LIGHTWEIGHT HIGH PERFORMANCE GUN BARRELS

ARMY SBIR CONTRACT W15QKN-04-C-1028
USMC SBIR CONTRACT NO: M67854-03-C-1011

M249 BARRELS

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PRESENTATION OUTLINE

- Statement of the Problem
- Fabrication Technologies Utilized
- Approaches/Solutions to the Problem
- Refractory Metal Composite Liners
- Ceramic Matrix Composite Liners
- Future Work
STATEMENT OF THE PROBLEM

- Standard gun steel and chromium plated gun steel barrels suffer from:
  - High weight
  - Excessive wear and erosion
  - Poor thermal management

- Micro-cracks and porosity in electrodeposited Cr allow hot propellant gases to reach and degrade the steel

- Executive order D013148 requires the usage reduction of hexavalent chrome by 50% by 31 December 2006.

- Approximately 80% of per year sustainment cost is due to barrel replacements.
APPROACHES/SOLUTIONS TO THE PROBLEM

- Fabricate two-component gun barrels, i.e., liner + overwrap, such that there is no abrupt interface between the two components

- Investigate bore liner materials that eliminate bore erosion and corrosion:
  - Ceramic matrix composites (CMCs)
  - Refractory metal composites (RMCs)

- Investigate light weight titanium or metal matrix composites (MMCs) for the overwrap material to reduce barrel weight and provide structural integrity
FABRICATION TECHNOLOGIES

- Ceramic Matrix Composite (CMC)
  - Liners with in situ rifling

- (EDM) Electrical Discharge Machining
  - Deep hole drilling
  - Chamber fabrication

- Electrochemical Machining (ECM)
  - Refractory metal liner rifling
  - Developing in-house process for Ta rifling

- Plasma Transfer Arc (PTA)
  - Barrel overwrap fabrication

- Metal Matrix Composites (MMC)
  - Nextel 610 alumina fiber with Al matrix
  - Barrel overwrap fabrication
PTA SFFF System

17’ Vertical travel

Deformation chamber

Expandable bellows for inert gas chamber
FIBER WINDING
CMC BARREL
REFRACTORY METAL COMPOSITE LINERS

- PTA Tantalum - Chromium Carbide (Ta-Cr$_3$C$_2$) Liner with PTA Ti Overwrap
  - ECM rifling was inconsistent
  - EDM rifling was unsuccessful

- Molybdenum-Rhenium (Mo-Re) Liner- Machined From Rod with MMC Overwrap
  - Drilled Mo-47.5%Re rods were used to prove material suitability
  - ECM rifling was successful
  - Barrel was live fire tested to about 600 rounds
    - 200 round at 5 round bursts; 200 rounds at 50 round bursts; and 200 round burst
    - ROF diminished gradually – gas port obstructed from hole misalignment
    - Surface temperature reached 601 °C
REFRACTORY METAL COMPOSITE LINERS

- Molybdenum-Rhenium (Mo-Re) Liner- Machined From Rod with PTA Ti Overwrap
  - Drilled rods are used to prove material suitability
  - Three compositions investigated: 47.5%, 22%, and 14% Re
  - EDM is used for deep hole drilling
  - ECM is used for rifling
  - Mo-47.5%Re is ready to be live fire tested
REFRACTORY METAL LINERS WITH PTA
Ti OVERWRAP

As-produced

After machining OD

Ti
Mo-Re
CMC LINERS

- Prototype barrels with a CMC liner and Ti or MMC over wrap
  - Graphite mandrel is wrapped with Alumina fiber (Nextel 610)
  - Infiltrated with liquid ceramic (SiC) matrix
  - A CVD SiC interlayer is deposited to prevent metal infiltration to the bore during squeeze casting of MMC overwrap
Repeat infiltration to eliminate porosity. Continue fiber wrapping and infiltrating with ceramic precursor until desired liner thickness is achieved.

Squeeze cast molten aluminum into fiber over wrap
MICROSTRUCTURES OF CMC LINERS
Graphite Mandrel | CMC | MMC
CMC LINERS (CONTINUED)

- Graphite mandrel removal
  - Gun drill a small hole into the mandrel
  - Oxidize graphite with a cal rod
  - Sand blast to remove remaining graphite

- Barrel contains both rifling and chamber

- Barrel weighs 56% less than a steel barrel
FUTURE WORK

- Evaluate the Mo-Re barrels
- Complete the ECM rifling process for Ta-W
- Fabricate Ta-W barrels and evaluate
- Complete the CMC lined barrels and evaluate