B16

超高分子量ポリエチレン繊維複合材によるアルミ合金製デブリバンパーからのイジェクタの低減

Reduction in Ejecta from Aluminum Alloy Debris Bumpers using Ultra-high Molecular Weight Polyethylene Fiber Composites

西田政弘, 渕田順也 (名古屋工業大学), 野村幸弘 (東洋紡)
Masahiro Nisida, Junya Fuchita (Nagoya Institute of Technology)
and Yukihiro Nomura (TOYOBO)

高強度繊維である超高分子量ポリエチレン繊維の複合材は, 防御材料として有望である. この材料を用いて, アルミ合金製デブリバンパーからのイジェクタの低減しつつ, バンパーとしての性能は同等もしくは向上するようなデブリバンパーを目指して, 研究している. その結果を報告する.

Ultra-high molecular weight polyethylene fiber composites of high strength fibers are promising materials for defense materials. Our group is trying to reduce ejecta from aluminum alloy debris shielding and to keep or improve bumper performance. We would like to report some results using ultra-high molecular weight polyethylene fiber composites.

第8回 スペースデブリワークショップ
2018年12月3日（月）～5日（水）JAXA 調布航空宇宙センター

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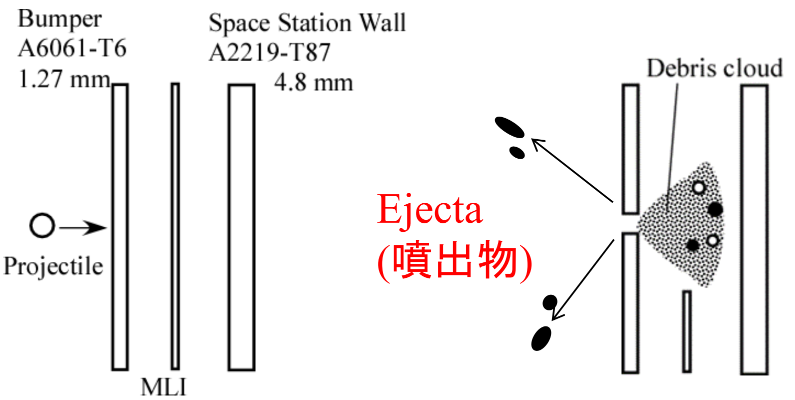
International Space Station

Courtesy of NASA
http://spaceflight.nasa.gov/gallery/images/shuttle/sts-127/html/s127e011212.html

JEM "KIBOU"

Courtesy of JAXA
http://www.jaxa.jp/projects/iss_human/kibo/index_j.html

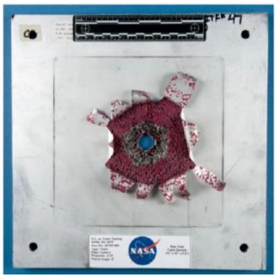
Bumper shield



Whipple shields　　Thin plate perforation

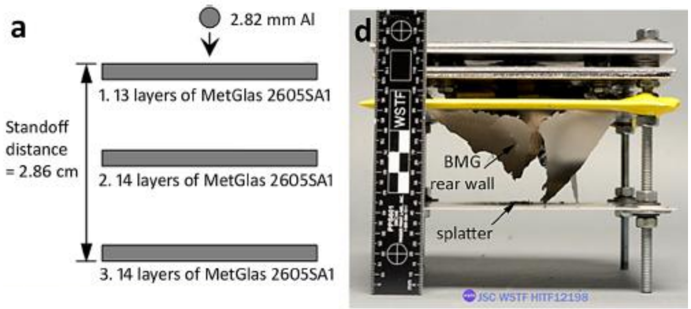
Improvements to Bumpers

8.33 mm al sphere → double-layer foam
6.9 km/s



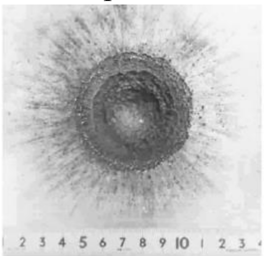
Ryan *et al.*, NASA/TM–2009–214793

2.82 mm al sphere → Metallic glass-stuffed
7.06 km/s



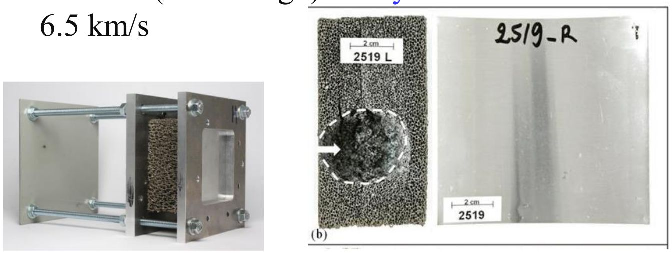
Douglas C. Hofmann *et al.*, Adv. Eng. Mat. 2014

ϕ20 mm, 2 mm Al plate → Mullite bumper
3.08 km/s



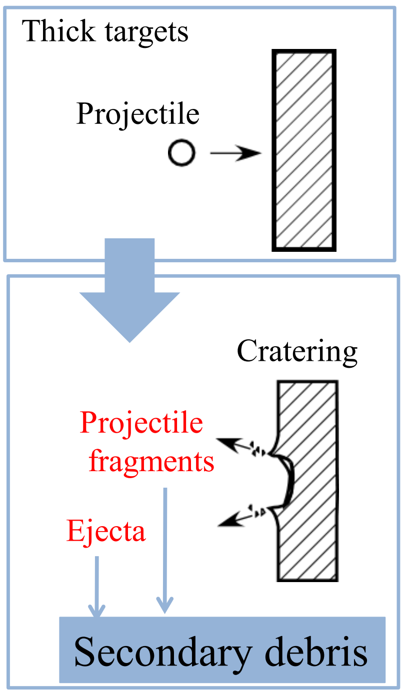
Kawai *et al.*, Int. J. Impact Engineering, 2008, p. 1612-1615

