Journal of Loss Prevention in the Process Industries 29 (2014) 277–282

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

Sensitivity of dimethyl amino ethyl azide (DMAZ) as a non-carcinogenic and high performance fuel to some external stimuli

Shahram G. Pakdehi [a,*], Sajad Rezaei [a], Hadi Motamedoshariati [a], Mohammad Hossein Keshavarz [b]

[a] Faculty of Chemistry & Chemical Engineering, Malek Ashtar University of Technology, P.O. Box 11365-8486, Tehran, Islamic Republic of Iran
[b] Department of Chemistry, Malek Ashtar University of Technology, Shahin-shahr, P.O. Box 83145/115, Islamic Republic of Iran

ARTICLE INFO

Article history:
Received 18 January 2014
Received in revised form
15 March 2014
Accepted 26 March 2014

Keywords:
DMAZ
Liquid fuel
Sensitivity
Safety

ABSTRACT

Hydrazine and its derivatives have been used extensively in space programs as liquid propellants. Since they are carcinogen, dimethyl amino ethyl azide (DMAZ) has been introduced as a non-carcinogenic fuel with high performance as compared to the best available fuels. DMAZ contains energetic group $-N_3$, which may be sensitive to some external stimuli. Thus, it is important to study various aspects of sensitivity of DMAZ in addition to its performance criteria. Various conventional tests as well as computer codes were used to investigate sensitivity of DMAZ to external stimuli such as impact, shock wave, Koenen, burning and electrostatic discharge. The results showed that DMAZ is not sensitive to impact, direct flame and shock wave. Meanwhile, it has moderate and high sensitivity to heat in confined volume and electrostatic discharge, respectively.

1. Introduction

Liquid propellants have some advantages such as high specific impulse and thrust levels as well as better thrust control as compared with solid propellants. They are commonly used in bipropellant systems for rocket launchers (Salvador & Costa, 2006). Computer codes or empirical methods can be used to evaluate their performance (Keshavarz, 2003; Mader, 2008). Among different liquid propellants, hydrazine and its derivatives, such as monomethyl hydrazine (MMH) and unsymmetrical dimethyl hydrazine (UDMH), have been used widely. Although they have high performance but they are carcinogen. Dimethyl amino ethyl azide (DMAZ) was introduced as a non-carcinogen and hypergolic liquid fuel, which has performance and some physical properties close to MMH (Pakdehi, Azhdari, Hashemi & Keshavarz, in press). It is also colorless, low viscosity, volatile and pungent in odor (Agrawal, 2010; Schmidt, 2001).

Due to the existence of $-N_3$ group, DMAZ is a high energetic liquid fuel. However, DMAZ belongs to hazardous materials, which need to consider specials cares during production, handling and storage in order to minimize accidents or events. Determination of sensitivity of the energetic materials is a key factor in practical applications because energetic compounds may expose to external stimuli such as friction, impact and electrostatic spark (Keshavarz, 2011; Suceska, 1995). However, it is necessary to test and predict the safety characteristics and hazard potentials of a desired energetic material before its production and using. The purpose of this work is to study the sensitivity of DMAZ to some external stimuli, which have not been reported elsewhere. The results may be important for prevention of unintentional explosion initiation of DMAZ during its production, handling and storage.

2. Experimental

2.1. Materials

DMAZ (≥99 wt% purity) was used in all tests. It was synthesized and purified from the reaction of dimethyl amino ethyl chloride and sodium azide (Schiemenz & Engelhard, 1959).

2.2. Test methods

2.2.1. Sensitivity evaluation of DMAZ by using of CHETAH software

Sensitivity determination tests for identification of chemical reactivity spend a lot of time and resources. The study of energetic materials by theoretical methods has been accelerated dramatically over recent years and provided a considerable insight into the understanding of factors affecting their behavior (Keshavarz,

* Corresponding author. Tel.: +98 021 44382561.
E-mail address: sh_ghanbari73@yahoo.com (S.G. Pakdehi).

http://dx.doi.org/10.1016/j.jlp.2014.03.006
0950-4230/

Motamedoshariati, Pouretedal, Kavosh, & Semnani, 2007). CHETAH software was used to predict the reactive hazards of DMAZ. This software uses Benson contribution group (Shanley & Melham, 2000) to evaluate explosion potential hazard of an organic compound or mixture of organic compounds. It contains a data bank of thermodynamic properties for organic and inorganic compounds. It contains five groups of elements, gas molecules, Benson groups, crystalline molecules and ionic group. Seven criteria in CHETAH program are: maximum heat of decomposition, heat value - heat of decomposition, oxygen balance (OB), energy release evaluation (ERE), over-all energy release potential, net plosive density and adiabatic decomposition temperature (Hada & Harrison, 2007; Saraf, Rogers, & Mannan, 2003). Oxygen balance is not applicable for free oxygen compounds (Saraf et al., 2003). So, degree of hazard from CHETAH program is not valid for DMAZ ($C_4H_{10}N_4$) on the basis of oxygen balance.

