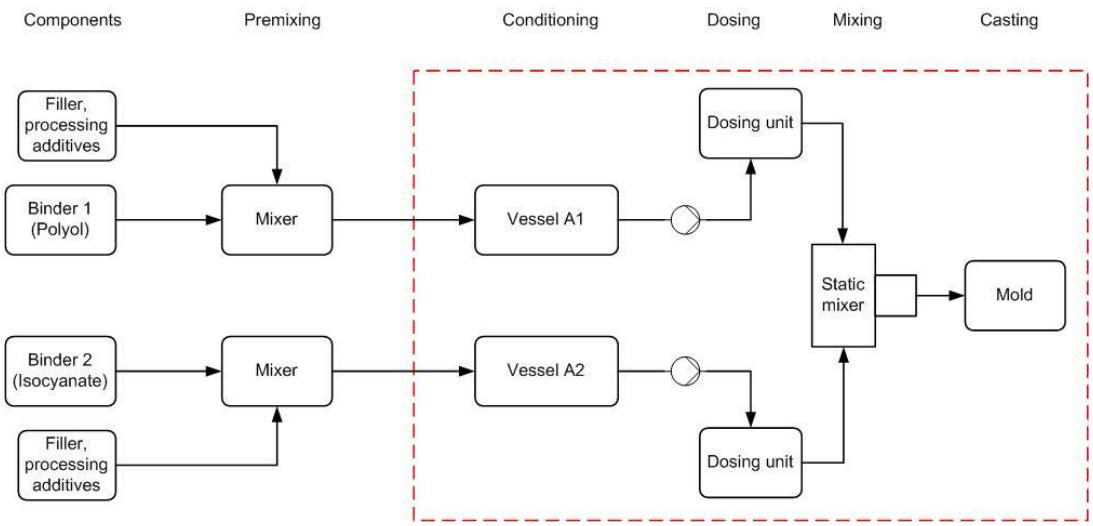

Fig. 1: The principle of the RIM process

The energetic solid filler material is distributed on both binder components and premixed in two mixers outside of the machine to obtain a homogeneous system. These premixtures are loaded into two vessels in the machine. From there the mixtures are conveyed by a piston into the dosing cylinder and then into the static mixer. Here, both premixtures come together and flow into the mould where the reaction takes place. Due to the high solid filler content the viscosities of the premixtures are very high so that the injection time is relatively long. The machinery is equipped with some special features so that energetic material can be processed safely with it. Pressure and temperature are measured at different points in the equipment and recorded by a computer.

We used a mould in which six foamed propellants can be manufactured simultaneously. Eleven of such moulds can be filled in one batch in the machinery so 66 pieces of foamed propellants can be produced in one batch.

3. Results

In the next figure a caseless ammunition based on a foamed propellant with bullet in the fully telescoped version is shown.

Fig. 2: Caseless ammunition consisting of foamed propellant, bullet and powder

In this configuration it becomes clear that a very compact and light ammunition system is presented. This is a great advantage compared to conventional ammunition with a metallic shelter.

The focus of our work described here was to investigate the quality and reproducibility of the foamed propellants in one manufactured lot.

The first step in manufacturing foamed propellants is to adjust the dosing volume and the dosing time for the premixtures of the chosen formulation. The shorter is the dosing time the higher are the pressures during processing of the premixtures.

The next figure shows as an example the pressure values of the two premixtures during an injection moulding experiment. The pressure in the isocyanate line is in the range of 8 bar, the pressure in the polyol line is just below 10 bar. The viscosities of the isocyanate and polyolpremixture were 204 Pas and 304 Pas, respectively. It is important that the pressure values are very uniformly during the whole process of filling of each mould.

