Advanced Sabot System Design

Simulations, LLC

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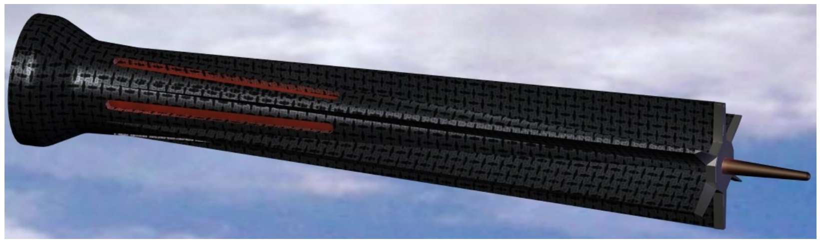

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PROBLEM STATEMENT

Electromagnetic (EM) launchers are being developed by the US military for various potential weapon applications. These EM launchers propel integrated launch packages (ILP) and projectiles to velocities exceeding 5000 m/s. Reaching these velocities requires extreme acceleration in-bore thus challenging current industry technology. These highly accelerated ILPs must be launched in a manner where the ILPs projectile, internal components, aeroshell, interfacing structures, and their subsystems survive the intense acceleration. Withstanding the in-bore lateral and setback Gee loads are critical. This is done by encasing the ILP with a highly stiff, lightweight and custom designed sabot, providing the durability necessary for in-bore survivability.

A sabot is a structure that encases sub-caliber projectiles in-bore while being launched. A sabot can serve many purposes. In general, the sabot's three basic functions:

1) keep the projectile laterally stable by withstanding the intense balloting loads
2) prevent propellant gas from blowing by the projectile during launch, and
3) discard and separate from the projectile immediately upon muzzle exit.

The ongoing engineering focus continually minimizes sabot mass since the sabot is entirely parasitic and has no ballistic need once it has exited the bore.

Simulations, LLC is developing a low-cost, lightweight, high-strength 3D-composite sabots for use with gun launched projectiles with high acceleration (50k Gees objective) throughout the test series in the Innovative Naval Prototype (INP) for an Electromagnetic Railgun (EMRG) System.

WHO CAN BENEFIT?

In addition to the use in the Electromagnetic Railgun System (EMRG) INP, the sabots being developed by Simulations, LLC will transition to the System Development & Demonstration Acquisition Program sponsored by NAVSEA IWS3C. The use of these low-cost, light-weight, and high-strength 3D-composites are also in demand by the weapons, munitions and missile industries, as well as aerospace and transportation industries. The material development herein is applicable to new, conventional, developmental and future launched aerostructures, aeroshells, ILPs and payloads of endless shapes and applications.

Primes that can benefit from this material development include General Dynamics, Boeing, ATK, BAE Systems, Draper Labs, Raytheon, General Atomics, Lockheed, and others.

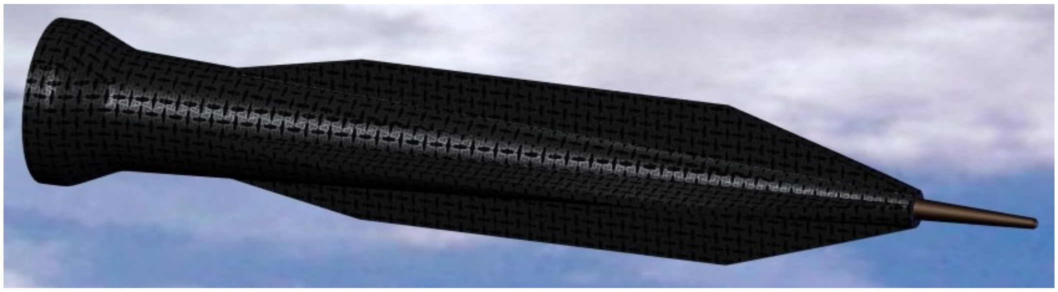
BASELINE TECHNOLOGY

The baseline technology provides the industry with dense conventional materials that limit in-bore acceleration of projectiles. Conventional materials such aluminum and steel alloys, have either too low of a strength and/or stiffness, or have too high of a density, which in all cases prevent the necessary accelerations for state-of-the-art projectiles. Further, existing composite sabots remain as 2D laminates which are commonly known to delaminate, crack, lose strength and stiffness, thus limit ILP acceleration.

The sabot mass is entirely parasitic (of no use outside of the bore), thus goals and efficiencies are limited due to these density, stiffness, compressive and shear strength, and delamination properties of conventional materials.

TECHNOLOGY DESCRIPTION

The technology we develop employs custom and patented 3D fiber weaving and braiding of carbon fibers, infused in a toughened, high-temperature resin matrix. The distinct strength and stiffness features we achieve are due to patented fiber placement techniques that provide minimal to no-bend radii in preselect fiber tows. The preforms we fabricate consist of fiber tows oriented in 3D, which significantly improve interlaminar shear strength and remove delamination characteristics. We are forwarding railgun sabots to a parasitic mass less than 25%. We are developing this low-cost, lightweight 3D material technology which is immediately applicable to conventional powder launched projectiles, electrothermally launched projectiles, a vast assortment of structures launched at leading edge acceleration profiles, and for various bore sizes and sub-caliber ILPs.



