



## Influence of nitromethane concentration on ignition energy and explosion parameters in gaseous nitromethane/air mixtures

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### ABSTRACT

The aim of this paper is to provide new experimental data of the minimum ignition energy (MIE) of gaseous nitromethane/air mixtures to discuss the explosion pressure and the flame temperature as a function of nitromethane concentration. Observations on the influence of nitromethane concentration on combustion pressure and temperature through the pressure and temperature measure system show that peak temperature (the peak of combustion temperature wave) is always behind peak pressure (the peak of the combustion pressure wave) in arrival time, the peak combustion pressure of nitromethane increases in the range of its volume fraction 10–40% as the concentration of nitromethane increases, and it slightly decreases in the range of 40–50%. The maximum peak pressure is equal to 0.94 MPa and the minimum peak pressure 0.58 MPa. Somewhat similar to the peak pressure, the peak combustion temperature increases with the volume fraction of nitromethane in the range of 10–40%, and slightly decreases in 40–50%. The maximum peak temperature is 1340 °C and the minimum 860 °C. The combustion temperature rise rate increases with the concentration of nitromethane in 10–30%, while decreases in 30–50% and its maximum value of combustion temperature rise rate in 10–50% is 4200 °C/s at the volume fraction of 30%. Influence of the concentration of nitromethane on the combustion pressure rise rate is relatively complicated, and the maximum value of rise rate of combustion pressure wave in 10–50% is 11 MPa/s at the concentration 20%.

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### 1. Introduction

Nitromethane is an energetic material with a wide variety of applications, which include its use as a monopropellant, a liquid explosive, a solvent for chemical processing and analysis, and a high-performance fuel additive for internal combustion engines and pulsed detonation engines.

At atmospheric pressure and room temperature, nitromethane is liquid. When it is used as one of the additive components in propellants and explosive materials, liquid nitromethane will evaporate into the air and mix with air to form flammable gaseous nitromethane/air mixtures, leading to serious hidden troubles in the process of production. The dangerous degree of an accident possibly caused by one of the hidden troubles is mainly dependent on the minimum ignition energy (MIE) of the gaseous nitromethane/air mixture. The harm of the accident has a direct

relationship with the explosion action described by those parameters such as explosion pressure and explosion temperature.

Up to now, a lot of works have made a contribution to the study of nitromethane as one component of liquid explosives [1–4] and propellants [5–7], and obtained a good knowledge of the characteristics of its combustion and explosion. Some works have also paid attention to the explosion process of gas–liquid two-phase and gas–liquid–solid three-phase within the pipe with a large length diameter ratio [8]. However, except the cellular structure of the detonation in gaseous nitromethane and its mixtures with oxygen [9,10] and the DDT process of gaseous nitromethane mixtures [11] in slender pipes, there are less research reports following with interest in pure gaseous nitromethane mixtures.

In the production circumstances involving nitromethane, the evaporation of liquid nitromethane is unavoidable. In such cases, the knowledge of the characteristics of the ignition and explosion of gaseous nitromethane is an important basis of accident prevention. In earlier time, Tricot et al. [12,13] studied the reaction of nitromethane with oxygen, and Hsu et al. [14] suggested a detailed chemical mechanism describing the ignition of high-temperature gaseous nitromethane. It has been found that the ignition characteristics of flammable gases [15–18] and their

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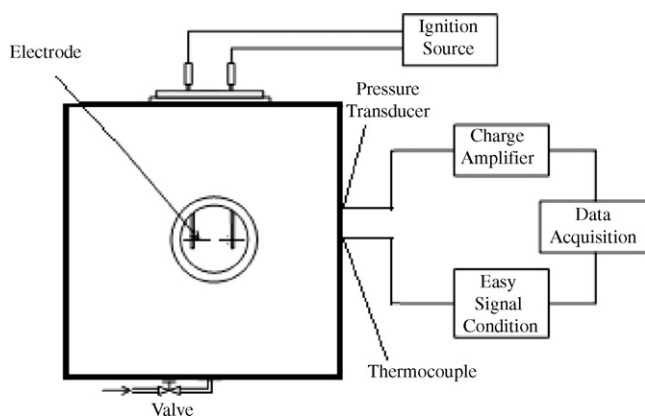


Fig. 1. Experimental set-up.

explosion performances [19,20] bear close relationship with their concentrations. Although plenty of research achievements have been made in the respect related to the combustion parameters of flammable gases and their MIEs, unfortunately, fewer researchers have paid attention to the behavior of combustion for mixtures of pure nitromethane and air.

