Roxel

Propulsion systems

The Evolution of IM Rocket Motors for Anti-Armour Application

By Konrad Nofer (Roxel UK) and Raymond Coleno (Roxel France)

Paper Prepared for NDIA IMEMT Symposium, 15-17 Nov 2004

Contents

- Summary
- Introduction
- Early Pedigree Rocket Motors (up to 1980's)
- Next Generation (late 1980's through 1990's)
- Current Developments
- Conclusion
- References

Roxel

Summary

- Anti-armour missile systems with Roxel rocket motor grains singled out
  - High production volume
  - Particular IM difficulties
  - Notably, Minimum Smoke propellants required
- Early motors (some still in service) had reasonable IM performance
  - 1.3 Class propellants
  - No monolithic steel cases
- IM shortcomings identified and considered thro' 1990's to present day
- Current development and future anti-armour projects with Min Smoke propellant rocket motors **are now capable of full IM compliance**
- Scope for improvement in higher energy and density 1.3 propellants

Roxel

Introduction - Roxel Anti-Armour Missile Propulsion

- High volume
- Simplicity and low cost
- Minimum Smoke propellant
  - Some with secondary flame suppression
    - For Stealth, Guidance, Survivability
- Man portable, ground vehicle, helicopter launch
- Ranges up to 8km +

Introduction - Roxel Anti-Armour Missile Propulsion (cont)

- IM characteristics of earlier rocket motors
- IM shortcomings
- IM improvements with state-of-art techniques

Early Pedigree – Rocket Motors (up to 1980's)

Anti-Armour Missile Systems with Roxel Grains

Missile Data

System	Guidance	Launch Platform	Range (m)	Initial ISD/ Nos.
LAW 80	Unguided, spotting rifle	Man portable	500	~1985
Vigilant	Wire-guided	Vehicle	1600	1964
Swingfire	Wire-guided, optically tracked	Vehicle	0 - 5000	1969/ 44000
RBS 56	SACLOS, wire-guided	Man portable/ Vehicle	150 -2200	1988
MILAN	SACLOS, wire-guided	Man portable/ Vehicle	2000	1972/ >350000
HOT	SACLOS, wire-guided	Vehicle/ Helicopter	75 - 4000	1974/ >85000
ACL89	Unguided	Man portable	400	1975
APILAS	Unguided	Man portable	25 - 350	1983

Roxel

Early Pedigree – Rocket Motors (up to 1980's)

Anti-Armour Missile Systems with Roxel Grains

Rocket Motor Characteristics

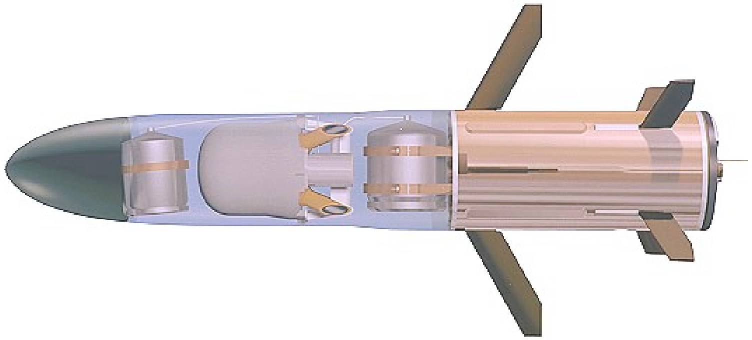
For Missile System	Case Material	OD (mm)	Propellant		Standard SI (s)		≡ NOL Cards	
			B	S	B	S	B	S
LAW 80	KOA	102	HTPB	-	248	-	0	-
Vigilant*	Al. alloy	114	CDB	CDB	226	224	28	26
Swingfire*	Al. alloy	165	CDB	CDB	226	223	27	30
RBS 56	Al. alloy	116	CDB	-	236	-	29	-
MILAN*	Al. alloy	87	CDB	CDB	212	214	< 70	< 70
HOT	Al. alloy	120	EDB	CDB	220	211	70	85
ACL89	Al. alloy	89	EDB	-	226	-	74	-
APILAS	Kevlar	112	EDB	-	226	-	74	-

