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Burning performances of some guanidine derivative compound/ammonium nitrate/copper (II) oxide mixtures

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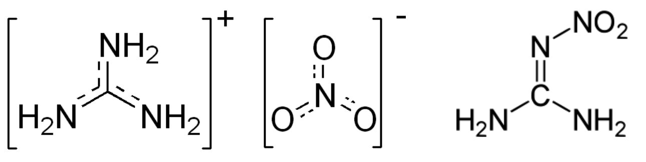
Abstract

Linear burning rates and rates-of-pressure-rise of some guanidine derivative compound/ammonium nitrate (AN)/ copper (II) oxide (CuO) mixtures, where guanidine derivative compound was either guanidine nitrate (GN) or nitroguanidine (NQ), were measured. While GN/AN/CuO mixture with 5 wt% CuO has shown the maximum linear burning rate among GN/AN/CuO mixtures that were studied, and also close to that of GN/strontium nitrate (SrN)/ basic copper nitrate (BCN) mixture that is used commercially as gas generating agent for automobile airbag inflators, all NQ/ AN/CuO mixtures that were studied has shown equivalent burning rates and also equivalent to that of GN/SrN/BCN mixture. As for the average rate-of-pressure-rise, GN/AN/CuO mixture with 5 wt% CuO has also shown the maximum value among all GN/AN/CuO mixtures that were studied and also close to that of GN/SrN/BCN mixture, while NQ/AN/ CuO mixture with 10 wt% CuO has shown the maximum value among all NQ/AN/CuO mixtures that were studied, and also exceeding that of GN/SrN/BCN mixture.

Keywords : guanidine nitrate, nitroguanidine, ammonium nitrate, linear burning rate, rate-of-pressure rise

1. Introduction

Throughout the years, there have been researches and developments going on regarding ammonium nitrate (AN) based gas generating agents for automobile airbag inflators[1)-6)]. In order to use AN as an oxidizer for new gas generating agents in automobile airbag systems, the burning performances of AN based mixtures need to be improved. In this study, either of guanidine derivative compounds, i.e. guanidine nitrate (GN) (Figure 1 (a)) or nitroguanidine (NQ) (Figure 1 (b)), was selected as fuel component, and to improve burning characteristics, copper (II) oxide (CuO) was selected as an additive. Burning performances of some guanidine derivative compound/AN/CuO mixtures were measured through linear burning rate tests and rate-of-pressure-rise tests.



(a) Guanidine nitrate (GN) (b) Nitroguanidine (NQ)

Figure 1 Chemical structures of (a) guanidine nitrate and (b) nitroguanidine.

2. Experimental

2.1 Sample preparation

GN, NQ and AN were dried separately at room temperature under reduced-pressure, and they were crushed separately through separate ball mills, and subsequently sieved separately to particle size ranges between 75 -150 μm, 75 -150 μm and 75 -149 μm, respectively. After either of the guanidine derivative compounds and AN were mixed at stoichiometric ratio (GN/AN : 43.28 wt%/56.72 wt% ; NQ/AN : 39.40 wt%/ 60.60 wt%), 1, 5, 10 or 20 parts by weight of dried CuO was added to 100 parts of GN/AN mixture, and 5, 10 or 20 parts by weight of CuO was added to 100 parts of NQ/AN mixture, and these mixtures were mixed mechanically through V- shaped rotating mixer.

2.2 Linear burning rate test

Approximately 4 g mixture was pressed at 190 MPa for 1 minute by using a hydraulic press to produce a cylindrical pellet with 14.7 mm in diameter. The side surface of cylindrical sample pellet was coated with flame-resistant silicone sealant (TSE 3941, Momentive Performance Materials), in order to achieve end-burning that is necessary for the measurement of the linear burning rate. Linear burning rate tests were carried out for all samples in a 1 L closed vessel. The procedures of the test could be found elsewhere[5].

2.3 Rate-of-pressure-rise test

A cylindrical pellet of approximately 4 g that was made by the same process as above without restrictor, in order to achieve side-burning of the pellet that emulates the combustion of gas generation agent pellets inside combustion chamber during deployment of an airbag, was produced and the rate-of-pressure-rise tests were carried out in the same closed vessel. The procedures of the test could be found elsewhere[5].

3. Results and discussion

3.1 Linear burning rate test

Figures 2 and 3 show the correlations between r and average absolute pressure, P, for GN/AN/CuO mixtures and NQ/AN/CuO mixtures, respectively.

Correlations between r and P for all mixtures could be approximated by equation (1), which is known as Vieille's equation.

$$r = aP^{n} \quad (1)$$

where a is a pre-exponential factor and n is a pressure exponent. Table 1 shows the summary of the correlations. GN/AN/CuO 5 wt% mixture has shown the maximum r among all GN/AN/CuO mixtures that were studied and it was close to that of GN/SrN/BCN mixture, while all NQ/AN/CuO mixtures studied have shown similar r and they were also equivalent to that of GN/SrN/BCN mixture.