Phenomena of gas explosions have been studied for many years [21,22]. Past experiences show that it is very important to carry out better experimental observations in order to clarify their mechanisms. Consequently, this work developed an ignition energy measure system which includes a 5 L explosion vessel, a transient pressure measure sub-system and a transient temperature measure sub-system. Through series experiments carried out in this system, the MIEs of gaseous nitromethane mixtures under different concentrations of nitromethane were studied, and the influence of the concentration of nitromethane on the combustion pressure and temperature and on the rise rate of combustion pressure wave front and combustion temperature wave front (denotes the slopes of combustion pressure wave front and combustion temperature wave front with time) were analyzed and discussed.

## 2. Experimental apparatus and procedures

### 2.1. General

The experimental set-up used in this study consisted of a 5 L cylindrical vessel coupled with an electric ignition system and a data acquisition system shown in Fig. 1.

Experiments were made in a cylinder explosion vessel with a central ignition. The height  $h$  of the vessel is equal to 160 mm and the inner diameter  $2R$  is 199 mm. In the experimental vessel, ignition was operated by an inductive–capacitive spark produced between stainless steel electrodes with rounded tips, using a spark gap of 1 mm. The electrode diameter used in the experiment is 1 mm. A spark gap of 1 mm was used in this work in order to obtain the smaller ignition energy. The spark energy and duration was monitored by means of an ignition energy measure system.

### 2.2. Explosion pressure and flame temperature

Explosions were monitored by means of Kistler pressure gauges and a fast response temperature transducer mounted on the wall of the experimental vessel. All results were stored through a data acquisition device.

The transient temperature measure sub-system is made up of two parts, hardware and software, in which the hardware part is composed of thermocouple transducer, signal conditioning module, data acquisition card, PXI chassis and controller etc.

The thermocouple transducer, WRe5-WRe26 thermocouple sensor manufactured by Nanmac Corporation, up to micro-second level for the response rate, is sufficient to satisfy the requirement of temperature measure. The signal is input into the signal conditioning module through the differential format and then into a gain 100 amplifier whose output signal is linked with a 2 Hz low pass filter. The modulated signal passes through the compensation wire and to the data acquisition card connected with the signal conditioning module, and the analog signal is transformed into the digital signal. The types of the data acquisition card and the chassis are NI PXI-5922 and XI-1042Q, respectively. The data acquisition system was triggered by the control unit, recording the pressure and temperature data individually in a sampling frequency of 1 MHz and 0.1 MHz.

### 2.3. Spark ignition energy

By means of a traditional igniting test, one can easily determine the ignition energy on the basis of the given capacitance and voltage through simple calculation. The traditional test, referred to as a simple method, follows the general relation described as

$$E = \frac{1}{2}CU^2 \quad (1)$$

where  $C$  is the capacitance of capacitor,  $U$  is the voltage of capacitor discharge and  $E$  is the energy stored in capacitor, which is regarded as the ignition energy traditionally.

If the voltage varying with time on both ends of an igniting bridge thread can be measured and recorded and so can the current, the accurate ignition energy can be obtained, which is given by the following equation

$$E = \int_0^t u(t)i(t)dt \quad (2)$$

where  $E$ , different from the value in Eq. (1), is an accurate value of ignition energy,  $u(t)$  is the voltage between both ends of the electric bridge thread,  $i(t)$  is the current through the electric bridge, and  $t$  is the duration of ignition process.

Typical waveforms obtained by means of above energy measure system are shown in Fig. 2. In this figure, Curve 1 is the voltage waveform and Curve 2 is the current waveform. The waveforms may be shown and analyzed automatically by a specially designed computer code in the computer.

In the calculation of ignition energy, it requires to know the voltage time history and the current time history at both ends of the electric thread. In order to meet these requirements, it is necessary to establish a special measure system.

Theoretically, the best way with high accuracy should be the method using integration to determine the ignition energy at present. Once the voltage of both ends of electrode varying with time and the current through the electrode varying with time are measured, the ignition energy can be calculated by the integration of their product with respect to time in the interval of the duration of discharge. The result obtained from this method represents the real case acted on the electrode. Consequently, in the developed ignition energy measure system in this paper, a high voltage sensor P6015A and a voltage sensor P6139A were used to measure the voltage time history and the current time history.

