Metal–Fluorocarbon Pyrolants: VIII.[1]‡ Behavior of Burn Rate and Radiometric Performance of two Magnesium/Teflon/Viton (MTV) Formulations upon Addition of Graphite§

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Abstract: *The burn rate, u (mm s^{-1}) of fuel rich magnesium/Teflon/Viton (MTV) is increased by 23-36 % upon addition of 5 wt% graphite whereas the spectral efficiency E_β (J g^{-1} sr^{-1}) remains largely unaffected.*

Keywords: *Burn rate, graphite, magnesium, MTV, polytetrafluoroethylene, radiometry, Teflon™, Viton™*

Introduction

Magnesium/Teflon/Viton, better known as MTV, is the most widely used aerial infrared decoy flare material.[1-4] Its success is mainly based on the high spectral efficiency, E_λ, in both α and β bands at sea level not reached by any other material. There have been numerous reports on the alteration of MTV combustion rate. Kuwahara has proposed applying zirconium as burn rate modifier to yield an increase in burn rate by factor ~ 1.4 at 10 wt% Zr.[5] Nielson has proposed applying nanometric carbon fibres to enhance the burn rate by factor of ~1.11 at 2 wt% fibres.[6] Shortridge and Wilharm reported the modification of MTV burn rate with nanometric aluminium (ALEX) and observed an increase in burn rate by factor of $n \approx 1.44$ at ~27 wt% ALEX.[7] All these methods have in common the application of very expensive materials thus restricting their use for small scale applications. Nadler has disclosed a method to improve the performance of MTV based flares by adding graphite to MTV but without further specifying the achieved rate of improvement.[8] Although based on different chemistry the burn rate behaviour of magnesium sodium nitrate pyrolants is similar to MTV as they show the same dependency of burn rate on the weight fraction of magnesium.[9,10] Singh *et al.* have reported the influence of graphite on the burn rate of magnesium/sodium nitrate 70/30 pyrolant. They observed an increase in burn rate of ~1.15 upon addition of 2 wt% graphite.[11]

It was now decided to investigate the effect of addition of 5 wt% graphite on two fuel rich compositions having either 57 or 60 wt% magnesium, 10 wt% Viton binder and the remainder being polytetrafluoroethylene.

The compositions were prepared in 5 kg batches with conventional mixing in a 5 l planetary blender. Thus magnesium (non-ferrum Metallpulver, A-5111 St. Georgen, ECKA Mg-Pulver LNR-61, mean particle radius: 20 µm) and graphite (Edelgraphit GmbH, D-53175 Bonn, E 321) were wetted with acetone and mixed in a blender until a dark grey mass resulted. Addition of PTFE powder (Dyneon, D-84504 Burgkirchen, TF-9205, mean particle radius: 2 µm) and Viton (MACH I Inc, King of Prussia, USA, FC-2175) dissolved in acetone followed. Now the heating jacket of the blender was heated to ~40 °C and the mass was mixed until small granules had formed. These were spread on stainless steel drying pans and dried at reduced pressure at 40 °C for 12 h.

‡ For Part VII see ref. 1.

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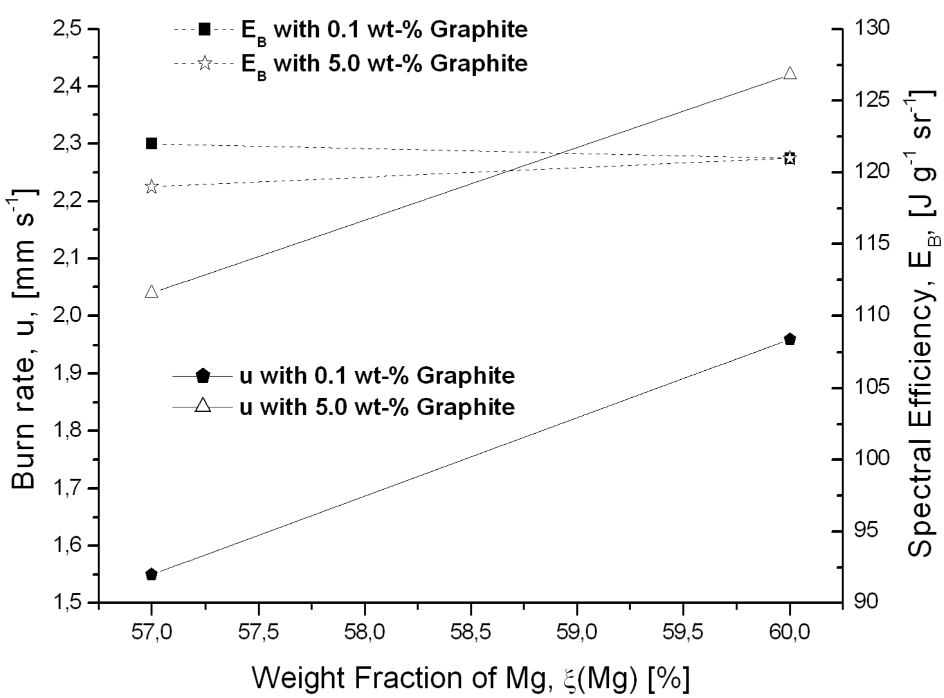

