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MK 82 BALLUTE RETARDER SYSTEM UPDATED FOR ADVANCED WEAPONS PROGRAM

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Abstract

Updating a proven bomb decelerator by substituting materials of construction presents fabrication challenges when the original nylon is changed to high performance Vectran cloth. In a current technology demonstration program for dispensing smart munitions from high performance aircraft, the Munitions Directorate of the Air Force Research Laboratory at Eglin AFB, Florida, is interested in packaging multiple units of the Low Cost Autonomous Attack System (LOCAAS), a miniature smart munition on new small munitions dispensers. A low cost approach to utilize a proven ballute design in the demonstration program to save packing volume is not straightforward. The fabrication and test experience of converting the MK 82 retarder system to utilize a high tenacity engineering fabric are described.

Background

The Air Force Munitions Directorate at Eglin AFB awarded a technology development program to Boeing Phantom Works in St. Louis, MO, to demonstrate a small munitions dispenser (SMD). The new aircraft dispenser is being designed to fit current and near term fighter and bomber aircraft with the ability to eject loadouts of the next generation of advanced weapons, the Small Smart Bomb and LOCAAS, Low Cost Autonomous Attack System, Fig. 1.

Fig. 1 - LOCAAS Smart Munition

ILC Dover is supporting Boeing in the program for the development of a secondary dispenser to accommodate the flight envelope release requirements of the LOCAAS munition. The LOCAAS is being developed for the Air Force by Lockheed Martin Vought Systems. The weapon is to have the ability to fly under it's own power and to search for targets through a LADAR seeker. The LOCAAS is stowed in a compact shape with it's wings and tail surfaces folded until it's carrier vehicle slows below the speed set as an upper limit for safe flight surface deployment.

ILC Dover's task is to bridge between the Boeing dispenser's capability to release payloads at high speeds and a lower speed environment more suitable for release of the LOCAAS munition. In the preliminary design phase of the LOCAAS Subpack in the SMD program, a number of ballute configurations were evaluated. The ram air sustained MK 82 bomb ballute developed by Goodyear, Ref. 1, was a close match for the deceleration requirements for the LOCAAS payload. Especially attractive for this demonstration program with very limited funding, was the fact that the MK 82 retarder had been proven in extensive wind tunnel testing, over 50 air drops in it's development and has exhibited excellence performance in combat operations as an inventoried munition, Fig. 2.

Fig. 2 - Mark 82 Bomb in High Drag Configuration

The weight and release envelope for the Subpack and the Mark 82 General Purpose bomb were close enough to consider utilizing a scaling factor for the Subpack ballute shape. The reduction in risk and cost led the ILC Dover team to model a Subpack ballute after the Goodyear BSU-49/B Air Inflatable Retarder. CDR Parachute Systems, as a consultant to ILC Dover, performed the deceleration and stability analysis. The mission launch envelope (ejection from the aircraft dispenser) extends from the ground to 50K feet and in speeds to Mach 1.5. The scaled Subpack version (factor 0.7603) resulted in a max diameter across the burble fence of 43.7" vs. 57.5" for the BSU-49/B AIR, Ref. 2. As the MK 82 flight envelope is similar and the larger diameter structure is subjected to higher loadings, a LOCAAS Subpack ballute utilizing Goodyear's design features should result in a conservative solution with respect to maximum deceleration loads.

The dimensions of the MK 82 ballute canister are about 18 inches in length by 8 inches in diameter, Fig. 3.

