'THE JERK' - THE THIRD DERIVATIVE, AN EMPIRICAL SOLUTION

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ABSTRACT

This paper presents an empirical method to measure the shock acceleration or Jerk loading of a free falling body. This free falling body is connected to a fixed ceiling beam by an 8 foot Kevlar test bridle that is assumed to be inelastic. This technique may be best described as "bungee jumping" with zero stretch.

INTRODUCTION

"Shock" is an inexact term that is usually used to describe rapidly applied impulsive force or energy. The energy is applied quickly and the motion is stopped swiftly. A shock force may be simply defined as a very violent impact or a very large force acting on a body during a very short time interval.

The jerk is defined as the rate of change of acceleration. It too is an inexact term usually used to describe rapidly applied impulsive force or energy. It is felt that the two terms are similar and may be used somewhat interchangeably.

The most common example of motion with very nearly constant acceleration is that of a free falling body near the earth's surface. A free falling body is defined as a body that experiences no force except that of earth's gravity.

A specially configured test body has been developed to measure the "g" loading of a drop body that free falls from a height of approximately 8 feet. This test apparatus, designated Shock Acceleration Measurement Instruments (SAMI), was designed to measure triaxial acceleration profiles and peak or maximum accelerations during a specific time period. SAMI takes advantage of advances in solid state electronics during the past ten years as an economical means of acquiring continuous motion data at sufficiently high data rates to adequately define a total shock profile. Experimental data will be presented using this technique.

TEST APPARATUS

The advances in solid state electronics in the past decade has allowed for increasingly complex solid state data acquisition systems to be built. These devices have advanced to the point that data can be measured and stored at sufficiently high data rates to define a shock profile in great detail. They can be triggered on a preset acceleration or run continuously and record events at high data rates. The use of these measurement systems has varied from measuring shock effects of high speed race cars hitting a solid wall1 [1] to determining detailed shock environments for NASA sounding rocket flights. [2] Their use is limited only by one's imagination. The many and varied uses of these devices has resulted in significant cost reduction to affordable levels. By using these devices, it becomes very easy to perform laboratory tests that could not be performed previously.

Initial drop tests of SAMI I indicated the magnitude of the vertical acceleration exceeded the capability of the EDR-1. It became apparent that a method of determining range of values of the vertical shock or jerk was required. Two SnapShock 2000 devices with a 500 g accelerometer range were added to the SAMI I assembly.

The SnapShock 2000[1] is a compact, battery powered, single axis peak acceleration recorder. Each data point is marked with the time and date. It measures and records the peak acceleration or shock level to which it is exposed. The SnapShock 2000 senses and records the peak acceleration that occur within a preprogrammed "time bin" period. A time bin period of 4.47 seconds was selected for these tests. The SnapShock 2000 is programmed using an IBM personal computer and a two way infa-red (IR) data port. The SnapShock 2000 is 1.5 inches x 3.2 inches x 1.45 inches and weighs approximately 7 ounces and had an accelerometer range of 500 g's with less than 1.3 g resolution. If numerous shocks occur with a given time bin period, the SnapShock saves the largest level and tags it with a time and date.

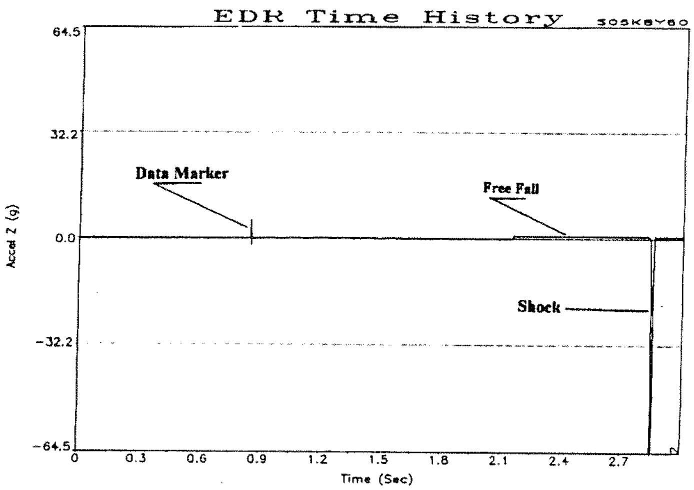

Figure 3: Vertical Acceleration Time History- for 13,500 Pound UTS Kevlar Strap (Drop Weight = 20.14 Pounds)