Figure 1. *Burn rate and spectral efficiency as a function of stoichiometry.*

The compositions were pressed in a 22.4 mm cylindrical die with 100 MPa pressing pressure and 10 s hold time to give consolidated strands of 25 g mass. The lateral surfaces of the strands were wrapped in Kraft paper and the top face was applied with an ignition dip of boron, potassium nitrate, nitrocellulose (12/84/4) mix.

The pellets were placed between steel split pins on a brass cylinder and ignited by an electric igniter enhanced with a quickmatch fixed with adhesive tape on top of the strands.

The burn rate was measured with the timer of the video camera. The radiometric performance was determined in the β-band (3.5–4.8 μm) with an IR radiometric system (RM 6600 and un-cooled pyro-electric detector RkP 575 both from Laser Probe USA).

The burn rate of MTV generally is a function of stoichiometry and rises exponentially with increasing magnesium content between ξ(Mg) = 0.3–0.7 as has been observed by Kuwahara,[5] Kubota[12] and Koch.[1] This behaviour is mainly

Table 1. *Composition details.*

Component	**1**	**2**	**3**	**4**
Magnesium	57	57	60	60
Polytetrafluoroethylene	28	32.9	25	29.9
Hexafluoropropene vinylidene fluoride copolymer	10	10	10	10
Graphite	5	0.1	5	0.1
Experimental density/g cm^{-3}	1.75	1.76	1.71	1.73

Table 2. *Performance of compositions.*

Component	Unit	**1**	**2**	**3**	**4**
Burn rate	mm s^{-1}	2.04	1.55	2.42	1.96
Increase factor	—	1.36	—	1.23	—
Spectral efficiency	J g^{-1} sr^{-1}	119	122	121	121

attributed to the increasing thermal conductivity of the pyrolant.[13] Hence it would seem logical to increase the condensed phase conductivity to achieve a higher burn rate.

Figure 1 shows burn rate and spectral efficiency as a function of stoichiometry. The burn rate observed for compositions **2** and **4** is significantly lower than those with equal magnesium content reported by the author earlier[1] (2–3 mm s^{-1} versus 7–8 mm s^{-1}). This is due to higher Viton content which is known to slow down the combustion rate[14] and due to the lower density of the latter samples.

The burn rate now increases by 36 and 23% upon addition of 5 wt% graphite. Interestingly the reduction in fluorine content due to the lower PTFE content affects neither burn rate nor spectral efficiency. This is in accord with findings that substitution of Viton binder for thermoplastic polystyrene does not decrease the performance of magnesium/PTFE pyrolants either.[15]

The burn rates and radiometric performances for the pyrolants are given in Table 2.

With the graphite modified $Mg/NaNO_3$ pyrolant Singh *et al.* speculated that graphite would oxidise at the surface of the strand and thus contribute to the heat of combustion and hence alter the burn rate.[11] In view of the negative oxygen balance of $Mg/NaNO_3$ (70/30), $\Lambda = -31.95\%$ oxidation of carbon directly at the strand surface appears very unlikely. Hence the underlying mechanism must be mainly physical in nature.

The spectral efficiency of a flare material, E_λ, generally can be written as follows:

$$E_\lambda = \frac{1}{4\pi} \cdot H_c \cdot F_\lambda$$

with H_c being the enthalpy of combustion (J g^{-1}) and F_λ (—) the fraction of radiation emitted in the band of interest determined mainly by the combustion temperature, T_c. As no significant changes in spectral efficiency are observed the burn rate modification must be due to physical effects not affecting either enthalpy of combustion or combustion temperature.

These may be:

- Increased heat feedback from gas phase to condensed combustion zone due to the high emissivity/absorbtivity of graphite.
- Increased thermal conductivity of pyrolant grain due to high thermal conductivity of graphite thus promoting pre-ignition reactions far behind the regular reaction zone.

If this accounts for the actual mechanism then addition of diamond particles should be even more beneficial as they possess the highest thermal conductivity of any material available and are easily converted to highly emissive graphite particles within the condensed combustion zone.

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