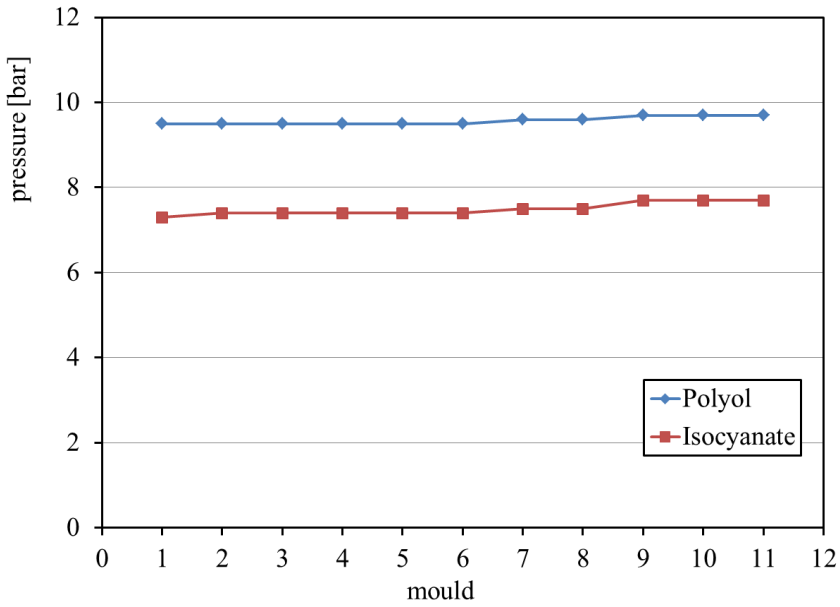

Fig.3: Mean pressure of polyol and isocyanate during the injection process

After manufacturing of a lot of foamed propellants their weight accuracy is a good criterion for quality reasons. In the next figure the weights of the foamed propellant of one lot are shown, each mould contains six foamed propellants. In this experiment a very good accuracy was achieved. The mean value of the weight of the 66 foamed propellants is 9.9 g, the standard deviation is 0.09 g (0.9% of the mean value).

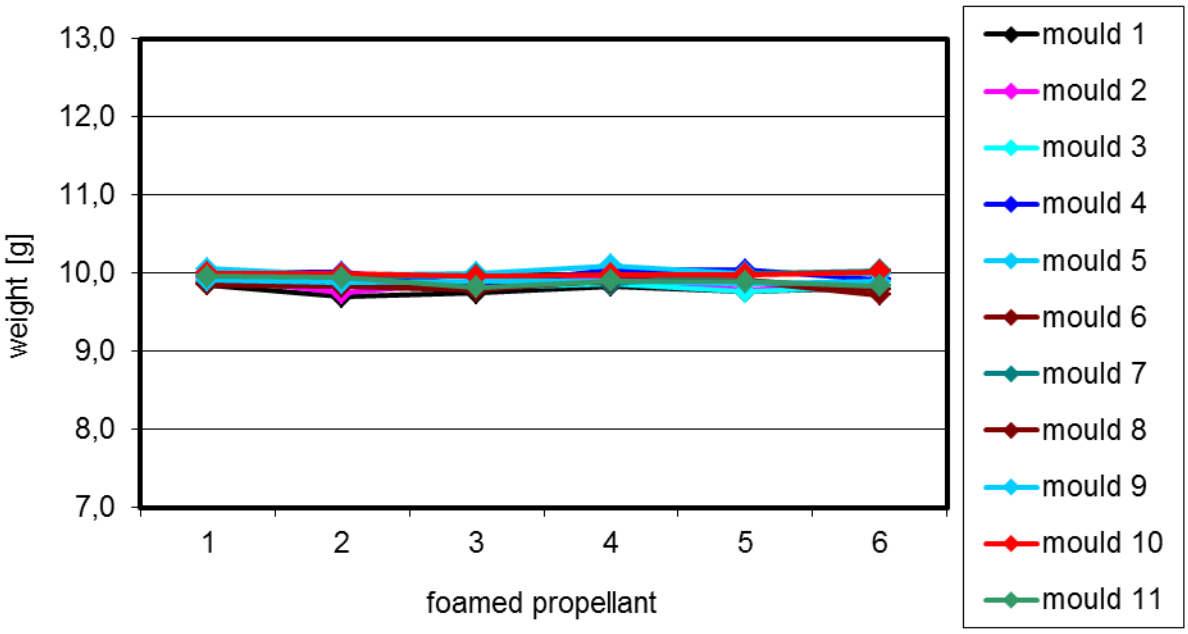

Fig.4: Weight values of the foamed propellants of one manufacturing lot

The homogeneity and quality of the foamed propellants was determined using y-ray investigations. The following pictures show two examples. The first one shows the foamed propellants of three moulds with a low quality. There are a lot of blowholes of different sizes in all foamed propellants.