* Dual propellant Boost (B) – Sustain (S) single grain main motor

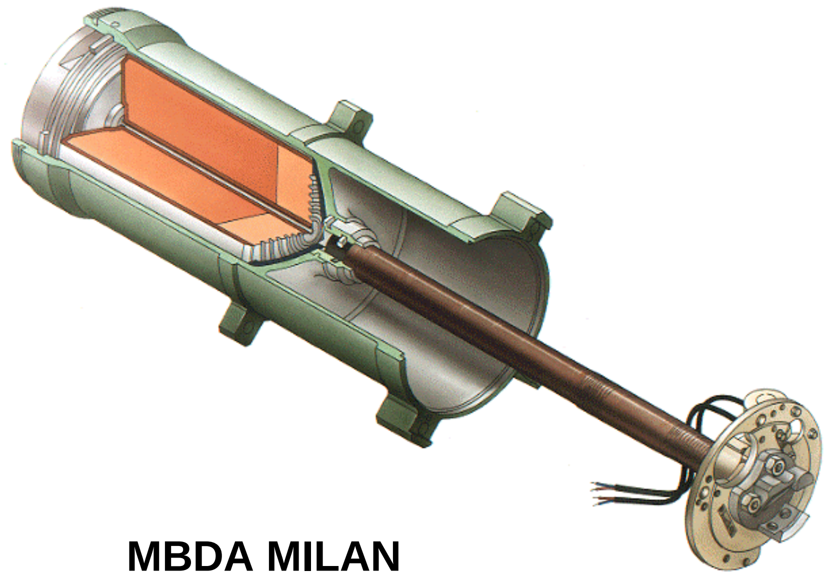
Key : CDB = unfilled (no nitramines) conventional cast double base
EDB = unfilled extruded double base
NOL = United States Naval Ordnance Laboratory Large Scale Gap Test
KOA = Kevlar overwound aluminium
B = boost phase, S = sustain phase
Red = predicted by read across from similar propellant

Roxel

Early Pedigree – Rocket Motors (up to 1980's)



Bofors RBS 56 (BILL)



MBDA MILAN

Early Pedigree – Rocket Motors (up to 1980's)

Anti-Armour Missile Systems with Roxel Grains

Estimated IM Rocket Motor Responses

For Missile System	FCO	SCO	BI	FI	
				1830 m/s	2530 m/s
LAW 80	V	I/ III	V	V	V
Vigilant	IV/ V	III	V	V	V[2]
Swingfire	IV/ V	III	V[1]	V	V[2]
RBS 56	IV/ V	III	V	V	V[2]
MILAN	IV/ V	III	V	V[2]	V[2]
HOT	IV/ V	III	V	V[2]	Not known
ACL89	IV/ V	III	V	V[2]	Not known
APILAS	IV/ V	III	V[1]	V[2]	Not known

1 = measured response
2 = the possibility of Type V is strong on 'low propellant sensitivity' grounds, although practical evidence is tenuous

NB – IM WAS NOT A DESIGN CONSIDERATION

Roxel

Early Pedigree – Rocket Motors (up to 1980's)

IM Performance Summary

- Predicted relatively benign responses
  - Low sensitivity propellant (non-use of energetic fillers)
  - Relatively easily weakened cases
    - Note the absence of monolithic steel cases

- IM shortcomings
  - Slow cook off
  - Fast cook off improvement
  - Constraint on 'low card gap' Minimum Smoke propellant (for Fragment Impact)

Next Generation (late 1980's through 1990's)

- Roxel Fr rocket motors for
  - Long Range (LR) TRIGAT
  - Medium Range (MR) TRIGAT
  - ERYX

- MURAT (IM) requirements a consideration
  - Hybrid case construction
    - Kevlar overwound thin aluminium shell

