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Luminous Efficient Compositions Based on Epoxy Resin

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ABSTRACT

Magnesium/sodium nitrate illuminating compositions with epoxy resin - E 605 have been studied for luminosity and luminous efficiency by varying fuel oxidizer ratio and binder content. The compositions have been evaluated for impact and friction sensitivities, burn rate, thermal characteristics, and mechanical properties. Flame temperature and combustion products are evaluated theoretically by using REAL program. Experimental results show that, luminosity, burn rate, and calorimetric value are higher for polyester resin-based compositions. The high luminous efficiency composition is achieved with magnesium/sodium nitrate ratio of 70/30 with 4 per cent epoxy resin.

Keywords: Epoxy resins, luminous efficiency, compositions, polyster-based compositions, magnesium/sodium nitrate

1. INTRODUCTION

Long duration white light which is produced by illuminating flare is used to illuminate the area for target acquisition and emergency landing. The requirement of illuminating compositions are high luminous efficiency, good mechanical strength, easy processibility and safety in handling.

Illuminating pyrotechnic compositions are primarily based on magnesium, sodium nitrate and a binder. Binders increase cohesion between particles aiding consolidation. An equally important function of binder is to coat and protect the reactive components, such as metal powders, which may react with oxygen or moisture. They also modify the burning rate and so the performance. Various types of binders are used in illuminating flares to improve the performance[1-4]. In order to develop new compositions with better performance, a number of compositions were studied by varying magnesium/sodium nitrate ratio 60:40–75:25 and with 4 per cent and 6 per cent binder epoxy-E 605.

2. EXPERIMENTAL

2.1 Materials

Magnesium Grade 'O': purity-98 per cent; Sodium Nitrate: purity-99 per cent, Epoxy resin–E 605; Hardener 762: A proprietary items of M/s Dr Beck and Co (India) Ltd, and HSR 8111, Catalyst Q8013; Accelerator Q8021: A proprietary item of M/s Bakelite Hylam Ltd.

2.2 Preparation of Compositions

The compositions were prepared by coating the Magnesium powder with resin and Sodium nitrate was then added to the resin coated magnesium powder and again mixed by hand. All compositions

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(200 g each) were pressed into paper tubes of ID 42 mm at a dead load of 20 ton.

2.3 Methods

Impact sensitivity was measured by Fall Hammer apparatus using 2 Kg drop weight on 20 mg sample and CE is used as a reference sample. Friction sensitivity was determined on Julius Peter apparatus by placing 10 mg sample over ceramic friction plate. Calorimetric value (cal-val) was determined under Argon atmosphere in a Parr1241 Adiabatic Bomb Calorimeter and is calibrated using Analar grade benzoic acid. Locally fabricated DTA apparatus was used to measure the ignition temperature of the sample at a heating rate of 40 ^{0}C/min using 10 mg sample and Al_2O_3 is kept as reference. The luminosity and burning time were measured by EG&G make photometer model 550 at a distance of 6 m from the flare which was mounted inside the tunnel of dia. 1.5 m with a wind velocity of 4-5 m/s. Photometer is calibrated using black body.

3. RESULTS & DISCUSSIONS

The details of compositions studied are given in Table 1. Burn rate, luminosity, and luminous efficiency of the compositions are presented in Table 2. Luminosity and luminous efficiency increase with increase in magnesium content (up to 70/30 magnesium/sodium nitrate ratio) and then decrease

Table 1. Illuminating flare compositions

Comp. No.	F/O ratio	*Mg* (%)	$NaNO_3$ (%)	Binder %
1	60:40	57.60	38.40	4, E-605
2	65:35	62.40	33.60	4, E-605
3	70:30	67.20	28.80	4, E-605
4	75:25	72.00	24.00	4, E-605
5	60:40	56.40	37.60	6, E-605
6	65:35	61.10	32.90	6, E-605
7	70:30	65.80	28.20	6, E-605
8	75:25	70.50	23.50	6, E-605
9	60:40	56.40	37.60	6, HSR 8111
10	70:30	65.80	28.20	6, HSR 8111

Table 2. Luminosity and luminous efficiency

Comp. No.	Linear burn rate (mm/s)	Luminosity $\times 10^5$ (cd)	Luminous efficiency $\times 10^4$ (cd.s/g)
1	2.6	2.1	3.5
2	2.8	2.4	3.6
3	3.1	3.0	4.1
4	3.6	2.8	3.3
5	2.0	1.5	3.0
6	2.2	1.8	3.4
7	2.4	1.7	3.2
8	2.8	1.6	2.4
9	3.5	2.6	2.9
10	5.6	3.6	2.7