CHETAH program was also used to compare properties of DMAZ with three convenient liquid fuels and explosives: MMH, nitromethane (NM) and nitroglycerine (NG). It should be mentioned that NM will be exploded at high pressures and temperatures in the presence of impurities in a closed vessel at 260 °C (Kit & Evered, 1960).

2.2.2. Impact sensitivity test for DMAZ

Fall Hammer BAM device was used for determination of impact sensitivity of DMAZ (NATO STANAG 4489, 1999). DMAZ was poured into the cylinder, which was supported by piston. Weights of 1, 2, 5 and 10 kg may be used at different height of device by using of an opening and closing lever. On the basis of standard method (Kit & Evered, 1960), the test was done on DMAZ six times with 10 kg weight.

2.2.3. Burning test in small scale

Burning test in small scale is used to responding a material to fire (Klapötke, 2012; United Nations, 2009). About 100 g sawdust was mixed with 200 cm^3 kerosene. A 30 cm $\times$ 30 cm bed with 2.5 cm thickness was also prepared. A thin wall plastic beaker was used for this test. At first, 10 g DMAZ was poured into the beaker. Then, the beaker was inserted at the center of sawdust- kerosene bed. Sawdust was ignited. The experiment was repeated two times with 10 g sample and two times with 100 g sample.

2.2.4. DMAZ sensitivity test to electrostatic discharge

Electrostatic discharge test is used to determine the sensitivity of the material to electrostatic discharge (MIL-STD-1751A, 2001; Suceska, 1995). DMAZ sensitivity to electrostatic discharge was carried out with electrostatic discharge test equipment (model PHYWE ESD, Germany). A nylon tube with 10 mm length, 5 mm outer diameter and 3 mm inner diameter was used to make sample. For this purpose, a steel pin with 3 mm diameter and 25 mm length was inserted in a tube with 7 mm depth. However, an empty space with 3 mm diameter and 3 mm depth was created for charging the sample in the tube. Then, about 20 mg DMAZ was poured into the empty space in the tube. During the test, ambient light was reduced to distinguish the pyrophoric occurrences.

2.2.5. Koenen test

Koenen test is performed for determination of materials sensitivity to severe heat effects in a confined volume (Klapötke, 2012; United Nations, 2009). The apparatus for this purpose contained a protective box. Four burners were over the chamber. The burners heated steel sleeve containing DMAZ. A flow meter on the gas flow passage was used to adjust the transferred heat to sampling vessel. At first, the steel sleeve was filled with 27 cm^3 dibuthyl phthalate. The door of sleeve was closed and a thermometer was inserted in the cylinder. The gas flow was adjusted so that the rate of heat increase was 3.3 $\pm$ 3 °C.

2.2.6. DMAZ sensitivity test to explosive detonator

Sensitivity test to explosive detonator is used to determine materials sensitivity to detonation of standard detonator (Suceska, 1995). In this test, DMAZ sensitivity to initiation was studied by a no.8 standard detonator. The test arrangement is illustrated in Fig.1. At this test, the effects of DMAZ fuel explosion on steel tube were evaluated. The steel tube with 200 mm length and 2.8 mm thickness was closed at one end by a Teflon cap to prevent DMAZ leakage. Then, it was charged with DMAZ. A cap equipped with detonator was inserted to the other end of tube. The detonator was stimulated by using of detonating cord.

2.2.7. DMAZ sensitivity test to shock wave

Shock wave test was designed to determine minimum shock wave pressure which causes the complete explosion of DMAZ. For this purpose, two arrangements were used. At first, the test arrangement was prepared according to sensitivity test to large scale shock method, US naval ordnance laboratory's (NOL) method (Suceska, 1995). The shock wave was produced by 160 g hexogen (RDX). Shock wave pressure was over 200 kbar in this test (Agrawal, 2010). One end of steel tube (140 mm height, 36.5 mm inner diameter and 47.6 mm outer diameter) was closed and sealed by a 0.08 mm thickness layer of polyethylene. Then, the cylinder was inserted on the steel witness plate with 10 mm thickness. A steel washer with 1.6 mm thickness was inserted between the tube and the witness plate. DMAZ was poured into the steel tube. A cardboard tube with 50 mm inner diameter and 250 mm height was also inserted over them and charged with a hexogen (RDX) booster with 50 mm diameter and 50 mm height for generating shock wave. Finally, tube cover and no.8 detonator were inserted over them.

At next step, DMAZ sensitivity to shock wave was studied by using transporting standard of dangerous goods (United Nations, 2009). This test is basically like to previous method but it is different in some cases. The test arrangement contained a wooden base and test set is inserted over it. Firstly, a cardboard tube with 50 mm inner diameter was charged with 160 g RDX explosive with 50 mm height. Detonator holder with detonator no. 8 connecting to detonating cord was inserted in the desired location. Then, steel tube (40 mm inner diameter, 48 mm outer diameter and 400 mm height) was connected by a tape to paper tube containing booster

Fig. 1. The test arrangement of DMAZ sensitivity to standard detonator.