4 mm al (AlCu4Mg1) → Hybrid metal foams
6.5 km/s



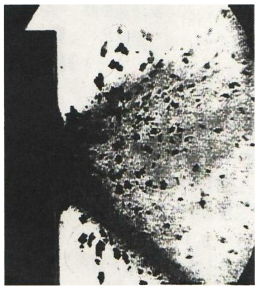
Andreas Klavzar *et al.*, Procedia Engineering, 103 (2015)

Thick Plate Penetration

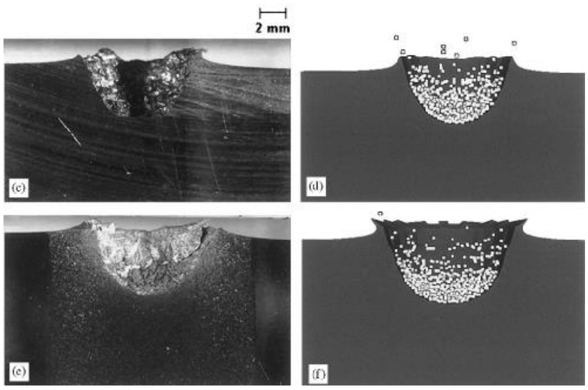


Composition of ejecta

Numata, Kikuchi, Sun, Kaiho, Takayama, Proc JSSW, (2006), pp. 221-222.



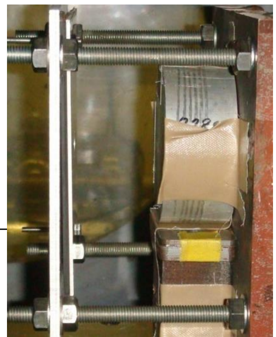
Projectile fragments and ejected materials



Murr, Int. J Impact Eng., (2006), pp. 1981-1999.

Earlier Studies of Our Group

Experimental Setup



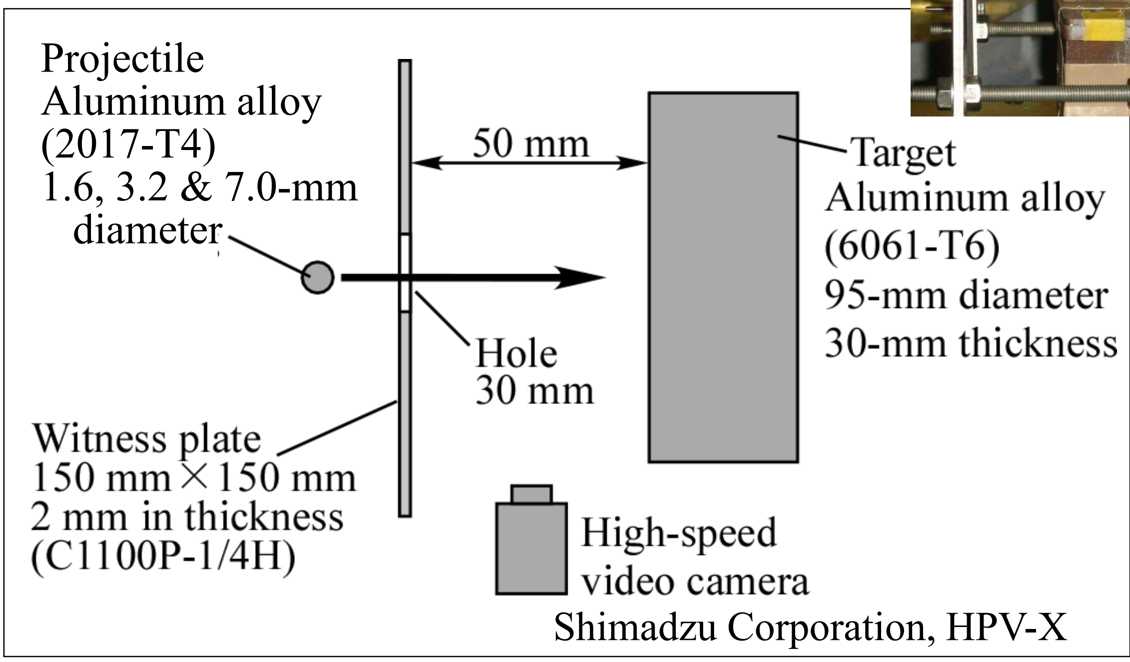
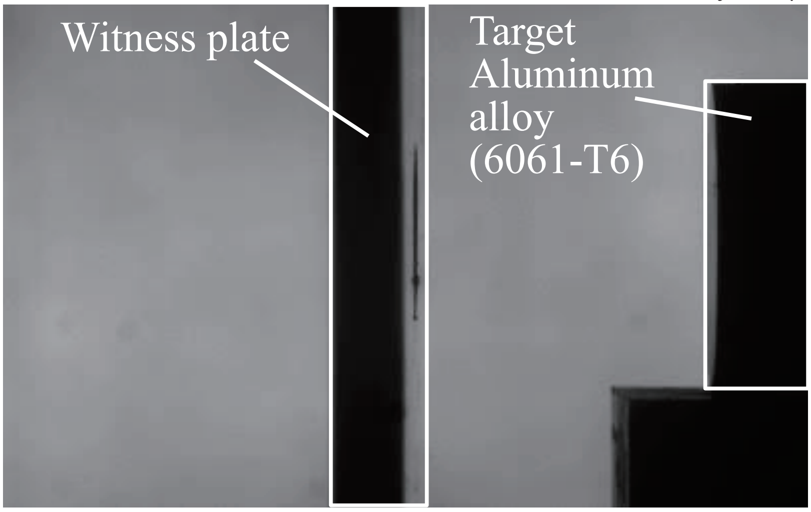