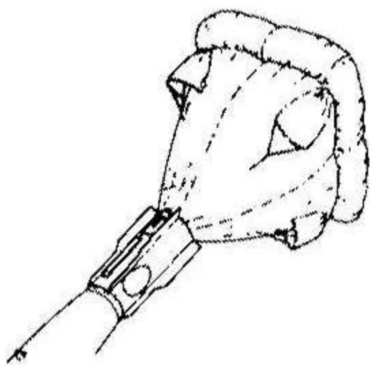

Fig. 3 - Mark 82 with Retarder

The SMD payload length requirement was set to assure that the new Smart Munitions Dispenser (SMD) with its munitions would fit in the confined payload bays of advanced fighter aircraft. With the two LOCAAS weapons, the maximum length available for a ballute canister in the new Subpack is only 7 inches. The canister is also smaller in diameter than the MK 82, a restriction telegraphed down such that the SMD with its weapons load would clear the bomb bay doors in certain advanced aircraft, Fig. 4. In this restricted design space, a double walled nylon ballute proven for the MK82, even scaled, could not be packed into the LOCAAS Subpack canister.

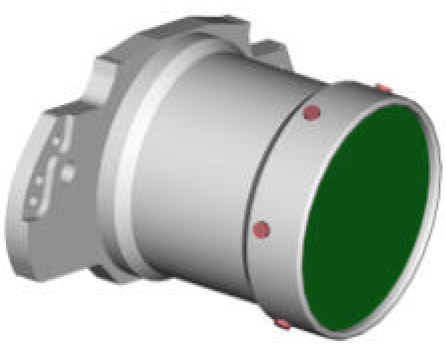

Fig. 4 - Subpack Ballute Canister

Ballute Design

Selection of Fabric Materials

To pack the Subpack ballute in the smaller canister space, a fabric was needed that could exhibit in a single thin layer at least the same strength of the double layer nylon of the MK 82. In recent years a number of high strength fibers with excellent engineering properties have become commercially available. See Table 1 for comparison of the properties of high performance yarns. ILC Dover evaluated Vectran, Kevlar, and Spectra high tenacity fabrics. Based on the experience gained by ILC in the design and mission success of the Mars Pathfinder airbag decelerator system, Ref. 3, Vectran was selected as providing the best properties in this application. Vectran fabric has high strength and modulus, retention of properties after flexing and creasing, excellent performance in high and low temperatures, and good chemical resistance.

Substitution of Kevlar webbing for the bulky nylon webbing in the MK 82 saved additional space and weight. Using the new materials, a ballute of slightly smaller than the MK 82 decelerator was packed in a canister less than one-third the volume.

For the main gores, burble fence and ram air inlets, 400 denier Vectran fabric, 53 x 53 count, plain weave was selected for its increased strength at low temperature and 99% strength retention at 170 ^{o}F. To attain a slightly lower porosity than the Goodyear double layered nylon, the air permeability of the Vectran was adjusted with a thin coating of silicone rubber. The meridian webbing assembly, the inlet reinforcement, and inlet support cords were Kevlar webbings. The ballute gore seams were fell construction. The burble fence to ballute and inlet cloth to the main gore seams were lap seams with Kevlar webbing. Kevlar cord was utilized in the stitching. From Ref. 2 and from ILC Dover material specifications and testing experience, the design strength requirements and factors of safety for the Subpack ballute were derived, Table 2.

Assembly

An actual Mk 82 ballute was inflated and measurements were taken of the gore patterns and ram air inlet ports and scaled to the 39 inch base diameter calculated to meet the LOCAAS Subpack deceleration requirements. Given the proven performance of the Goodyear design, the general shape of the ballute and the profile of the ram air inlets were carefully noted. Utilizing the MK 82 model for the initial Subpack design duplicated the 4-gore ballute main body with an 8-gore burble fence, and 4 ram air inlets. The 8 gore burble fence was fabricated with 28 degree and 62 degree intersections like the MK 82, Fig. 5, resulting in a squarish planform (The geometry selected by Goodyear based on performance and production costs, Ref. 2).