### 2.4. Experimental procedure

For gaseous nitromethane/air mixtures, their concentrations of nitromethane were evaluated from the volume of experimental vessel. A measured amount of liquid nitromethane were drawn out, weighed by means of an electronic balance, and then put into the experimental vessel. Subsequently, heating the outer surface

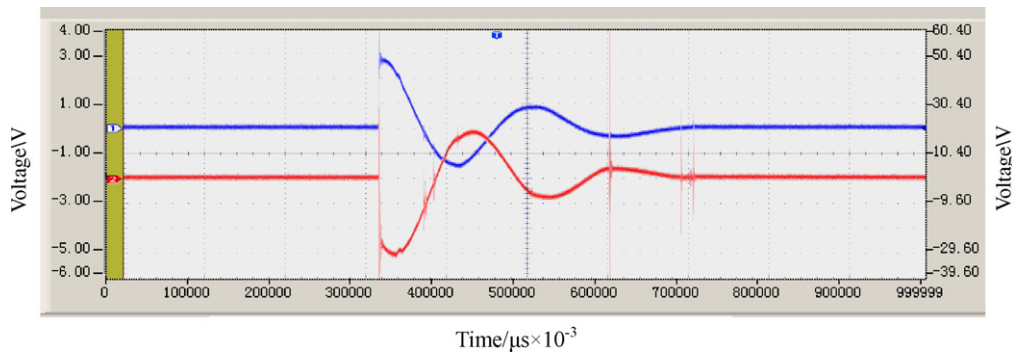


Fig. 2. Voltage waveforms of electric bridge thread and sampling resistance on screen of oscillograph (1 for electric bridge thread and 2 for sampling resistance).

of the vessel to the specified temperature ( $70^{\circ}\text{C}$ ) made all of the nitromethane vaporized in the vessel, since the vapour pressure of nitromethane at normal atmospheric conditions is too low to reach explosion vapour concentrations. The vessel containing liquid nitromethane needs to be heated for half or one hour to be vaporized. The gaseous mixture was stirred for 1 min and then the mixture was left to become homogeneous and quiescent for 1 min before ignition. Next the gaseous nitromethane/air mixture was ignited by an electric spark generated by a spark generator. After the ignition occurred within the gaseous mixture, a combustion wave formed and propagated from the position of ignition to the wall of vessel. The histories of pressure and temperature resulted from the gaseous nitromethane/air mixture explosion were recorded at different points in the vessel by the pressure gauges and temperature transducer connected to the data acquisition system. Finally, the maximum values  $(dp/dt)_{\max}$  and  $(dT/dt)_{\max}$  of the derivatives of pressure and temperature with respect to time were obtained on the basis of the experimental recordings of pressure  $p(t)$  and temperature  $T(t)$ .

### 3. Experimental results

#### 3.1. Flame temperatures and explosion pressures

The data acquisition system consisted of Kistler pressure gauges (its type is Kistler 211M) and a thermocouple mounted on the wall of the experimental vessel and a data acquisition device. Pressure and temperature data were recorded by the data acquisition system with a sampling frequency of 1 MHz.

The flammability limits of the gaseous nitromethane in air are 7.1–63.0%. In experiments, the environment conditions were as follows: the relative humidity 20% and the initial temperature and pressure of the gaseous nitromethane/air mixture are  $70^{\circ}\text{C}$  and 0.15 MPa, respectively. The volume concentrations of nitromethane in the gaseous mixtures were 10–50%. Typical results of pressures and temperatures recorded in experiments are shown in Figs. 3 and 4, in which curves correspond to cases of the volume fraction of nitromethane 10% and the ignition energy 17 mJ, the volume fraction 20% and the ignition energy 0.7 mJ, the volume fraction 30% and the ignition energy 0.7 mJ, the volume fraction 40% and the ignition energy 2.1 mJ, and the volume fraction 50% and the ignition energy 39 mJ, respectively.

For a given volume fraction of gaseous nitromethane, the measured pressure and temperature change with time and reach their peak values after the fronts of pressure wave and temperature wave. The peak values are defined as the peak pressure and the peak temperature. The peak pressure and the peak temperature vary with the volume fraction of gaseous nitromethane. The minimum peak explosion pressure denotes the minimum value of peak explosion pressures obtained within the examined range of

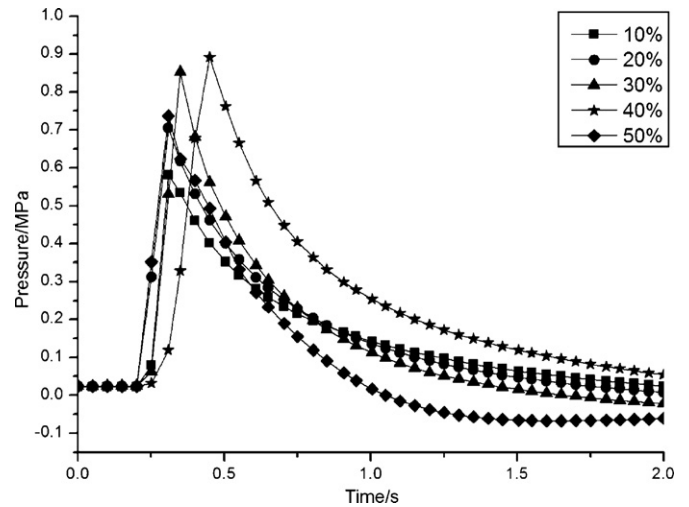


Fig. 3. Combustion pressures of gaseous nitromethane for different concentrations.