Image of Scattering Ejecta

Every 10 μs

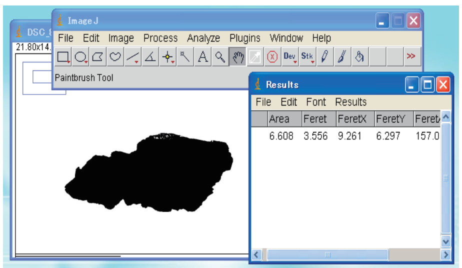


Projectile: Aluminum alloy (2017-T4)
3.2-mm diameter

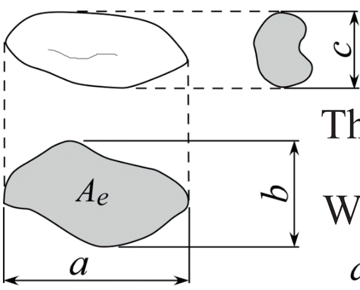
Impact velocity 4.14 km/s

Definition of Ejecta Size

Image analysis software
(Image J)



Length > 0.5 mm



Thickness

Width

$a \geqq b \geqq c$

Projected area

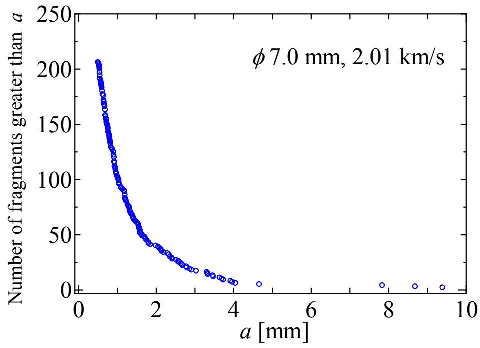
Ejecta length
(Maximum length)

ϕ7mm, 2.92 km/s

Today's Presentation Contents

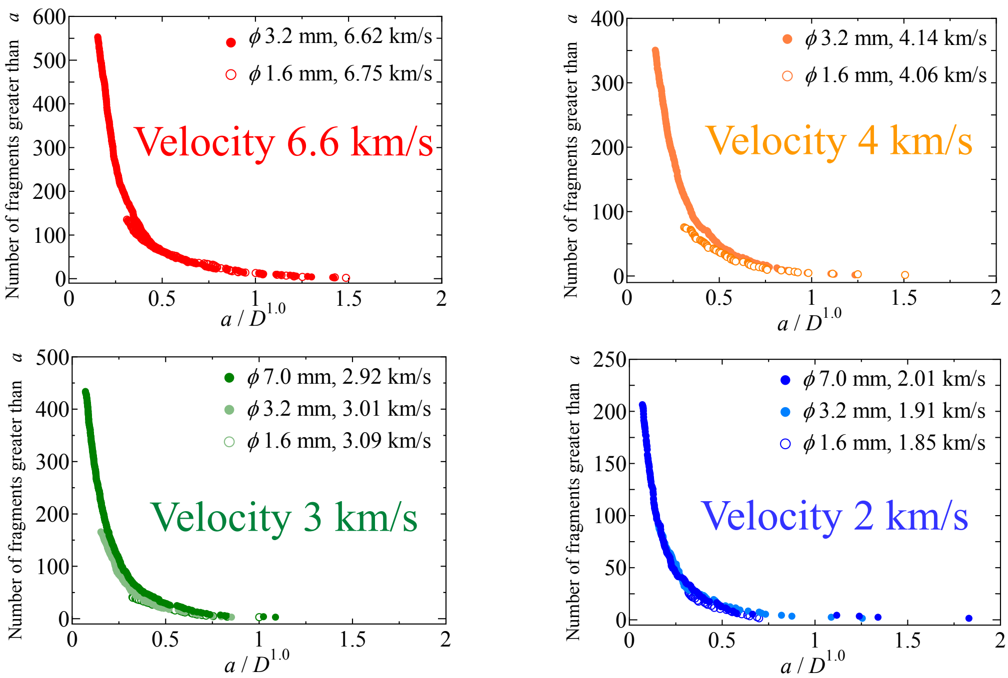
1. Hypervelocity impacts of aluminum alloy spheres on aluminum alloy targets