Roxel

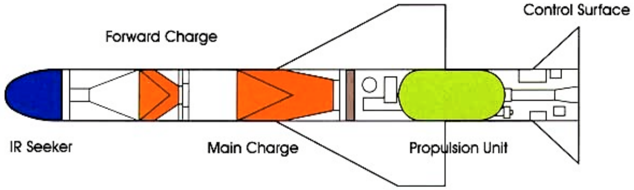
Next Generation (late 1980's through 1990's)

Missile Data

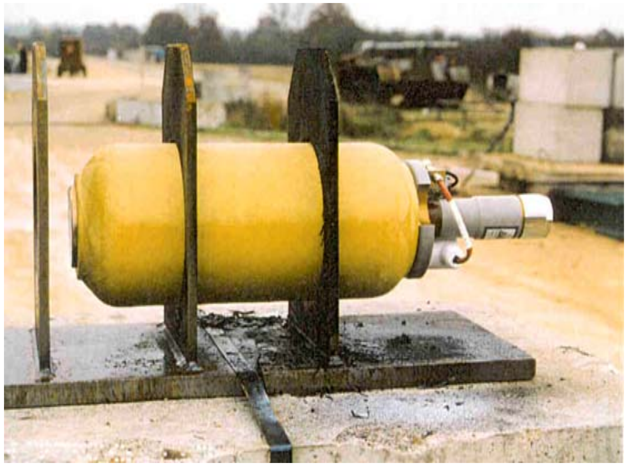
System	Guidance	Launch Platform	Range (m)
LR TRIGAT	Passive IR	Helicopter	500 - 5000, extendable to 8000
MR TRIGAT	Coded laser beam riding	Man portable	200 - 2400
ERYX	Wire-guided, optically tracked SACLOS	Man portable	50 - 600

Roxel

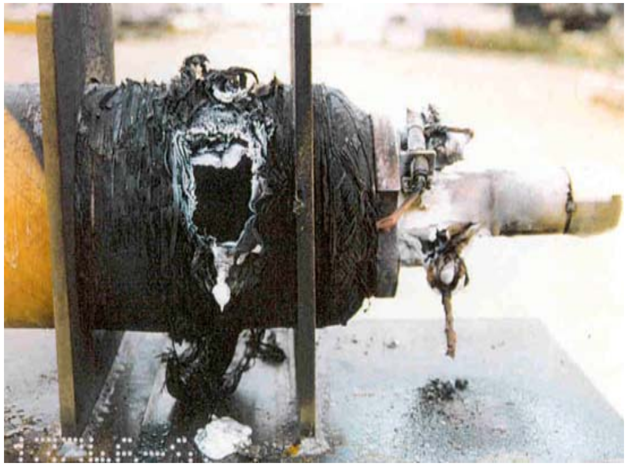
Next Generation (late 1980's through 1990's)



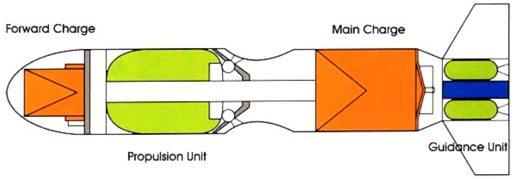
- LR TRIGAT
  - Hybrid case
  - Min Smoke nitramine filled CDB propellant
  - FCO - Type V to STANAG 4240
  - BI - Type V to STANAG 4241

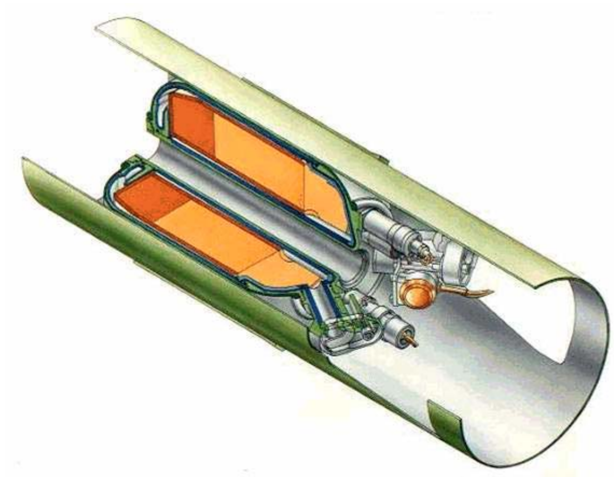


Bullet Impact Trial



Next Generation (late 1980's through 1990's)