concentrations. The combustion temperature (or pressure) rise rate denotes the change of temperature (or pressure) wave rise front with time. The rise rate of pressure wave front and temperature wave front varies with the volume fraction of gaseous nitromethane. The maximum rise rate of pressure wave front denotes the maximum value obtained within the examined range of concentrations.

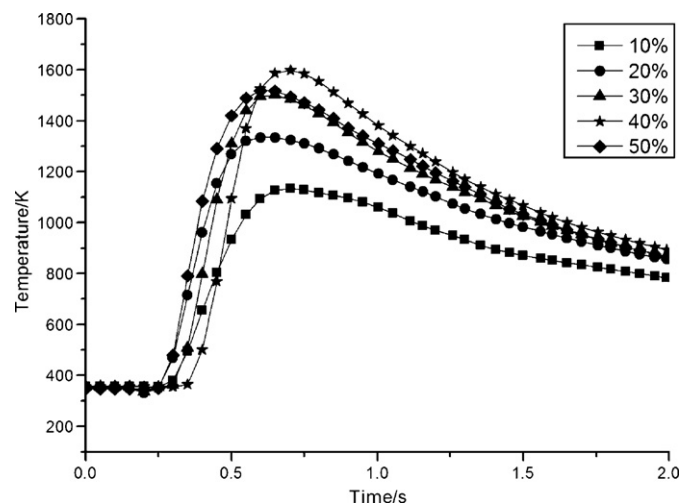


Fig. 4. Combustion temperatures of gaseous nitromethane for different concentrations.

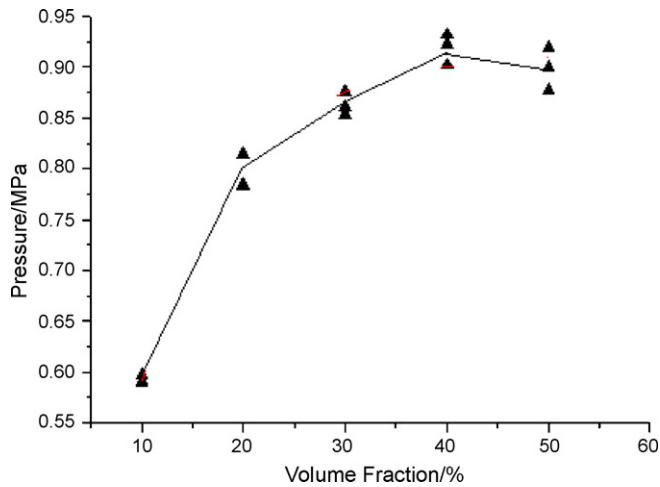


Fig. 5. Influence of volume fraction of gaseous nitromethane on peak explosion pressure.

### 3.2. Minimum spark energies for ignition

Minimum ignition energy (MIE) denotes the lowest energy value which can initiate combustion within the examined range of concentrations in this work. Although the attempt to measure MIE by integrating the current/voltage product is justified, the result still significantly depends on the choice of pulse shape, discharge gap, and even electrode material [23,24]. The results of all experiments are summed up in Table 1. In the table, the term “Experiment times” represents the number of experiment repetitions, in which “F” and “S” denote “failure” (the mixture in the vessel was not initiated in the experiment) and “success” (the explosion of the mixture was not initiated). MIE varying with the concentration of nitromethane in the gaseous nitromethane/air mixture is shown in Fig. 4.

Examination of the energies corresponding to situations F and S shows that they are quite far away. In fact, energy value between the energy input in a “failed ignition” and a “successful ignition” may initiate combustion of the mixture also. The MIE may be less than the energies corresponding to situations F. Therefore, the lowest energy corresponding to situations F is defined as the affirmative value of the MIE, and the average between the energy input in a “failed ignition” and a “successful ignition” is defined as the estimated value of the MIE in this work. The affirmative value and the estimated value of the MIE are listed in Table 2. It is worth to note that the affirmative value of the MIE is adopted only in order to clearly describe the experiment results by the authors. It is not a universal term in the safety engineering community. The lowest affirmative value of MIE among the values determined for all investigated mixtures in this work is 0.7 mJ.