2. Length distribution of ejecta collected from test chamber



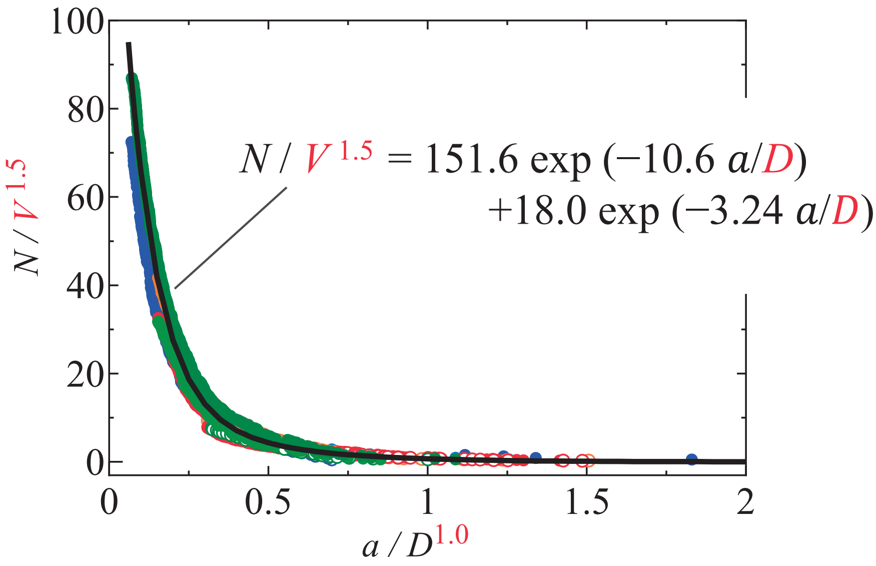
3. Scaling law for ejecta length

Normalization on Horizontal Axis



Ejecta length on horizontal axis divided by projectile diameter $D^{1.0}$ → Good agreement

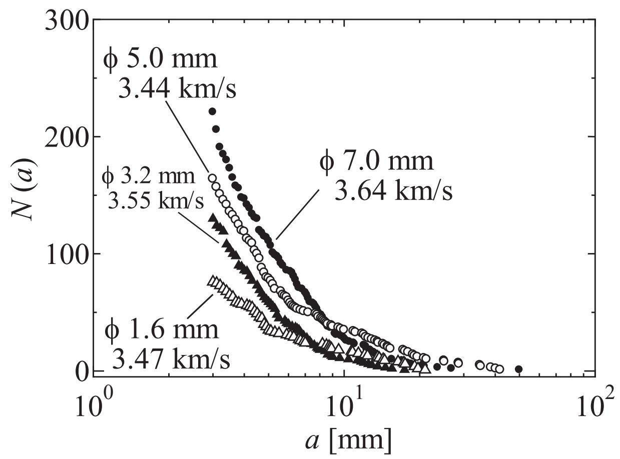
Normalization of Vertical Axis & Horizontal Axis



Masahiro Nishida, Yasuyuki Hiraiwa, Koichi Hayashi, Sunao Hasegawa, Scaling laws for size distribution of fragments resulting from hypervelocity impacts of aluminum alloy spherical projectiles on thick aluminum alloy targets: Effects of impact velocity and projectile diameter, International Journal of Impact Engineering, 109, (2017) pp. 400-407.

The Number of Ejecta on Front Side

Effects of projectile diameter



Al sphere → CFRP plates
(Front side of target)

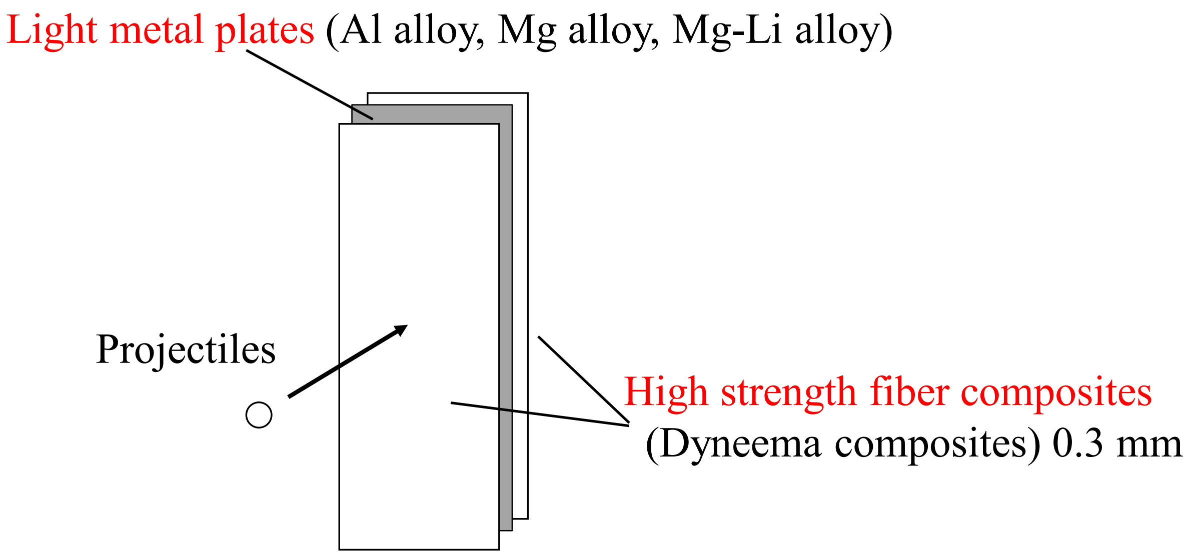
⇩

Reduction of ejecta

西田，林，東出，材料（2018）

Projects for Reduction of Ejecta

Project : High strength fiber composites / Al (Mg)



(接着剤， Adhesive?)