Following are the features, advantages, and benefits of this technology:

Table 1: Features, Advantages, and Benefits

Features	Advantages	Benefits
Shape	Continuous fiber preforms allowing varying x-sections in the same preform	Aerostructures can be fabricated with unconventional innovative shapes and features
3D braided out-of-pane fibers	Removes & decreases interlaminar delamination	Increased shear strength
Braiding & Weaving methods	Optimize fiber alignment and placement with fiber tows straight	Fiber tows have no bends in principal axial direction thus increased strength & stiffness
Specific-strength	Inertial acceleration capability withstands 30-50 kGees	High inertial compressive strength property
Decreased parasitic mass	Sabot mass < 25%	Increased payload mass / increased acceleration
Compliancy and Draping	Braided preforms drape and form to complex shapes	Preform integrity maintained during fabrication & draping
Density	40% - 50% lighter than conventional sabots	Increased payload mass / increased acceleration

With the 3D composite technology developed herein, the sabot is significantly lighter and stronger than the baseline. This mass savings, if needed, can be re-applied to the projectile mass and the payload allowing for more intelligence hardware on-board, which in summation creates a better aeroballistic component with more on-target mass.

For the EM railgun application, the sabot snugly encases the projectile aeroshell, having features such as ribs, riders and lateral stiffeners that ride along the railgun inner bore rail surfaces. With railgun bores having highly unconventional cross-sectional shapes these ribs and riders have inherently customized shaped features. Thus when transitioning this sabot material technology to conventional steel tube gun bores, interfacing with these bores will be a much simpler design with less engineering challenges
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CURRENT STATE OF DEVELOPMENT

Concept hypersonic flight demonstrators are now being designed and fabricated, with a series of saboted airframes scheduled for launching in air, chemical and electromagnetically launched guns. We are currently at a Technology Readiness Level (TRL) 3. This has been accomplished by designing, modeling and coding high fidelity structural simulations, 3D weaving and manufacturing of various composite preforms, infusing toughened resins, and performing certified static strength material tests. These material strength tests on the 3D preforms we fabricated have properties fulfilling the Navy performance requirements for their current EM railgun threshold and objective goals. To bring this material to TRL 6, tests commence in February 2011. Actual sabots for these tests will be fabricated from the 3D preforms that we have recently weaved, and launched in the Navy's EM railgun.

Phase II, Basic Effort: June 30, 2009 - June 29, 2010 (Fully Funded and Completed)
Phase II, Option 1: April 20, 2010 - April 19, 2010 (Fully Funded and Underway)

Test Plans
Feb 2011: 1st Series of Dynamic Material Property Tests/Launches
Apr 2011: 2nd Series of Material Candidate Static Tests
May 2011: 2nd Second Series of Material Candidate Dynamic Tests

REFERENCES

NAVSEA
Technical Point of Contact: 540-653-2098

WHEN THE TECHNOLOGY WILL BE READY FOR USE

Currently at TRL 3, we are working with NAVSEA and ONR preparing the first series of test launches, simultaneously engineering the next candidate 3D composite preforms. Within the next six to twelve months, dynamic material characterization tests, simple shape sabot launches, material coupon and projectile slug tests will all be performed moving the technology towards TRL 4, 5, and 6. Baseline testing in an actual railgun is expected to be performed at the Navy Dahlgren EM railgun facility funded by NAVSEA and/or ONR. Developmental dynamic material strength testing will be performed at the US Army Research Laboratory funded also by ONR. Following Phase II, a TRL 9 is achievable by performing even further the scientific reviews of our material architectures, performing higher fidelity analytical simulations, locating actual Army and Navy launch packages that need saboting, and then designing, fabricating and testing sabots with those launch packages. Standard test launches of various baseline ILP configurations will guide this material technology to a TRL 9.

ABOUT THE COMPANY

Simulations, LLC is a professional design, analysis, engineering and systems integration firm, having within their facility portfolio all the engineering tools, software, and computer hardware necessary to technically lead and analytically perform all structural material development, finite element analyses, and simulations for this program. Simulations, LLC internally utilizes Ansys, LS-DYNA, ICEM CFD, SolidWorks, FloWorks CFD, and a vast amount of the many technical software tools needed for analysis and support.

In 2003 the US Army Research Laboratory (ARL) contracted Simulations, LLC to design and analyze railgun integrated launch packages. This was based on the railgun design and test experience of Simulations' principal investigator that began twenty-five years ago. The success of this contract allowed Simulations to manufacture integrated launch packages, sabot systems, armatures, pulsed power forming network inductors, power magnets, as well as customized parts for the EM railgun industry. The lessons learned for Simulations with ARL, as well as from their principal investigator's railgun career, creates the necessary experiential foundation to provide innovative 3D composite sabots and structures to the aerostructural industry. The company and its core technical and business personnel, are fully seasoned in research, development, project and program management, fabrication, and testing.

From design, analysis, fabrication and test, Simulations has been involved during conceptualization through to production with the follow typical projects, programs and systems:

- Electromagnetic Railgun Hypervelocity Launchers
- Hybrid Propulsion
- Hypervelocity Projectiles
- Electromagnetic Armature Design
- Railgun Muzzles
- Railgun Barrel Joints
- 3D Composite Sabot Design
- Catheter Intravascular Component Design
- Medical Production Chemical Mixing System
- Spinal Implant Vertebrae Replacement/Fusion
- Submersible Robotics
- Patient Lift Systems
- Safe / Arm Energetics
- Igniters / Detonators
- Instrumentation
- Explosive Separation Systems
- Electro-Mechanical Components
- Flight and Vehicle Structures
- Energetic–Propulsion Systems
- Fire truck Hose Deployment Safety Alarms and System
- Automated Chemical Mixers