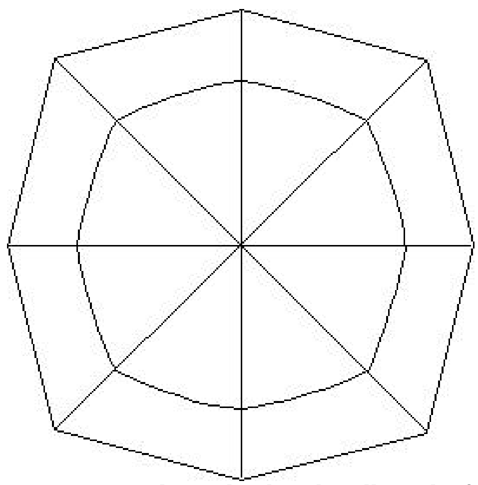

Fig. 5 - MK 82 and Initial Subpack Ballute Planform

The design diameter for the Subpack was 43.75 inches maximum across the burble fence. The ballute length was 35.7 inches and the cylindrical interface at the attachment canister was 7 inches. Other features were duplicated as in the MK 82 retarder, Fig. 6.

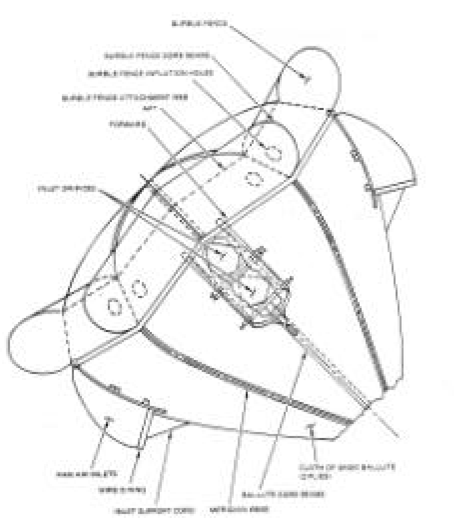

Fig. 6 - Subpack Ballute Replicated from MK 82

Ballute Deployment

The MK 82 ballute is deployed by the drag of the 8-inch end cover that is latched to the back of the fabric canister with dogs. When unlatched by a lanyard, the cover enters the air stream and pulls the fabric out of the canister. The ballute is inflated through the 4 ram air scoops. The dispenser drop envelope and physical properties of the LOCAAS Subpack require a significantly faster deployment and inflation for stability after clearing the bomb bay. A sabot or mortar ejection of the ballute was needed to quickly get the scoops positioned.

A very cost effective solution was developed utilizing an automotive steering wheel airbag gas generator manufactured by Talley Defense Systems. Talley's D60 non-azide all pyrotechnic inflator, Fig. 7, was found to provide sufficient gas to both eject the tightly packed Vectran ballute from its canister and to partially inflate the ballute.

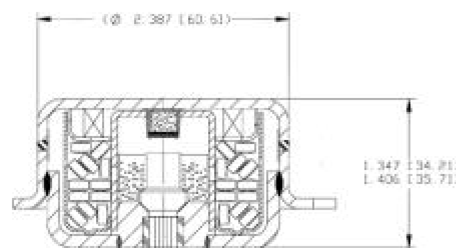

Fig. 7 - D60 Driver Inflator for Ballute Ejection/Inflation

Ground Testing

The ballute design as well as the other Subpack functions for secondary release of the LOCAAS weapons were to a factor of safety of at least 1.4 for all components. The ground test program was designed to demonstrate this level of performance.

Low Speed Wind Tunnel Tests

Prior to committing to the ballute design with the deployment and material changes, a demonstration of the performance of the new ballute was arranged at the low speed (~ 220 Knot) University of Maryland Recirculating Wind Tunnel. A full scale canister/ballute system was fabricated for the test. Ballute ejection, initial inflation, ram air pressurization, and stability were observed to be successful at the wind tunnel test, Fig. 8, 9, and 10.