Earlier Studies of Debris Shielding (1/2)

PBI coating/CFRP

Polybenzimidazole (PBI):
Atomic Oxygen Protective Coating

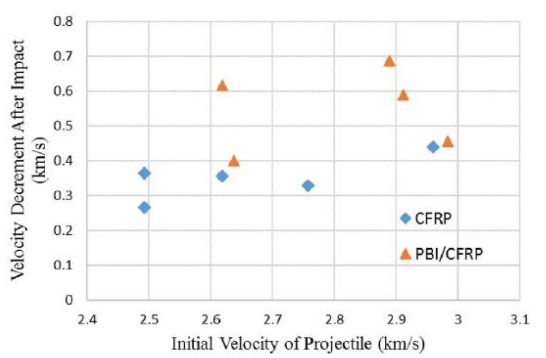
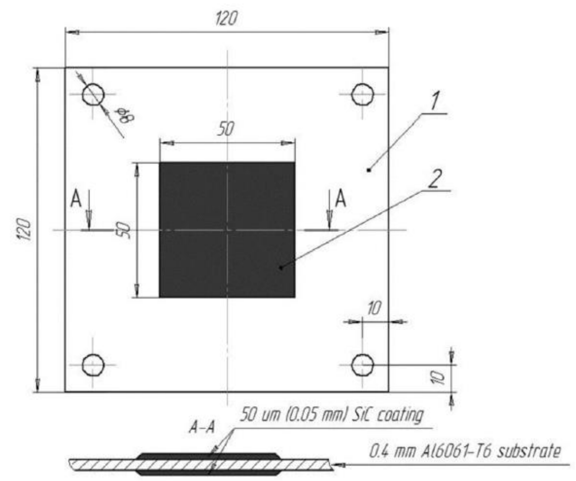


Fig. 5. Velocity decrement of the projectile after impact with CFRP and PBI/CFRP.

Sarath Kumar Sathish Kumar, et al., Polybenzimidazole (PBI) film coating for improved hypervelocity impact energy absorption for space applications, Composite Structures 188 (2018) 72–77

SiC coating/Al



Aleksandr Cherniaev, Igor Telichev, Sacrificial bumpers with high-impedance ceramic coating for orbital debris shielding, International Journal of Impact Engineering, 119 (2018) 45–56

Earlier Studies of Debris Shielding (2/2)

Ti-Al nylon impedance-graded materials

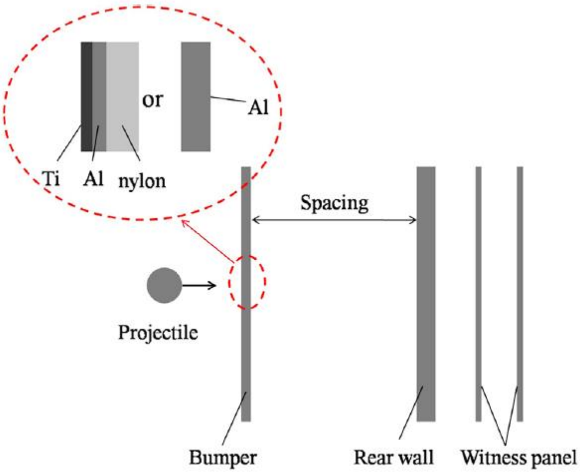


Fig. 1. Experiment schematic diagram.

Zhang P.L., et al., Study of the shielding performance of a Whipple shield enhanced by Ti-Alnylon impedance-graded materials, International Journal of Impact Engineering 124 (2019) 23–30

Kevlar/ CFRP

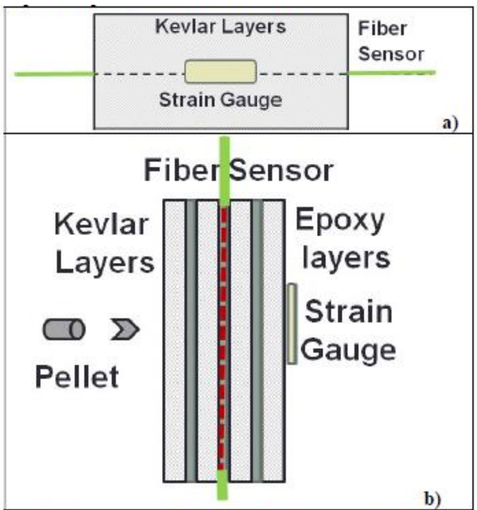
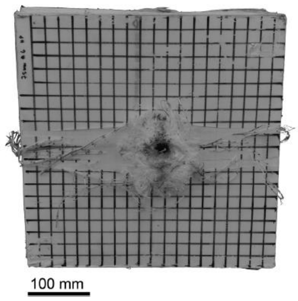


Figure 6, Four layers Kevlar/Epoxy, a) Top Front View; b) Cross Section Side View Strain Gauge and FBG (example Shot #79)

Emile Haddad, et al., Mitigating the effect of space small debris on COPV in space with fiber sensors and self repairing materials, Proc. ECSSMET (2018)

Project 3 High strength fiber composites / Al (Mg)