It can be seen from Figs. 3 and 4 that the peak temperature is always behind the peak pressure in arrival time. Results in Table 1 show that the ignition energy calculated by  $0.5CU^2$  is much higher than that by  $\int uidt$ , while the latter represents the actual energy of the electrode ignition. When the volume fraction of nitromethane in the gaseous nitromethane/air mixture increases in the range of 20–50%, the MIE increases at first and then decreases as the volume fraction changes. In the range of 20–40% for the volume fraction, there are not very obvious differences among the MIEs. However, the MIEs vary sharply either from the volume fraction of nitromethane 10% to 20% or from 40% to 50%. Under the specified experimental conditions in this work, the affirmative minimum ignition energy of gaseous nitromethane/air mixtures is equal to 0.7 mJ.

Under the condition of MIE, the peak combustion pressure of nitromethane increases in 10–40%, and it slightly decreases in

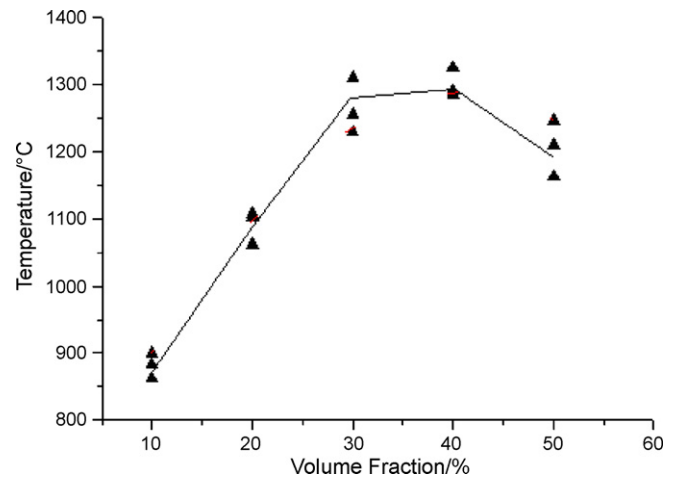


Fig. 6. Influence of volume fraction of nitromethane on peak explosion temperature.

40–50%, which is shown in Fig. 5. For the given experimental conditions, the maximum peak pressure obtained at the various concentrations of gaseous nitromethane in air is 0.93 MPa, and the minimum peak pressure obtained at the various concentrations of gaseous nitromethane in air is 0.59 MPa. Similarly, the peak combustion temperature of gaseous nitromethane/air mixtures increases as the volume fraction of gaseous nitromethane increases in 10–40%, and it slightly decreases in 40–50%, as shown in Fig. 6. The maximum peak temperature obtained at the various concentrations of gaseous nitromethane in air is 1340 °C, and the minimum obtained at the various concentrations of gaseous nitromethane in air is 860 °C in the experiments of this work.

When the volume fraction of gaseous nitromethane lies in 10–30%, the rise rate of combustion temperature wave front of gaseous nitromethane/air mixtures with time increases with the volume fraction, while when the volume fraction lies in 30–50%, the rise rate of combustion temperature wave front decreases with the volume fraction, as shown in Fig. 7. When the volume fraction of gaseous nitromethane is 30%, the rise rate of combustion temperature wave front at the various volume fractions reaches its maximum value 4200 °C/s. Relatively, the influence of volume fraction of gaseous nitromethane on the rise rate of pressure wave front with time is much complicated, as shown in Fig. 8. Under the MIE condition, when the volume fraction of gaseous nitromethane is equal to 20% in the gaseous nitromethane/air mixture, the rise

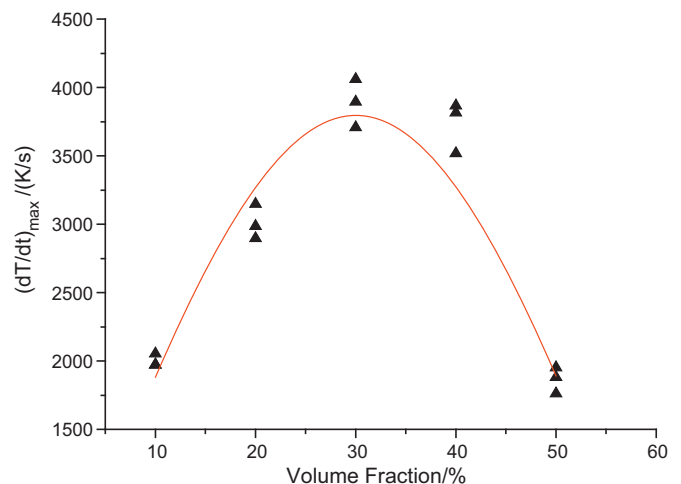


Fig. 7. Influence of volume fraction of nitromethane on rise rate of temperature wave front.