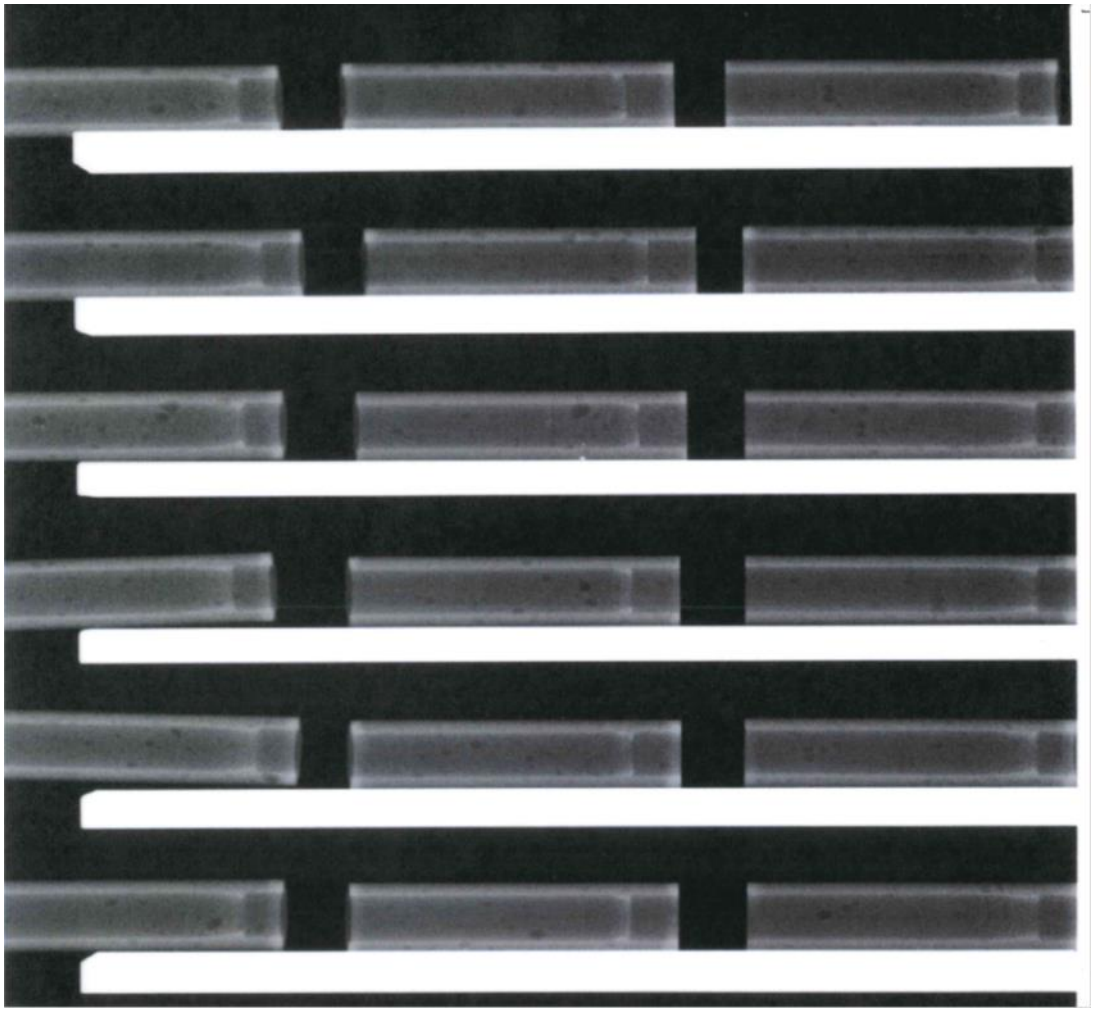

Fig.5: X-ray pictures of foamed propellants of three moulds in one lot

The second picture shows a better result, the foamed propellants are very homogeneous in the pore size distribution. In this experiment other processing parameters were used during manufacturing of the foamed propellants.