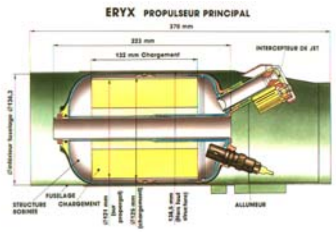




- MR TRIGAT
  - Hybrid case
  - Min Smoke unfilled CDB propellant
    - < 70 cards NOL
  - FCO - Type V demonstrated
  - BI - Type V predicted
  - FI - Type V predicted with STANAG 1830m/s fragment

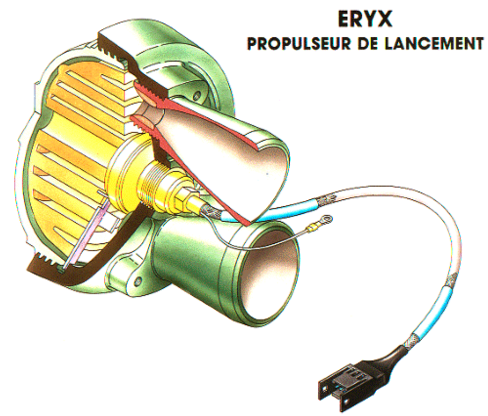
Fuel Fire Trial

Next Generation (late 1980’s through 1990’s)



© MBDA

- ERYX Main Motor
  - Hybrid case
  - Min Smoke unfilled CDB propellant
    - 77 cards NOL
- ERYX Eject Motor
  - Aluminium alloy case
  - Min Smoke unfilled EDB propellant
    - 74 cards NOL
- At system level
  - BI - Type V demonstrated
  - FCO - Type V demonstrated
  - SD - no propagation

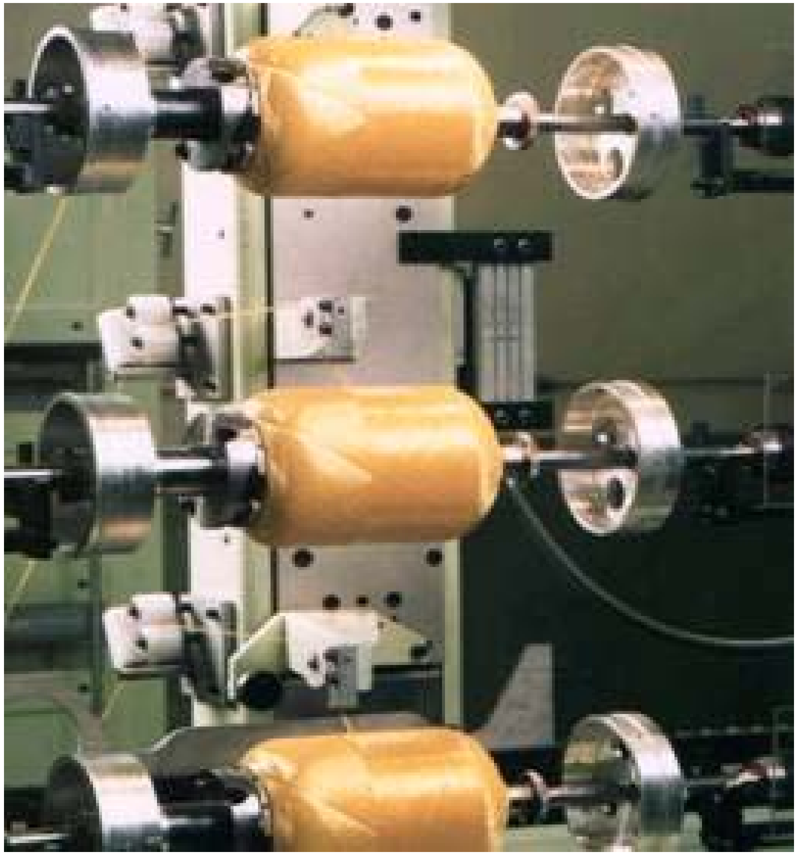


Roxel

Next Generation (late 1980’s through 1990’s)