**Table 1**  
Experimental results of ignition in gaseous nitromethane/air mixtures.

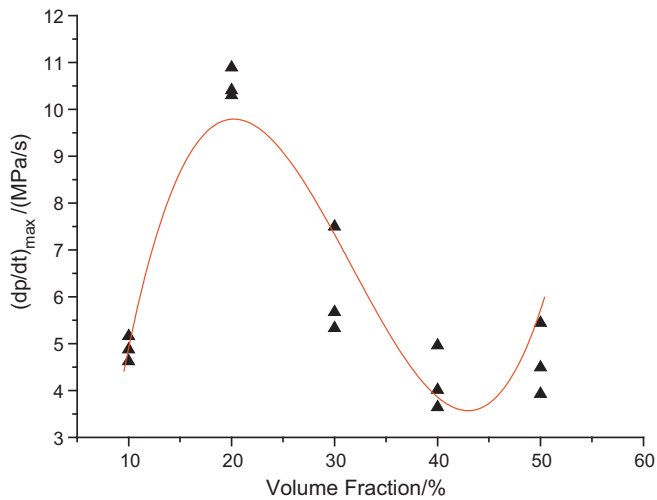
Capacitance ( $\mu\text{F}$ )	Voltage (V)	Volume fraction (%)	Ignition energy (mJ)		Experiment times (F/S)	Maximum temperature ( $^{\circ}\text{C}$ )	Maximum pressure (MPa)	$(dp/dt)_{\text{max}}$ ( $\text{MPa s}^{-1}$ )	$(dT/dt)_{\text{max}}$ ( $^{\circ}\text{C s}^{-1}$ )
			$0.5CU^2$	$\int uidt$					
0.4	100	10	2	0.4	3(F)	–	–	–	–
0.4	200	10	8	2	3(F)	–	–	–	–
0.4	300	10	18	7	3(F)	–	–	–	–
0.4	400	10	32	17	1(S)	899.0	0.59	4.63	1973.9
0.4	100	10	2	0.4	3(F)	–	–	–	–
0.4	200	10	8	2	3(F)	–	–	–	–
0.4	300	10	18	7	3(F)	–	–	–	–
0.4	400	10	32	17	1(S)	861.9	0.59	5.16	2053.7
0.4	100	10	2	0.4	3(F)	–	–	–	–
0.4	200	10	8	2	3(F)	–	–	–	–
0.4	300	10	18	7	3(F)	–	–	–	–
0.4	400	10	32	17	1(S)	882.3	0.60	4.88	1973.0
0.1	100	20	0.5	0.12	3(F)	–	–	–	–
0.1	200	20	2	0.7	1(S)	1101.4	0.82	10.89	3148.9
0.1	100	20	0.5	0.12	3(F)	–	–	–	–
0.1	200	20	2	0.7	1(S)	1106.9	0.78	10.41	2987.1
0.1	100	20	0.5	0.12	3(F)	–	–	–	–
0.1	200	20	2	0.7	1(S)	1061.1	0.78	10.31	2896.5
0.1	100	30	0.5	0.12	3(F)	–	–	–	–
0.1	200	30	2	0.7	1(S)	1229.9	0.85	5.68	3708.8
0.1	100	30	0.5	0.12	3(F)	–	–	–	–
0.1	200	30	2	0.7	1(S)	1255.7	0.86	7.50	3896.4
0.1	100	30	0.5	0.12	3(F)	–	–	–	–
0.1	200	30	2	0.7	1(S)	1310.0	0.88	5.33	4060.0
0.1	100	40	0.5	0.12	3(F)	–	–	–	–
0.1	200	40	2	0.7	3(F)	–	–	–	–
0.1	300	40	4.5	2.1	1(S)	1291.2	0.90	4.97	3519.0
0.1	100	40	0.5	0.12	3(F)	–	–	–	–
0.1	200	40	2	0.7	3(F)	–	–	–	–
0.1	300	40	4.5	2.1	1(S)	1284.4	0.92	3.65	3867.3
0.1	100	40	0.5	0.12	3(F)	–	–	–	–
0.1	200	40	2	0.7	3(F)	–	–	–	–
0.1	300	40	4.5	2.1	1(S)	1325.5	0.93	4.01	3816.0
0.4	100	50	2	0.4	3(F)	–	–	–	–
0.4	200	50	8	2	3(F)	–	–	–	–
0.4	300	50	18	7	3(F)	–	–	–	–
0.4	400	50	32	17	3(F)	–	–	–	–
0.4	500	50	50	25	3(F)	–	–	–	–
0.4	600	50	72	39	1(S)	1247.4	0.92	5.44	1762.6
0.4	100	50	2	0.4	3(F)	–	–	–	–
0.4	200	50	8	2	3(F)	–	–	–	–
0.4	300	50	18	7	3(F)	–	–	–	–
0.4	400	50	32	17	3(F)	–	–	–	–
0.4	500	50	50	25	3(F)	–	–	–	–
0.4	600	50	72	39	1(S)	1162.9	0.88	4.50	1882.9
0.4	100	50	2	0.4	3(F)	–	–	–	–
0.4	200	50	8	2	3(F)	–	–	–	–
0.4	300	50	18	7	3(F)	–	–	–	–
0.4	400	50	32	17	3(F)	–	–	–	–
0.4	500	50	50	25	3(F)	–	–	–	–
0.4	600	50	72	39	1(S)	1210.3	0.90	3.93	1952.7