Fig. 8 - Subpack Simulant with Ballute Canister Mounted on a Pylon in the UMWT Test Section

Fig. 9 – Ballute at T = 0.067 Seconds

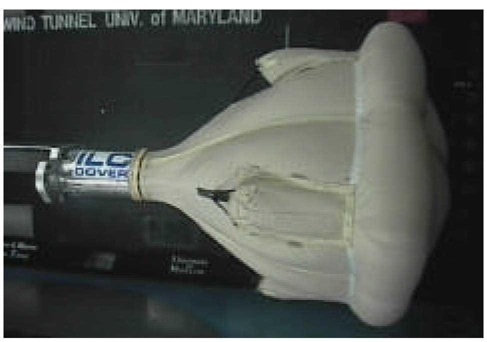

Fig. 10 – Ballute Fully Inflated at T = 0.433 Seconds

The ballute inflation times are expected to be much faster in an actual air drop as the Maryland Wind Tunnel maximum speed is lower than the lowest expected ejection speed in the Small Munitions Dispenser release envelope.

Ram Air Scoop Tests

The construction of the ram air scoops presented a challenge to test the ability of the scoop to take an initial shock load at the maximum dynamic pressure calculated in the flight envelope. The scoop opening "D" ring, the scoop seams, and the inlet support cord needed to be tested as attached to the ballute body. The test approach was to mold a scoop's internal shape with casting compound and then apply a frontal force on the hardened material with a hydraulic ram, Fig. 11. The scoop was attached to a section of the ballute gore and the gore was fixed to a plate allowing the scoop and gore to absorb the applied load. The scoop passed the 2,000-lb. requirement.

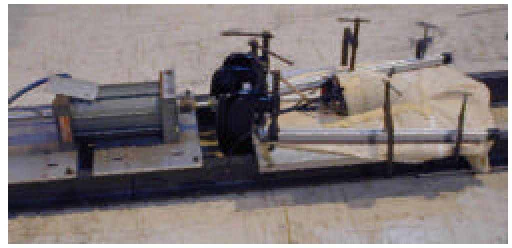

Fig. 11 – Ram Air Scoop Pressure Test

Ballute Pressure Tests

A full scale 4-gore ballute including the burble fence but omitting the ram air scoops was constructed with an internal bladder for pressurization with water. The test requirement was to survive an internal pressure of 10 psi. The construction failed with a seam rupture at only 3.75 psi. The post test analysis pin pointed a failure at a ballute seam miter joint at the burble fence, the highest stress point according to inflatable theory. It was postulated that the high tenacity Vectran yielded little to the pressure and resulted in a transfer of high loads to the seam. The elongation of nylon in the MK 82 ballute spread loads better, and as a result the gore pattern is more forgiving of stress risers.

The next iteration of ballute design was to build an eight gore ballute without scoops with gores at one half the width of the Goodyear gore and with a symmetrical octagon shaped burble fence with 45 degree miters, Fig. 11.

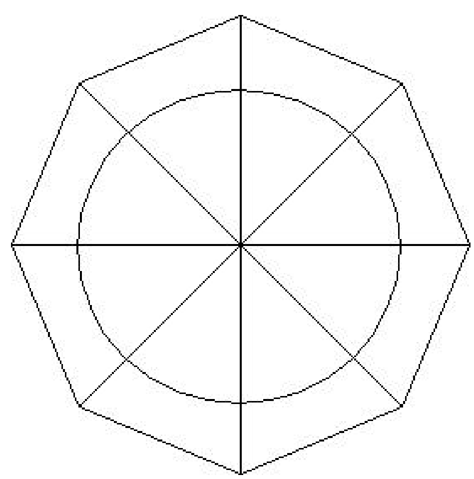

Fig. 12 – 8 Gore Ballute with Octagon Burble Fence

Upon inflation the aft dome was observed to be wrinkled and the ballute gore seams had tight lines. It was concluded that the dome should be a square root of 2 over 2 ellipse to evenly spread the loads, Fig.13.