Roxel Fr Hybrid Case

For Example : ERYX



Roxel

Current Developments

- ‘Design for IM’ now a major priority
- Special attention to
  - SCO mitigation
  - More readily IM degradable case structures
    - e.g. SSL, GC
- But still energy/density compromise with Min Smoke propellants for low sensitivity
  - e.g. Nitramine loading limitation
- Current examples of Roxel anti-armour rocket motor development
  - UK SLIM
  - US JCM

Current Developments - SLIM

Note
Further information on SLIM is included in a separate presentation at this NDIA Symposium

- SCO mitigation
  - Temperature sensitive venting mechanism
- SSL case
- EMCDB unfilled propellant
  - approx 50 cards NOL
- BI : Type V demonstrated to STANAG 4241
- FCO : Type V demonstrated to STANAG 4240

© UK MoD

Bullet Impact Trial

© UK MoD

Current Developments - SLIM

– Based upon Roxel IM Hellfire motor

– IM trialled to MIL-STD 2105

MIL-STD 2105 Test	FCO	SCO	BI	FI	
				1830 m/s	2530 m/s
IM Hellfire	V	V	V	V	I

Roxel

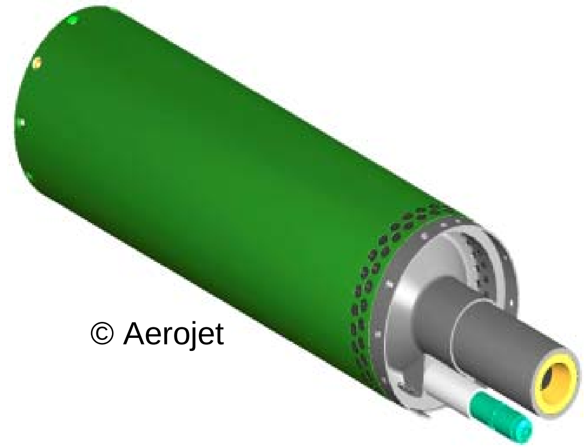
Current Developments - JCM

Note

There is a specific presentation on JCM at this NDIA Symposium

• Roxel supply grain and igniter, Aerojet is motor prime contractor

- SCO mitigation
  - Temperature sensitive venting mechanism
- Dual propellant cartridge loaded charge
  - Boost 50 cards NOL
  - Sustain 26 cards NOL
- FCO and FI (>1,830 m/s)
  - both Type V demonstrated to MIL-STD 2105 & STANAG 4439



© Aerojet

Fuel Fire Trial

© Roxel/ Aerojet

Conclusion

For Anti-Armour systems with Roxel grains :

- IM rating for earlier motors has never been poor
- IM shortcomings identified and given attention
  - Notably SCO mitigation
- All future projects are to be fully IM compliant
  - No worse than Type V (except for SR Type III)
- Roxel involvement with UK IM Hellfire, US JCM
  - **Full IM compliance with Minimum Smoke propellants**
  - Also, in the future for such projects as MCT (Missile de Combat Terrestre)
- Improvements sought
  - Mainly for 1.3 Class high energy and density formulations
    - IRDX
    - Ballistic versatility also important

Roxel

References

1. 'Roxel Approach to IM Rocket Motor Design' by Konrad Nofer and Jim Fleming (Roxel Group), NIMIC/ DOSG Workshop, 29 September – 2 October 2003

2. 'Minimum Smoke 1.3 Hazard Class High Performance Rocket Motors with IM' by Jim Fleming and Jean-Claude Nugeyre (Roxel Group), NDIA IM & EM Technology Symposium, 15 – 17 November 2004

3. 'Aerojet/ Roxel Minimum Smoke 1.3 Hazard Class Rocket Motor for JCM' by Patrick Wolf (Aerojet Inc.) and Jim Fleming (Roxel Group), NDIA IM & EM Technology Symposium, 15 – 17 November 2004