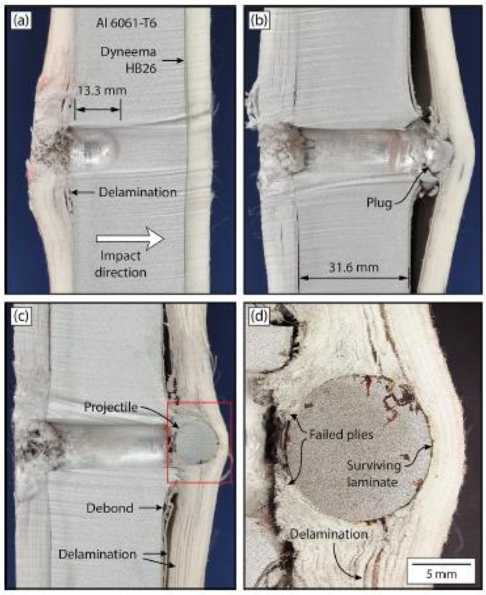
Earlier Studies of Dyneema Composites



1.59 km/s

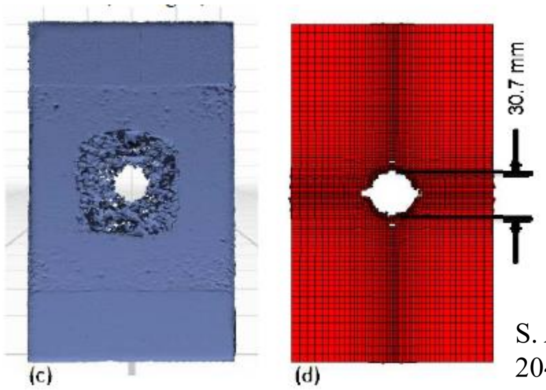
Fig. 3. Ballistic limit test target front face (75 mm thick target impacted by a 20 mm FSP at 1594 m/s).

Long H.Nguyen, Shannon Ryan, Stephen J.Cimpoeru, Adrian P. Mouritz, Adrian C.Orifici, Int. J. Impact Eng., 75 (2015) pp. 174-183.



(a) 0.80 km/s, (b) 1.22 km/s, (c) 1.36 km/s

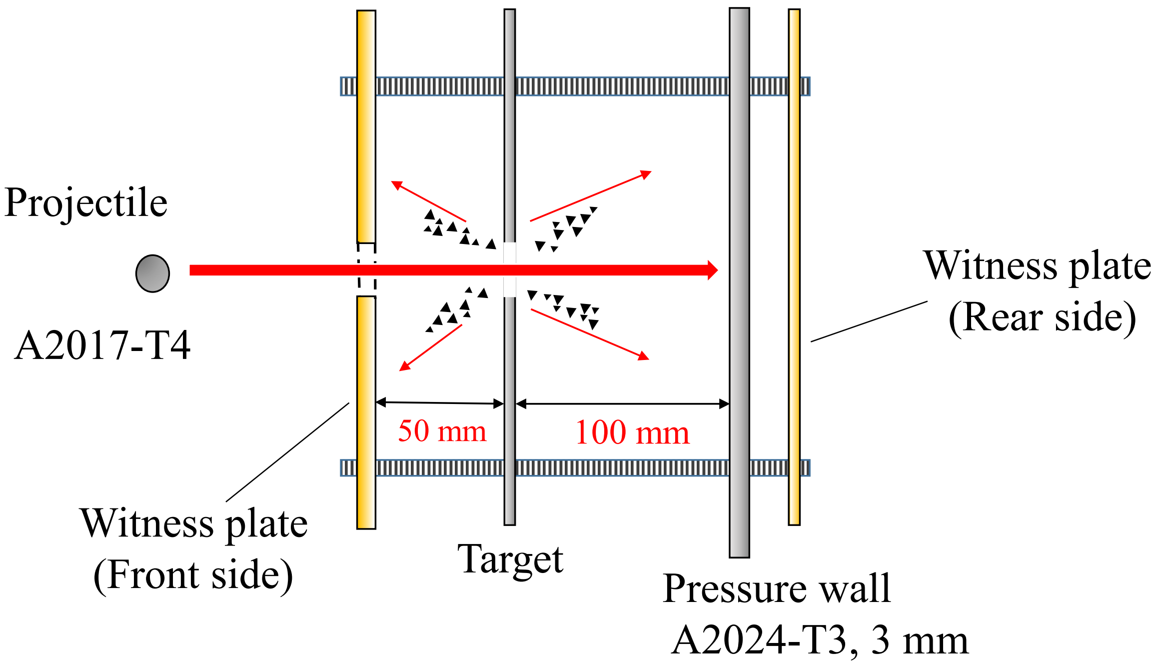
M.R. O'Masta, V.S. Deshpande, H.N.G. Wadley, Int. J. Impact Eng., 74 (2014) pp. 16-35.



