MILITARY APPLICATIONS FOR BETA TITANIUM ALLOYS

John Fanning
TIMET Henderson Technical Lab
Henderson, NV

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Two R&D Thrusts for Ti in Military Applications:

1. Reduced cost, improved availability and consistent ballistic performance for Ti-6Al-4V
   - Electron Beam Single Melting
   - Thermomechanical Processing Development

2. Advanced alloys with improved properties.
   - Armor
   - Mortars and Missile Tubes

Focus of this presentation
Outline

• Ballistic Protection
  – Armor Piercing Projectiles
  – Ball Projectiles
  – Sharp Instruments

• Mortar Barrels

• Missile Launch Canisters
Ballistic Protection Against AP Projectiles
Test Method

.30 (7.62mm) AP M2 Projectile

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Ballistic Protection Against AP Projectiles
Test Method (cont.)

Test Range Configuration for
Ballistic Limit Testing of Titanium Plates
Ballistic Protection Against AP Projectiles Ballistic Test Results

V50 Ballistic Limit vs. Titanium Alloy Plate Thickness
Results for Ti-6Al-4V Only

TIMETAL 6-4 (Ti-6Al-4V)
Linear Fit for TIMETAL 6-4
Ballistic Protection Against AP Projectiles Ballistic Test Results

V50 Ballistic Limit vs. Titanium Alloy Plate Thickness Results for Ti-6Al-4V and Beta Alloys

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V50 Ballistic Limit vs. Titanium Alloy Plate Thickness
Results for Ti-6Al-4V and Beta Alloys
Ballistic Mass Efficiency of Beta Alloys Compared to Ti-6Al-4V for .30 (7.62mm) AP M2 Projectiles

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Density</th>
<th>Mass Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g cm⁻³</td>
<td>lbs in⁻³</td>
</tr>
<tr>
<td>Ti-6Al-4V</td>
<td>4.46</td>
<td>0.161</td>
</tr>
<tr>
<td>Ti-5.5Al-5V-5Mo-3Cr-0.12O [555] STA</td>
<td>4.65</td>
<td>0.168</td>
</tr>
<tr>
<td>VST3553+0.6Zr STA</td>
<td>4.65</td>
<td>0.168</td>
</tr>
<tr>
<td>Ti-6.8Mo-4.5Fe-1.5Al [LCB] STA</td>
<td>4.79</td>
<td>0.173</td>
</tr>
<tr>
<td>Ti-15V-3Cr-3Sn-3Al-0.12O [15-3] STA</td>
<td>4.79</td>
<td>0.173</td>
</tr>
</tbody>
</table>

STA = Solution Heat Treated + Aged
Ballistic Protection Against AP Projectiles

Consideration of Failure Modes

Ti-6Al-4V defeats AP projectiles by entrapment only (core of projectile is not usually damaged).

Although hardenable titanium alloys have relatively low mass efficiencies as monolithic armor, some alloys (such as TIMETAL LCB) have shown an ability to fracture AP projectiles in some test conditions. This might offer benefits in some multilayer systems.
Ballistic Protection Against AP Projectiles

Entrapment of .30 (7.62mm) AP M2 Projectile in Ti-6Al-4V Plate
Ballistic Protection Against AP Projectiles

High partial penetration of LCB monolithic plate after testing against .30 (7.62mm) AP M2

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Ballistic Protection Against Ball Projectiles

TIMETAL 15-3 plate backed with aramid fabric was tested against 7.62 x 39mm M43 Soviet (7.96g [123 gr.]; FMJ, mild steel core) ammunition.

Results were better than that of a less titanium-intensive system that consisted of a thin sheet of Ti-6Al-4V backed by a greater thickness of aramid fabric.

Note that even though the system areal densities were roughly the same, the titanium-intensive system had a significantly higher V50. The ability of the TIMETAL 15-3 plate to damage the mild steel components of the projectiles potentially provides performance advantages in some systems.
Ballistic Protection Against Ball Projectiles

4.8mm TIMETAL 15-3 plus aramid fabric.
Areal Density = 30 kg m$^{-2}$ (6.2 psf)
V50 = 721 m s$^{-1}$ (2365 fps)

2.0mm TIMETAL 6-4 plus aramid fabric.
Areal Density = 28 kg m$^{-2}$ (5.8 psf)
V50 = 484 m s$^{-1}$ (1579 fps)

Effect of Proportion of Titanium on Performance of Armor
Residual Projectiles After Testing Against 7.62x39mm
Mortar Barrels

• Candidate Lightweight Materials:
  – Aluminum
  – Titanium
  – Composites
Mortar Barrels

To reduce the weight of the barrel on the 81mm M253 mortar, a TIMETAL 21S mortar barrel was designed, manufactured and tested by the U.S. Army.

Titanium was selected instead of aluminum or graphite reinforced epoxy composites based on computational modeling of the thermal and mechanical characteristics of a lightweight mortar tube constructed from each of the candidate materials.

In all cases, it was assumed that the interior of the tube would contain a steel liner for direct contact with the projectile.

REF: L. Burton, “Analysis of Titanium-Sheathed 81-mm Mortar Barrel”
Tensile Properties of TIMETAL 21S Plate at Elevated Temperature (SI)
Tensile Properties of TIMETAL 21S Plate at Elevated Temperature (ENG)
Mortar Barrels

Prototype TIMETAL 21S Mortar Barrel

REF: L. Burton, “Analysis of Titanium-Sheathed 81-mm Mortar Barrel”
Concentric Canister Launcher

TIMETAL 21S and other titanium alloys were evaluated for a Concentric Canister Launcher (CCL) for the Mk41 Vertical Launch System (VLS).

A prototype titanium CCL was manufactured and tested with a hemispherical head made from TIMETAL 21S.

Although the results were favorable, titanium has not yet been incorporated in this design concept.

Concentric Canister Launcher

EXHAUST PRODUCTS FLOW THROUGH ANNULAR SPACE

HEMISPHERICAL HEAD MADE FROM TIMETAL 21S (ON PROTOTYPE)

Effect of test temperature and strain rate on the yield strength at very high temperatures

Effect of test temperature and strain rate on the yield strength at very high temperatures

Summary

• Beta titanium alloys have mechanical, physical and ballistic properties potentially of interest in a variety of non-aerospace military applications. As discussed in this paper, observations of interest so far include:

• As monolithic armor, the ballistic performance of beta alloys is generally less than that of Ti-6Al-4V. However, the higher strength and hardness of beta alloys may offer advantages in certain types of armor systems for armor piercing projectiles.

• TIMETAL 15-3 plate backed with aramid fabric can provide an effective system for defeating ball ammunition.
Summary (cont.)

• The good elevated temperature properties of TIMETAL 21S make it potentially suitable for mortar barrel and missile launch canister applications.