**Table 2**  
Affirmative value and estimated value of MIE (mJ).

Volume fraction of nitromethane (%)	$0.5CU^2$		$\int uidt$	
	Affirmative value	Estimated value	Affirmative value	Estimated value
10	32	25	17	12
20	2	1.25	0.7	0.41
30	2	1.25	0.7	0.41
40	4.5	3.25	2.1	1.4
50	72	61	39	32

**Table 3**  
Experimental results and their deviations.

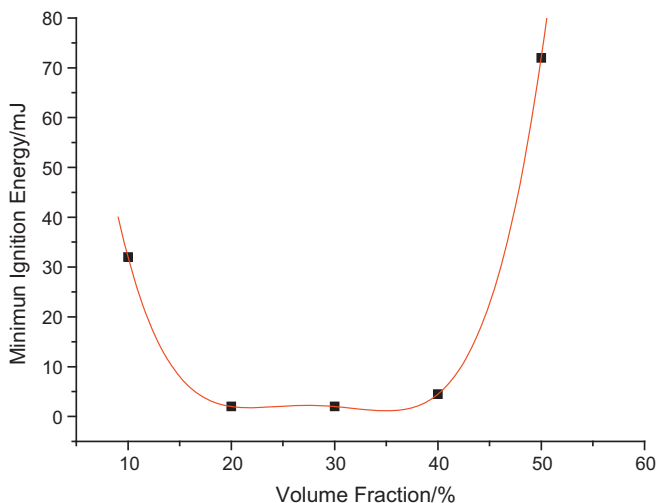
Volume fraction of nitromethane (%)	Pressure range (MPa)	Pressure deviation (MPa)	Temperature range (°C)	Temperature deviation (°C)
10	0.59–0.60	0.01	861.9–899.0	37.1
20	0.78–0.82	0.04	1061.1–1106.9	45.8
30	0.85–0.88	0.03	1229.9–1310.0	80.1
40	0.90–0.93	0.03	1284.4–1325.5	41.1
50	0.88–0.92	0.04	1162.9–1247.4	84.5

**Fig. 8.** Influence fraction of volume of nitromethane on rise rate of pressure wave front.

rate of combustion pressure wave front with time at the various volume fractions reaches the maximum value 11 MPa/s.

### 3.3. The errors estimation

In the experiments, the error of volume fraction of gaseous nitromethane is less than 0.7%. The maximum deviation of pressure measurements is 0.04 MPa at the volume fraction of nitromethane 20% and 50%, as shown in Fig. 9 and the corresponding average relative deviations are 2.5% and 2.1%,

**Fig. 9.** MIEs of gaseous nitromethane/air mixtures for different concentrations of nitromethane.

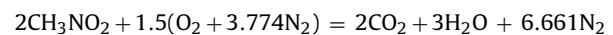
respectively. The maximum deviation of temperature measurements is 84.5 °C at the concentration of nitromethane 50%, as shown in Fig. 7 and its corresponding average relative deviation is 3.5%. Experimental results and their deviations are listed in Table 3.

## 4. Discussion

By using the developed ignition energy measure system including a 5 L explosion vessel and the measure system, this work studied the MIEs of gaseous nitromethane/air mixtures with different volume fractions of nitromethane. On the basis of experimental measure results, the analysis and discussion was carried out which is concerned with the influence of volume fraction of nitromethane on the peak explosion pressure, the peak explosion temperature, the rise rate of pressure wave front with time and the rise rate of temperature wave front for pure gaseous nitromethane/air mixture under the condition of MIE.