Table 3. Sensitivity and thermal characteristics

Comp.No	$H_{50\%}$ (cm)	FOI	Friction Insensitive Upto (Kg)	Cal.val. (Cal/g)	Ignition temperature (°C)
1	64	60	36	--	504
2	114	82	32.4	--	493
3	75	89	32.4	1025	502
4	82	87	36	951	494
5	89	84	36	1316	472
6	83	79	32.4	1193	519
7	91	84	36	1033	505
8	75	69	36	893	513
9	111	91	36	1461	512
10	92	86	36	1210	543

with 4 per cent binder. However, in the case of 6 per cent binder-based compositions, luminosity and luminous efficiency increase with increase in magnesium content (up to 65/35 magnesium/sodium nitrate ratio). The compositions are basically fuel rich in nature and draw oxygen from atmosphere during combustion. Hence efficiency is generally higher at higher fuel values.

Burn rate increases with increase in Magnesium content. Burn rates of the compositions with 4 per cent binder is higher than those with 6 per cent binder. Impact, friction sensitivities, ignition temperatures and cal-val are shown in Table 3. Cal-val decreases with decrease in oxidizer content. Figure of insensitivity ranges from 60 to 90 and most of the compositions are friction insensitive up to 36 kg. Ignition temperatures are in the range of 470 °C to 520 °C. Mechanical properties of the compositions are presented in Table 4. Compression strength of compositions with epoxy resin binder are comparable to that of polyester–based compositions when the composition is pressed after curing but compressive strength is high for epoxy–based compositions if they are pressed before curing.

Luminosity, burn rate, and cal–val are high for polyester resin based compositions compared to corresponding epoxy–based compositions probably due to high oxygen content. Luminous efficiency is directly proportional to burn time. Due to reduction in burn time luminous efficiency is less. Increase in binder content from 4 per cent to 6 per cent in the composition decreases burn rate, luminosity, and luminous efficiency. Since thermal conductivity decreases with increase in binder content, this reduction could be easily explained. The efficiency of composition based on 4% epoxy resin and

Table 4. Mechanical properties

Comp. No.	Compressive strength (kgf/cm^2)	% Compression	Modulus
1	257	3.8	8505
2	268	4.2	7731
3	160	3.8	5100
4	243	4.1	7445
5	210	4.8	5710
6	277	4.0	7811
7	155	4.1	4476
8	185	4.3	5222
9	230	3.7	11260
10	285	3.3	11000

Table 5. Thermochemical data

S. No.	Composition $Mg/NaNO_3$/E605	Temperature (°C)	*MgO* (Mass parts)
1	57.6/38.4/4	2449	0.463
2	62.4/33.6/4	1669	0.423
3	67.2/28.8/4	1528	0.422
4	72/24/4	1300	0.356
5	56.4/37.6/6	1693	0.417
6	61.1/32.9/6	1664	0.424
7	65.8/28.2/6	1516	0.422
8	70.5/23.5/6	1297	0.357
9	56.4/37.6/6 HSR8111	2037	0.436
10	65.8/28.2/6 HSR 8111	1612	0.421
11	67.2/28.8/4/O_2 10 parts	2771	0.460
12	67.2/28.8/4/O_2 20 parts	2943	0.499
13	67.2/28.8/4/O_2 30 parts	3002	0.487
14	67.2/28.8/4/O_2 40 parts	3012	0.476
15	67.2/28.8/4/O_2 50 parts	3006	0.466

70/30 Magnesium/sodium nitrate ratio is 30-35 per cent more than that of the polyester–based compositions.

Thermochemical data are given in Table 5. Flame temperature and combustion products were evaluated theoretically by using REAL program[5]. In anaerobic condition, flame temperature and Magnesium oxide content decrease with increase in Magnesium. In aerobic condition, flame temperature and Magnesium oxide content are high. Flame temperature increases with increase in O_2 up to 40 parts beyond that it decreases while *MgO* content increases up to 20 parts O_2.

4. CONCLUSIONS

Luminosity and burn rate are high for the compositions with 4 per cent binder content. Luminosity, burn rate, and cal–val are higher for polyester–based compositions. High luminous efficiency is achieved for the composition based on magnesium/sodium nitrate ratio 70/30 with 4 per cent epoxy resin. All formulations are safe for processing and handling.

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