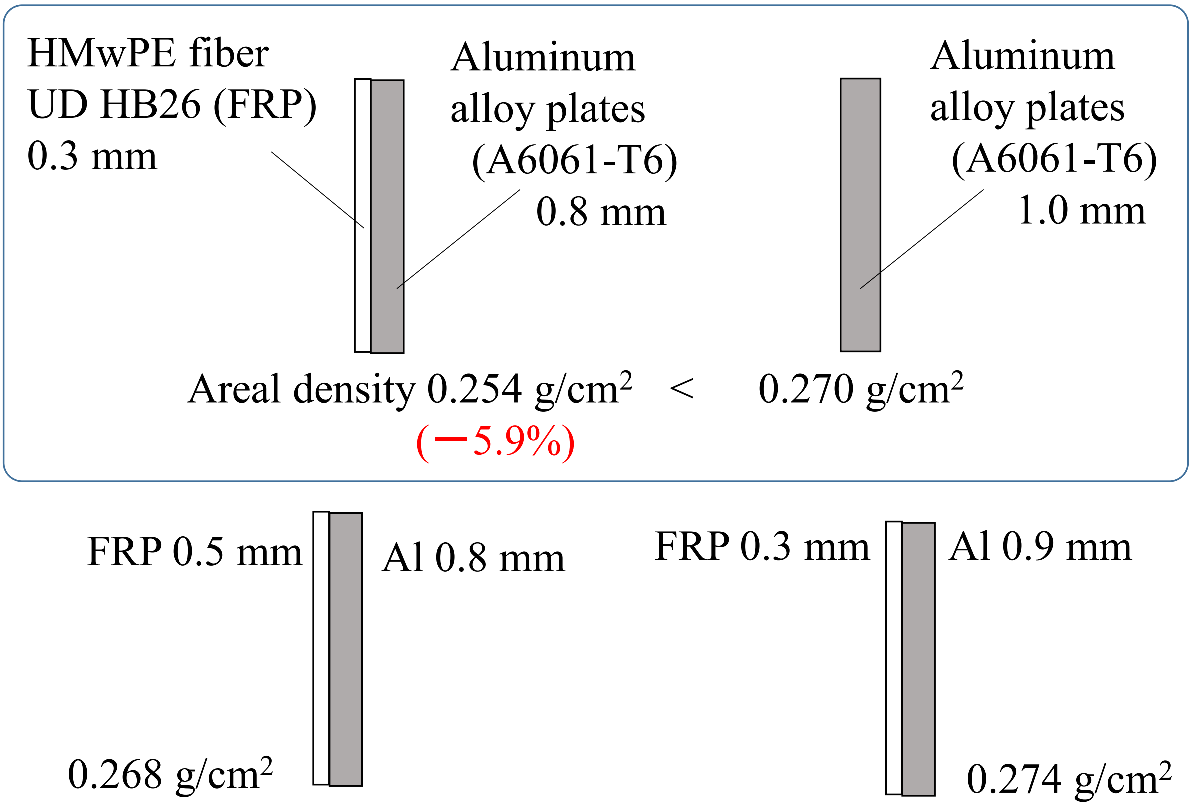
3.5 km/s

S. Austin et al., Procedia Eng. 204, (2017), pp. 51-58.

Experimental Setup



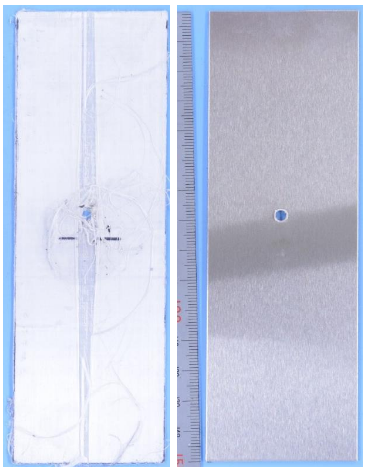
Dyneema Composites & Aluminum Alloy Plates



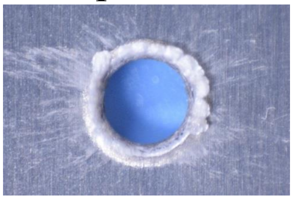
Results of projectile diameter 1.0 mm and impact velocity 6 km/s

Penetration Holes

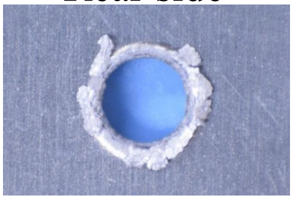
FRP 0.3 mm + Al 0.8 mm (shot 36)
(Projectile ϕ1.0 mm, 6.00 km/s)



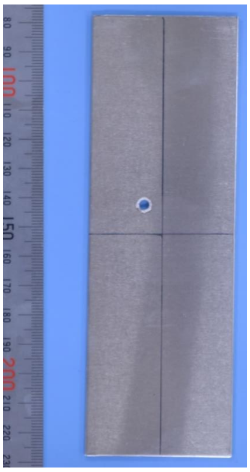
Impact side



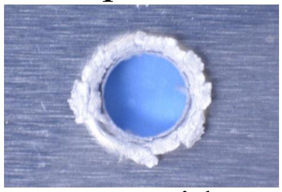
Rear side



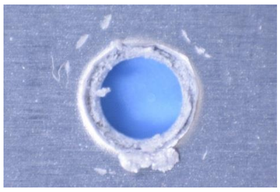
Al 1.0 mm (shot 18)
(Projectile ϕ 1.0 mm 6.24 km/s)



Impact side



Rear side



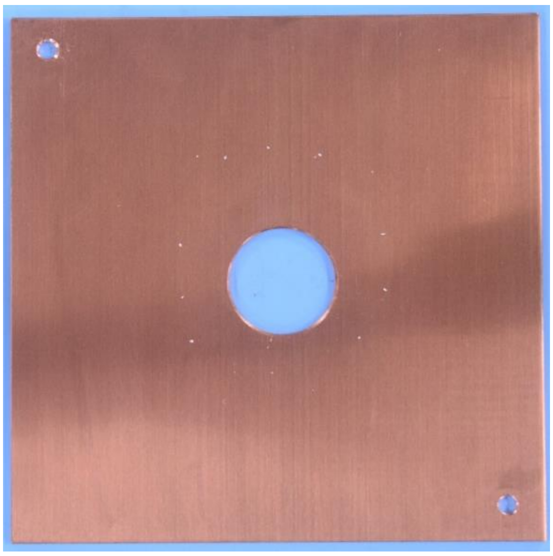
Penetration hole areas

FRP / Al	Al
10.81 mm^2 / 7.59 mm^2	7.64 mm^2

Witness Plates on Impact Side (1/2)