Nitromethane is an energetic material with a wide variety of applications, which includes its use as a monopropellant, a liquid explosive, a solvent for chemical processing and analysis, and a high-performance fuel additive for internal combustion engines and pulsed detonation engines. In this work the volume fraction of the gaseous nitromethane/air mixture, at which the combustion pressure and the combustion temperature reach their maximum values, was obtained in order to fully understand the explosion performance of the gaseous nitromethane/air mixture. To validate the measure results, the volume fraction of the gaseous nitromethane/air mixture corresponding to the maximum values of the combustion pressure and the combustion temperature obtained within the examined range of concentrations in the experiments is compared with the theoretical stoichiometric volume fraction.

The chemical reaction of the gaseous nitromethane/air mixture with the stoichiometric volume fraction is



The stoichiometric volume fraction of gaseous nitromethane/air mixture is

$$c = \frac{V_{\text{nit}}}{V_{\text{air}}} = \frac{2}{1.5(1 + 3.774)} = 0.28$$

where  $V_{\text{nit}}$  is the volume of gaseous nitromethane in the mixture,  $V_{\text{air}}$  is the volume of air in the mixture. The equation above illustrates that the peak combustion pressures and temperatures of the gaseous nitromethane/air mixture reach their maximum values at 28% volume fraction in theory.

In actual chemical reaction, it is impossible that all of elements C and H in mixture can be oxidized into  $\text{CO}_2$  and  $\text{H}_2\text{O}$ . In fact when the chemical reaction reaches balance state, CO,  $\text{H}_2$  and OH are always contained in the productions. Consequently, the volume fraction at which the peak combustion pressures and temperatures of the combustible gas/air mixture reach their maximum

values is always more than that in the stoichiometric state slightly. This agrees with the data reported in [25] also. In this experiment, the peak combustion pressures and temperatures of the gaseous nitromethane/air mixture reach their maximum values at volume fraction 30–40%. The analysis mentioned above shows that the measurement system and experimental results in this work are validated.

Eckhoff et al. built a copy of the standard ASTM spark generator for determination of MIEs of gases and vapours and obtained a MIE of 0.48 mJ for propane/air [16]. The MIE of the gaseous nitromethane/air mixture is not available in the previous literatures. The chemical character of propane/air is similar to that of gaseous nitromethane/air mixture. The MIE of gaseous nitromethane/air mixture obtained in this work is compared with propane/air reported in [16]. The lowest value of MIE among the values determined for all investigated mixtures in this work is 0.7 mJ which is more than 0.48 mJ for propane/air slightly. The average between the energy input in a “failed ignition” and a “successful ignition” is 0.41 mJ which is more close to 0.48 mJ. The experimental results of this work roughly agree with the data reported in [16].

## 5. Conclusion

More detailed conclusions are presented below.

- (1) If using the charge capacitance of the igniter and the charge voltage, the calculated MIE from the relation  $0.5CU^2$  has large error. Through the integration of the product of the measured transient voltage at two ends of the electrode and current through the electrode in experiment with respect to the time, the actual ignition energy with high accuracy can be obtained and it is much less than the calculation result from the relation  $0.5CU^2$ . Under the experimental conditions in this work, the MIE of the gaseous nitromethane/air mixture is equal to 0.7 mJ which is the affirmative lowest value of MIE among the values determined for all investigated mixtures. The average energy value between the energy input in a “failed ignition” and a “successful ignition” is 0.41 mJ (estimated value of the MIE).
- (2) Experimental results show that the peak temperature is behind the peak pressure in arrival time. For the gaseous nitromethane/air mixtures with the volume fraction of nitromethane 10–40%, the peak combustion pressure of nitromethane/air mixtures increases as the volume fraction of nitromethane increases, and it slightly decreases in the range of 40–50%. Under the given experimental conditions, the maximum peak pressure is 0.93 MPa, and the minimum peak pressure is 0.59. The peak combustion temperature also increases as the volume fraction of nitromethane increases in the range of 10–40%, and slightly decreases in the range of 40–50%. The maximum peak temperature is 1340 °C, and the minimum peak temperature is 860 °C.
- (3) When the volume fraction of gaseous nitromethane lies in 10–30%, the rise rate of combustion temperature wave front of gaseous nitromethane/air mixture increases with its volume fraction, and while in 30–50%, it decreases with the volume fraction. The maximum value is 4200 °C/s at the volume fraction of gaseous nitromethane 30%. The influence of the volume fraction of gaseous nitromethane on the maximum rise rate of pressure wave front is much complicated, and the maximum

value obtained from the experiments at the various volume fractions is 11 MPa/s at the concentration of nitromethane 20%.

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