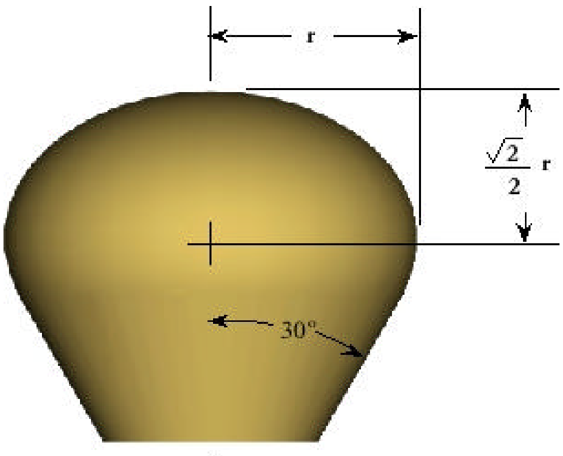

Fig. 13 – "2 over 2" Geometry

The ballute gores were fabricated to the square root of 2 over 2 configuration in the dome area, Fig. 13, and retested under pressure with an internal bladder. The redesigned gore pattern passed the 10 psi pressure test.

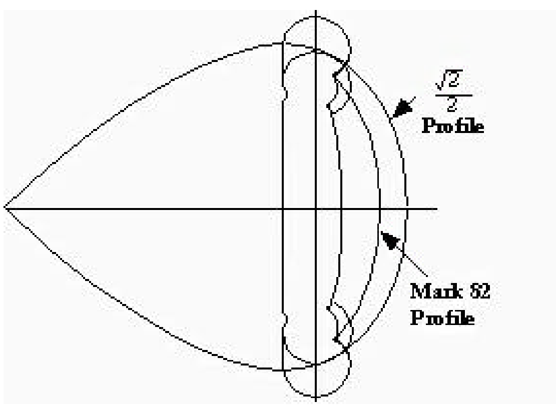

Fig. 14 – Aft Dome Redesign

Summary

The material substitution and ballute ejection scheme resulted in a very compact, economical solution for the technology demonstration program and provides for rapid deployment at even low speed. The high tenacity Vectran fabric was an enabling technology for this weapon delivery platform configuration.

Acknowledgement

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Table 1

COMPARISON OF YARN TYPES

PROPERTY	POLYESTER	NYLON	KEVLAR	SPECTRA	VECTRAN
Tenacity (g/d)	8.3	8.4	22	30	23
Modulus (g/d)	80	40	458	1400	525
Shrinkage @ 350°F, %	1.6	8	Minimal	Decomposes @ 296°F	Minimal
Resistance to Flex Cracking	Excellent	Excellent	Poor	Excellent	Good
UV Degradation	Good	Fair	Poor	Good	Poor
Hydrolytic Stability	Good	Poor	Excellent	Excellent	Excellent
Oxidation Resistance	Good	Fair	Excellent	Excellent	Excellent
Coating Adhesion	Excellent	Excellent	Good	Poor	Excellent
Creep Under Load	Good	Poor	Excellent	Poor	Excellent
Abrasion Resistance	Fair	Good	Poor	Excellent	Good
Elongation @ Break	16.3	18	3.6	3.5	3.3
Density	1.38	1.14	1.44	0.97	1.4

Table 2

STRENGTH REQUIREMENTS AND FACTORS OF SAFETY

		BSU-49/B		Subpack	
Component	**Load Required**	**Strength**	**FS**	**Strength**	**FS**
Ballute Base Material (main gores, burble fence, inlets)	366 lb/in	916 lb/in	2.5	800 lb/in	2.2
Ballute Gore Seams	366 lb/in	725 lb/in	1.98	512 lb/in	1.4*
Meridian Web Assembly	6,675 lb	12,700 lb	1.9	16,000 lb	2.4
Meridian Web to Gore Sewing	81 lb/in	288 lb/in	3.56	200 lb/in	2.5
Burble Fence Seams	103 lb/in	322 lb/in	3.13	234 lb/in	2.3
Inlet Cloth to Main Gores	60 lb/in	274 lb/in	4.58	234 lb/in	3.9
Inlet Webbing Restraint	1538 lb	2640 lb	1.72	4000 lb	2.6

*The minimum Factor of Safety for the seam. Gore seams were found to slip in the Instron jaws before breaking. Pressure testing of the ballute would verify the gore seam strength.