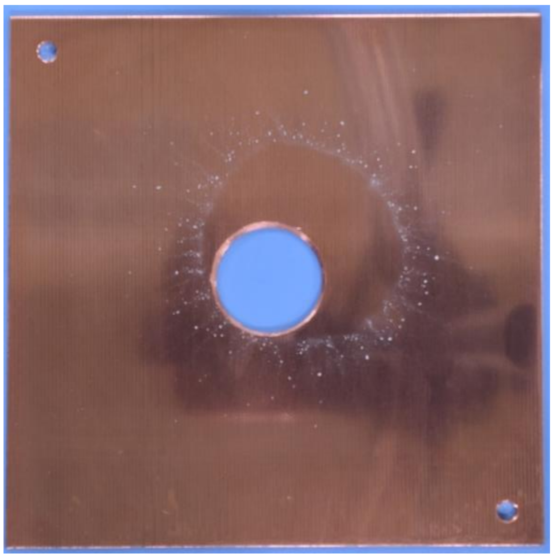
ISO 11227 : Test procedure to evaluate spacecraft material ejecta upon hypervelocity impact

FRP 0.3 mm + Al 0.8 mm (shot 36)



(Projectile ϕ1.0 mm, 6.00 km/s)

Al 1.0 mm (shot 18)

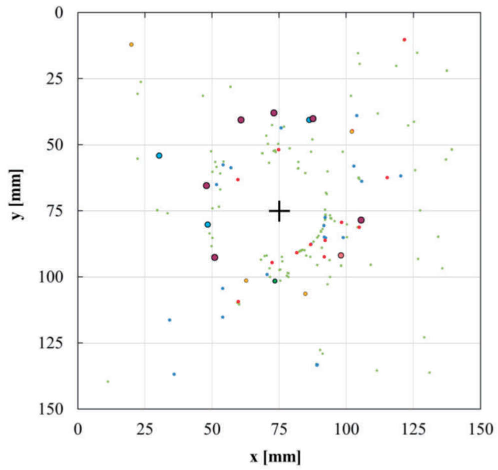


(Projectile ϕ 1.0 mm 6.24 km/s)

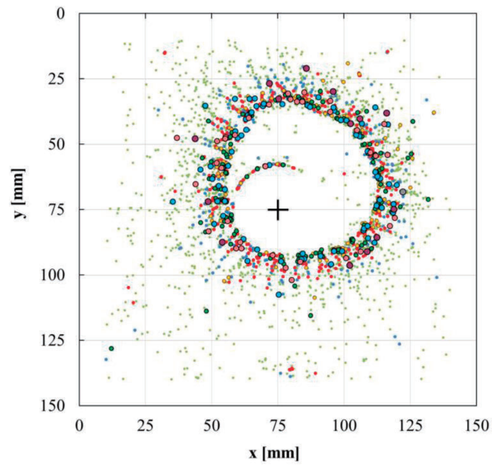
Witness Plates on Impact Side (2/2)

ISO 11227 : Test procedure to evaluate spacecraft material ejecta upon hypervelocity impact

FRP 0.3 mm + Al 0.8 mm (shot 36)

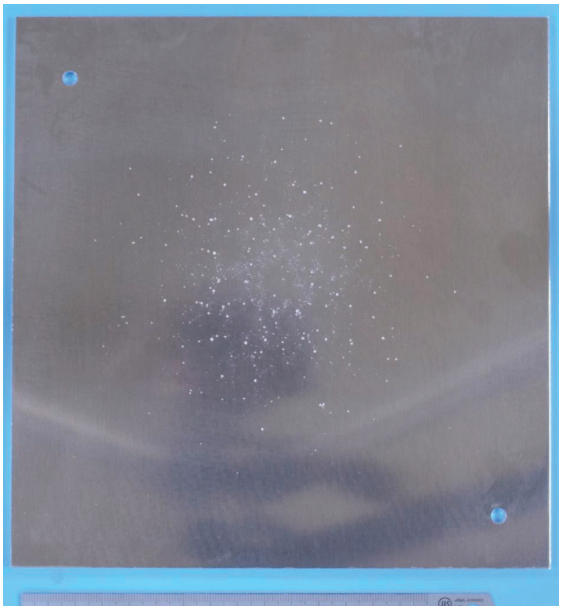


Al 1.0 mm (shot 18)



Pressure Wall

FRP 0.3 mm + Al 0.8 mm (shot 36)



(Projectile ϕ1.0 mm, 6.00 km/s)

Al 1.0 mm (shot 18)

(Projectile ϕ 1.0 mm 6.24 km/s)

Summary

Areal density of FRP/Al was – 5.9% of Al plates.

1. Penetration holes → No tendency
2. Witness plates on impact side → Low ejection velocity
3. The number of ejecta collected from test chamber → The same
4. Pressure walls → Less damage
5. Ballistic Limit Curve → Slightly improved

Unclear points （困っている点）

1. Welding of aluminum alloys?
2. Adhesive of FRP/Al?

Thank you for your kind attention

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nishida.masahiro@nitech.ac.jp

Acknowledgements
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