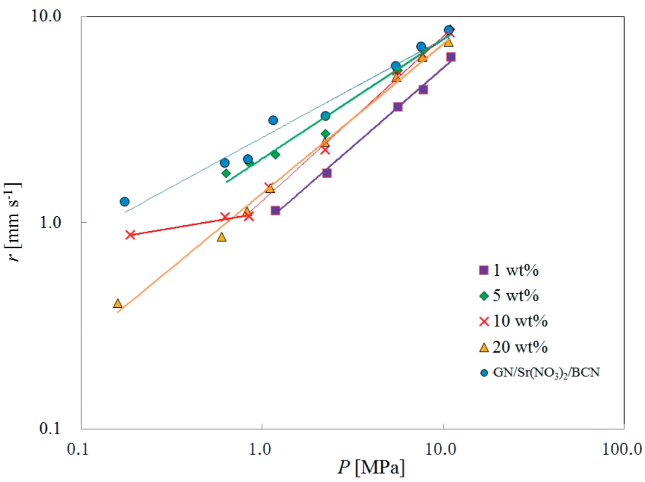


Figure 2 Linear burning rate data for GN/AN/CuO mixtures.

Table 1 Summary of linear burning rate tests for GN/AN/CuO mixtures and NQ/AN/CuO mixtures.

Mixtures	Amount of CuO [wt%]	a	n	P[MPa]
GN/AN/CuO	1	0.97	0.76	1.0~10
	5	2.05	0.58	0.5~10
	10	1.28	0.80	0.9~10
		1.11	0.15	0.1~0.9
	20	1.39	0.72	0.1~10
NQ/AN/CuO	5	2.40	0.55	0.1~10
	10	2.64	0.53	0.1~10
	20	2.51	0.53	0.1~10
GN/SrN/BCN[5]		2.59	0.48	0.1~10

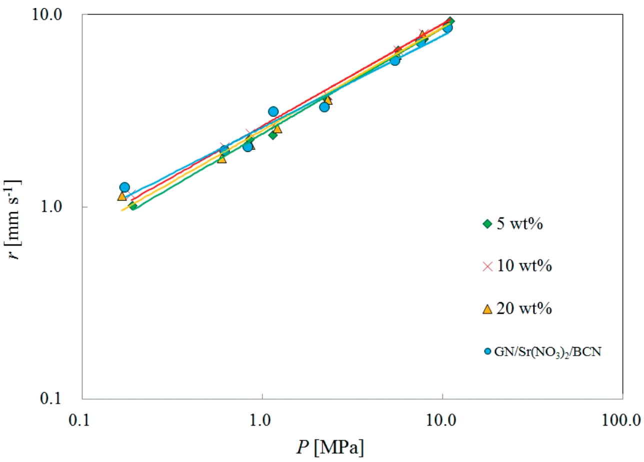


Figure 3 Linear burning rate data for NQ/AN/CuO mixtures.

It was found that the addition of CuO enhanced the combustion of GN/AN stoichiometric mixture which, by itself, did not burn at 0.1~10 MPa. It was also shown from Figure 2 that while GN/AN/CuO 1 wt% mixture could not sustain burning at 0.5 MPa or below, and 5 wt% CuO mixture could not sustain burning at 0.1 MPa, 10 wt% and 20 wt% CuO mixtures were able to burn at an initial gauge pressure between 0.1~10 MPa. Meanwhile, the data of 10 wt% CuO mixture could not be fitted by a single straight line, suggesting that there are two straight approximation lines that could be drawn below and above approximately 1 MPa. In contrast, sustained burning was observed from 0.1 MPa and above for all NQ/AN/CuO mixtures that were studied. It was also found that the addition of CuO also enhanced the combustion of NQ/AN stoichiometric mixture which, by itself, did not burn at 0.1~10 MPa also.

3.2 Rate-of-pressure-rise test

Table 2 gives the summary of the rate-of-pressure-rise test for both GN/AN/CuO mixtures and NQ/AN/CuO mixtures. It was shown that among all GN/AN/CuO mixtures that were studied, GN/AN/CuO 5 wt% mixture has shown the maximum average pressure-rise, $(\Delta P)_{av}$, and maximum average rate-of-pressure-rise, $(\Delta P/\Delta t)_{av}$, and they were close to those of GN/SrN/BCN mixture, while all NQ/AN/CuO mixtures exceeded in $(\Delta P)_{av}$ and

Table 2 Summary of rate-of-pressure-rise tests for GN/AN/CuO mixtures and NQ/AN/CuO mixtures.

Mixture	Amount of CuO [wt%]	$(\Delta P)_{av}$ [MPa]	$(\Delta t)_{av}$ [s]	$(\Delta P/\Delta t)_{av}$ [MPa s^{-1}]
GN/AN/CuO	1	0.46	6.29	0.073
	5	0.57	4.51	0.126
	10	0.49	4.76	0.103
	20	0.48	4.49	0.106
NQ/AN/CuO	5	0.60	3.85	0.156
	10	0.63	3.43	0.184
	20	0.58	3.35	0.172
GN/SrN/BCN[5]		0.52	3.90	0.133

$(\Delta P/\Delta t)_{av}$ as compared to those of GN/SrN/BCN mixture, and that NQ/AN/CuO 10 wt% mixture has shown the maximum for both values.

4. Conclusions

It was found that the addition of CuO enhanced the burning of both GN/AN mixtures and NQ/AN mixtures, and that GN/AN/CuO 5 wt% mixture has shown the maximum burning rate among GN/AN/CuO mixtures and it was close to that of GN/SrN/BCN mixture, while all NQ/AN/CuO mixtures studied have shown similar burning rates and they were also equivalent to that of GN/SrN/BCN mixture. There was also a decrease in the minimum initial gauge pressure from which the mixture starts to burn, with an increase in the amount of CuO, for GN/AN/CuO mixtures, while all NQ/AN/CuO mixtures started to burn from initial gauge pressure of 0.1 MPa.

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