Experimental Research on Parachute Deployment Load Control by Use of Line Ties

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Introduction

LINE ties have been used by Sandia Corporation to control parachute deployment and to minimize snatch load for more than 10 years. Line ties are generally made of $\frac{1}{2}$-in.-wide ribbon of various strengths from 100 to 1500 lb. The series of ties is usually made around a group of suspension lines or line tie loops and through tie loops on the canopy bag leaf for "lines first" deployment. The ties break in sequence as the parachute pack moves aft of the test vehicle promoting orderly deployment of lines and canopy. The ties also absorb some of the differential energy built up at line stretch.

The present series of four sled tests was devised to investigate the use of line ties in deploying a 110-lb simulated parachute pack at a velocity of 800 fps using two 10,000-lb-strength, 50-ft-long lines.

Apparatus

A rocket-powered sled was selected as the best method to achieve the desired representative deployment velocity of 800 fps and observe photographically the deployment, using on-board photo-sonic cameras (400 frames/sec) and stationary side-on cameras. The sled shown in Figs. 1 and 2 was boosted to speed by six 5-in.-diam. high-velocity aircraft rockets (HVAR) and the speed was sustained by two similar rockets. The simulated canopy pack shown in Fig. 2 was made of aluminum with an outer wood spindel and was connected to the cone cylinder, mounted on the sled, by two 10,000-lb tensile strength, special slotted webbings 50 ft long. The line is of relatively loose weave and has an abnormally high elongation of 40% at ultimate load, which tends to relieve shock loading. The two lines were tied together every 3 in. (see Fig. 3a) by a turn of 100 chord to unify the trailing line.

A 1- or 1.5-ft guide surface pilot chute was packed in a small bag on the rear of the simulated parachute pack to insure drag separation of the pack at deployment. The pod was held to the forward cylinder during sled acceleration by four $\frac{1}{2}$-inch-diam explosive bolts, which were fired at first stage rocket burnout to release the pod for deployment. At the same time a small drogue gun was fired to deploy the pilot chute.

The trailing line was packed in the forward cylinder accordian fashion with line ties 1 ft apart as listed in Table 2. The packed line is shown in Fig. 3. The line was attached to a 15,000-lb range load cell in the cylinder which was used to measure the snatch load. The signal was then telemetered to a receiving station in the sled control building. Special electrical conductor wires were used in the four tests as listed in Table 1 to investigate the feasibility of maintaining electrical signal transmission during deployment. The last test had

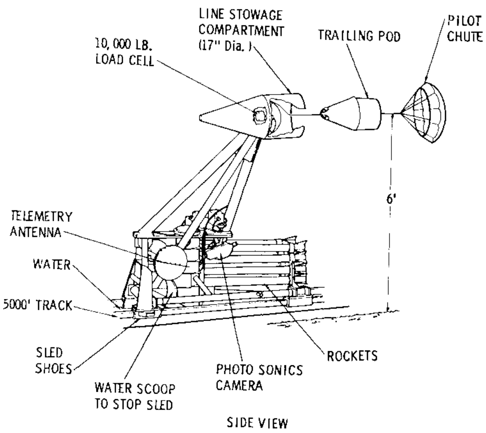


Fig. 1 Sketch of rocket sled used for trailing pod deployment tests.

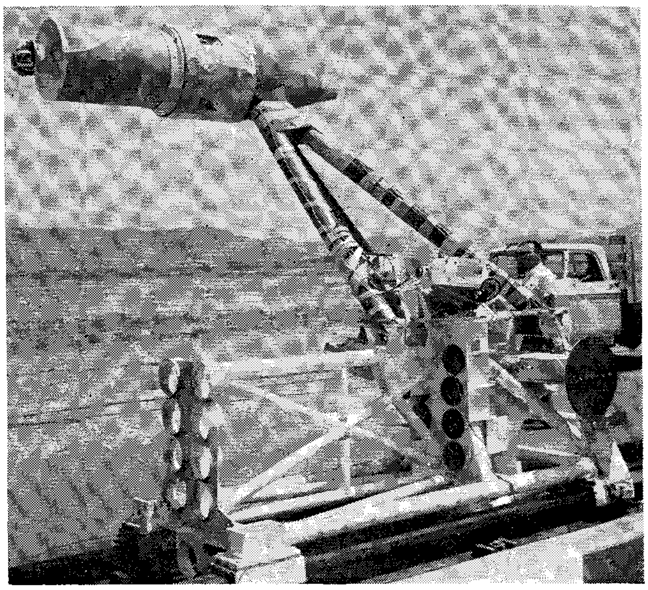
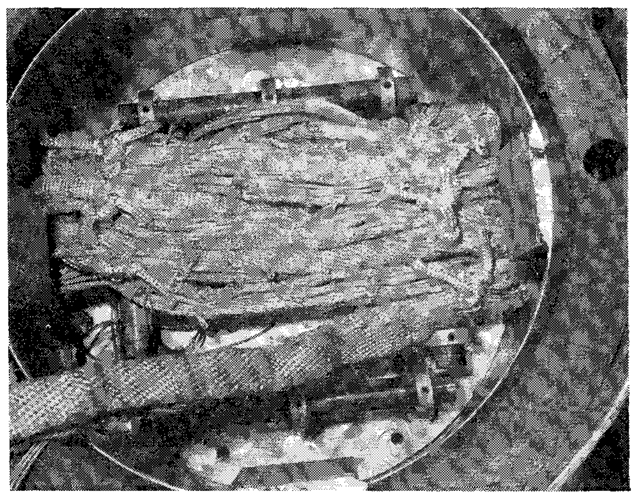