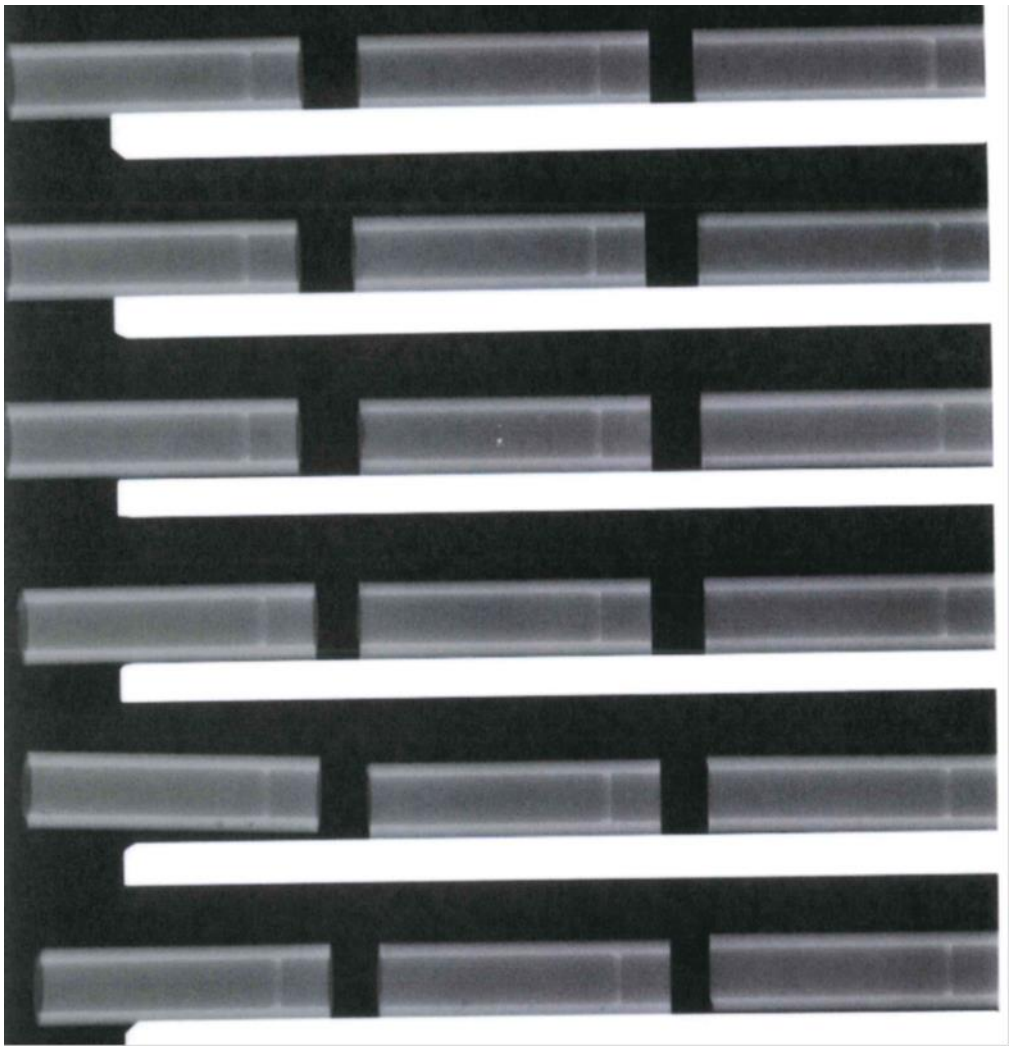

Fig.6: X-ray pictures of foamed propellants of three moulds in another lot

The quality of foamed propellants is investigated by determining the density of segments of foamed propellants, too. Therefore each foamed propellants was cut into two segments and the weight and dimensions of the segments were measured. The following table shows the results for six propellants of one mould. It is obvious that the lower segment (near the sprue) of each foamed propellant has a lower density than the upper segment of the same foamed propellant. This behaviour is reproducible.

Table 1: Weight and density of the manufactured foamed propellants and segments after cutting

	weight	density	density	density
	[g]	[g/cm^3]	[g/cm^3]	[g/cm^3]
Mould-foamedpropellant	original	original	Segment 1	Segment 2
			Lowerpart	Upperpart
1-1	10,61	1,24	1,21	1,27
1-2	10,40	1,23	1,18	1,26
1-3	10,45	1,23	1,19	1,26
1-4	10,53	1,23	1,19	1,27
1-5	10,62	1,25	1,20	1,28
1-6	10,46	1,23	1,19	1,26
Meanvalue	10,51	1,23	1,19	1,26
STD	0,09	0,01	0,01	0,01

This behaviour has to be investigated in more detail in the future.

4. Conclusions

Foamed propellants can be produced with a high reproducibility by reaction injection moulding. The properties of foamed propellants can be adjusted by changing the formulation as well as the porosity of the matrix. By using foamed propellants as combustible charges or caseless ammunition a high quality and reproducibility of their properties are needed. Therefore a lot of different examinations of the foamed propellants are performed to control the quality of a production batch.

Further experiments will be carried out investigating the density gradient in the foamed propellants.

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