Advantages of Titanium for Ballistic Applications

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Review of Advantages of Titanium

- High ballistic mass efficiency
  *Weight savings of 15-45%*

- Good Multi-hit ballistic capability
  *Typically exhibits full protection within one shot diameter*

- High strength-to-weight ratio
  *Almost half the density of steel*

- Extremely corrosion resistant
  *Lasts 50+ years in seawater with no corrosion*

- Compatible with PMCs
  *No galvanic reaction.*
  *Similar coefficient of thermal expansion.*

- Can be fabricated in existing facilities
  *Major armor manufacturers have found little difference once they got used to titanium.*

- No Environmental Problems
  *No painting or coatings required; non-toxic; fully biocompatible; no hazardous debris after a hit.*

- Non-Magnetic
  *Does not require de-magnetization; does not interfere with navigational equipment; reduces magnetic signature of vehicle.*

- Lower cost than PMCs or ceramics
Forged hatch for BFV
[after ballistic testing]
Ballistic Properties
Ballistic Properties

Purposes of Ongoing Ballistic Testing:

- Provide technical information to support applications
- Ensure that the specified processing has a robust capability to meet expected performance levels.
- Identify new alloys that may have improved performance.
TIMET Ballistic Evaluations

Test Range Configuration for Ballistic Limit Testing

Probability of Penetration vs. Impact Velocity

Example Partial Penetration (cross sectional view)

10 mm
0.4 in

40mm 6-4 Plate vs. 14.5mm B32 API

Example Calculation:

\[ V_{50} = \text{Average of High PP and Low CP} \]
\[ = \frac{(881 + 867 + 875 + 905 + 893 + 888)}{4} \]
\[ = \frac{5367}{4} \]
\[ = 885 \text{ m s}^{-1} \]
Characterization of Ti-6-4 Plate vs. AP Projectiles

V50 test against homologous threats

Ref [1]
Characterization of Ti-6-4 Plate vs. AP Projectiles
(cont.)

V50 test against homologous threats to determine overall trend.  

Ref [1]
Ballistic Mass Efficiency of Ti-6-4

Areal Density vs V50 Ballistic Limit for .50 Cal. AP M2
Aluminum alloys compared to Ti-6Al-4V

REFERENCES:
Ballistic Mass Efficiency of Ti-6-4

Comparison of Penetration of Metallic Armor vs. DU Rods (length = 77mm, l/d=10) at 0° Obliquity

Ref: M.S. Burkins, US Army Research Lab

Ref [4]
Ballistic Mass Efficiency of Ti-6-4

Areal Density vs V50 Ballistic Limit for 20mm FSP Aluminum and RHA Steel Compared to Ti-6Al-4V

- Ti-6Al-4V [1]
- Aluminum 5083 [2]
- RHA Steel

Ref [2,3]
<table>
<thead>
<tr>
<th>Material</th>
<th>Ballistic Mass Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AP</td>
</tr>
<tr>
<td>Rolled Homogenous Steel (RHA)</td>
<td>1.0</td>
</tr>
<tr>
<td>Aluminum (5083, 7039)</td>
<td>0.9</td>
</tr>
<tr>
<td>Ti-6-4</td>
<td>1.2</td>
</tr>
<tr>
<td>Aramid Fiber (Kevlar, Twaron)</td>
<td></td>
</tr>
<tr>
<td>Ceramic + Aramid Fiber</td>
<td>&gt;2.0</td>
</tr>
<tr>
<td>Ceramic + Metal</td>
<td>&gt;2.0</td>
</tr>
<tr>
<td>High Hardness Steel (HHS)</td>
<td>1.3</td>
</tr>
</tbody>
</table>

AP = Armor Piercing; FSP = Fragment Simulating Projectiles, KE = Kinetic Energy Penetrator

Ballistic Mass Efficiency = Areal Density of RHA / Areal Density of Ti-6-4

Information Derived from a Variety of Sources
Alloy and Cost Considerations
Cost and Availability Improvements

Electron Beam Single Melting [EBSM]

- Electron Beams
- Hearth
- Ingot Bottom (Dovetail)
- Feed
- Spray Shield
- Dip samples taken from molten pool
- Mold (other shapes are rectangular or double strand round)

Ref [5]
Implementation of EBSM

- First large scale production use of EBSM
  - Titanium (MIL-DTL-46077, class 2)
  - Plate form (E-beam melt process)
  - Turret structural components
  - Material properties have been excellent
  - Thickness range of 2.0” – 3.0”

REFERENCE: W. Herman, ITA, 2005
Implementation of EBSM (cont.)

**Gun Pod**
- Welded titanium armor plate
- EBSM MIL-A-46077
- Used as stand alone armor and as part of more complex recipes

**Turret Side**
- First use of a ring rolled Ti forging as an armor material ring rolled material
- Forms the base structure for the turret

REFERENCE: W. Herman, ITA, 2005
Development of Titanium Products

Ring for turret armor [after ballistic testing]

MGS in service

In the current environment, the time between development and service has been significantly shortened.
Performance of Titanium in Service

- Most equipment sees action immediately.
- No degradation of capability in operational environments.
- Titanium has consistently provided the expected level of protection.
- Titanium has a key role in saving lives and the successful completion of missions.

The above was presented at ITA 2007, but after another year of combat it is still valid!