Fig. 2 Sled and pod system.

a) Double 10,000-lb slotted webbing and double 4000-lb tubular webbing in between



b) Installation at 1500-lb line ties

Fig. 3 Trailing pod line installation.

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Table 1 Trailing pod

Test number	Test date	Trailing pod weight, lb	Trailing line length, ft	Pilot chute diam, ft	Deployment velocity, fps	Snatch load, lb	Deployment time, sec
1	6/7/68	88	35	1	780	14,000	1.1
2	6/8/68	90	50	1.5	765	5,000	...
3	6/14/68	110	50	1.5	780	10,000	0.69
4	6/25/68	110	50	1.5	775	10,000	0.84

Test number	Type of wire	Result
1	2 wires woven into 2100-lb webbing	Wire broke during deployment
2	2 aircraft cables in 4000-lb webbing	Wire broke during deployment
3	4 wires, two in each of two 4000-lb tubular	Wire broke after deployment at line stretch
4	4 wires, two in each of two 4000-lb tubular, 6 ft of slack provided	Continuity maintained during deployment

Table 2 Line tie sequence and strength

Test number	X, ft	0–5	5–10	10–20	20–25	25–30	30–35	35–50
1	Tie strength, (lb)	0	100	200	300	500	750	...
2,3,4	Tie strength, (lb)	0	200	300	500	750	1000	1500

two 4000-lb tubular webbings sandwiched in between the two 10,000-lb webbings. Each contained a special woven aircraft cable[2] making a total of four wires. Electrical continuity of these wires was monitored by means of the telmetry system on the sled.

Tests and Results

Pertinent test data for the four sled tests are listed in Table 1. The lines withstood deployment and snatch load without failure on all four tests. The snatch load measured on the first test, deploying a 35-ft-long line, was 14,000 lb, so for the remaining three tests the tie strengths were doubled since the line length desired was 50 ft, which would result in a higher snatch load. The snatch load was effectively reduced to 5000 lb on the second test by doubling the tie strength. Figure 4 shows the sled velocity as a function of time after launch for the third test. The snatch load was 10,000 lb on the fourth test, since the pod weight was some 20 lb greater than the first two tests and deployment velocity was near 800 fps. All ties, including the 1500-lb, extremely strong ones, were broken as desired during deployment. The four electrical aircraft cable conductors maintained continuity through snatch load.

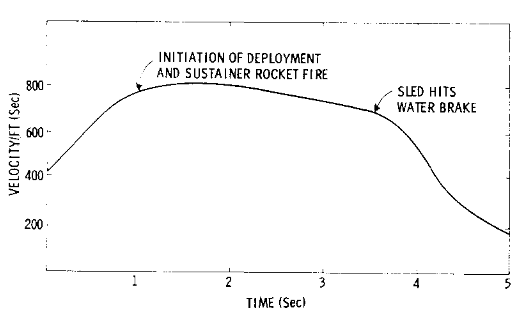

Fig. 4 Variation of sled velocity with time for test 3.

Conclusions

From the results of four rocket sled tests using line ties to control line stretch snatch load of a simulated parachute pack, the following conclusions can be drawn:

1) Line ties are very effective in controlling and minimizing the shock load at line stretch.

2) A 110-lb simulated canopy pack was successfully deployed rearward on a 50-ft-long line of double 10,000-lb tensile strength, special slotted webbing with a maximum line stretch load of 10,000 lb. The sled velocity during deployment was 800 fps.

References

[1] Pepper, W. B., "A 20-Ft.-Diam Ribbon Parachute for Deployment at Dynamic Pressures above 4000 psf," *Journal of Aircraft*, Vol. 4, No. 3, May-June 1967, pp. 265–267.

[2] Pepper, W. B., "Nylon Trailing Antenna Line," *Journal of Spacecraft and Rockets*, Vol. 4, No. 4, April 1967, pp. 543–544.

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