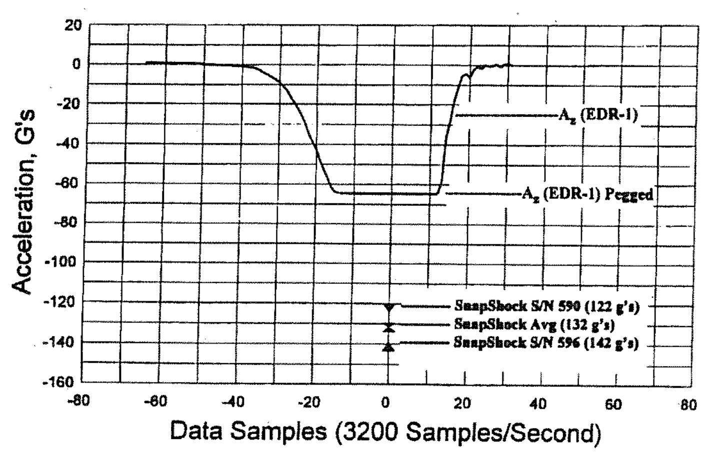

Figure 4: Vertical shock effects for 13,500 Pound UTS Kevlar Strap (Drop Weight = 20.14 Pounds)

Since the magnitude of the vertical acceleration exceeded the capability of the EDR-1, it became apparent that an accelerometer capable of measuring up to 200 g's was required to define the total shock profile. A EDR-3 data recorder having plus or minus 200 g's in all 3 axis became available to continue these tests. SAMI I was reconfigured to SAMI II, which utilized this EDR-3 recorder. Since the EDR-3 weighs 2.2 pounds, ballast was added giving SAMI II a total drop weight of 19.14 pounds. A continuous data recording rate of 3200 samples per second was kept to maintain data similarity. The two main differences between SAMI I and SAMI II were different accelerometer characteristics and a total drop weight difference of five per cent.

TEST RESULTS

Figure 3 presents the vertical component of a typical drop test. The EDR-1 could not measure the peak acceleration for these tests since its maximum measuring capability was approximately 65 g's. It is noted that figure 3 shows a truncated value and not maximum value. Figure 4 shows the shock caused by the vertical acceleration time history on an expanded scale. The shock duration was 73 data samples (22.813 milli seconds). The vertical acceleration exceeded the capability of the EDR-1 for 21 data sample (6.563 milli seconds). The data rate for this test was 3200 samples per second. The maximum value of this acceleration, as measured by the 2 SnapShock devices, is 122 and 142 g's. This gives an average value of 132 g's. The X and Y components of shock are the lateral accelerations and are not of primary interest for these tests.

[1] Available from Instrumented Sensor Technology (IST)
4704 Moore Street
Okemos, MI 48864-1722

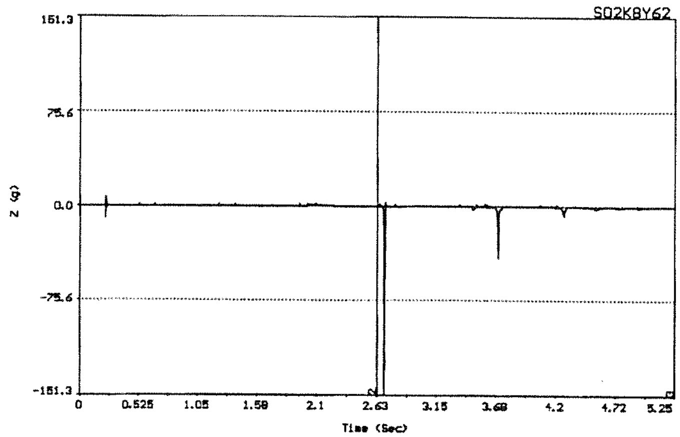

Figure 5: Vertical Acceleration Time History - 13,500 UTS Kevlar Strap (Drop Weight = 19.14 Pounds)

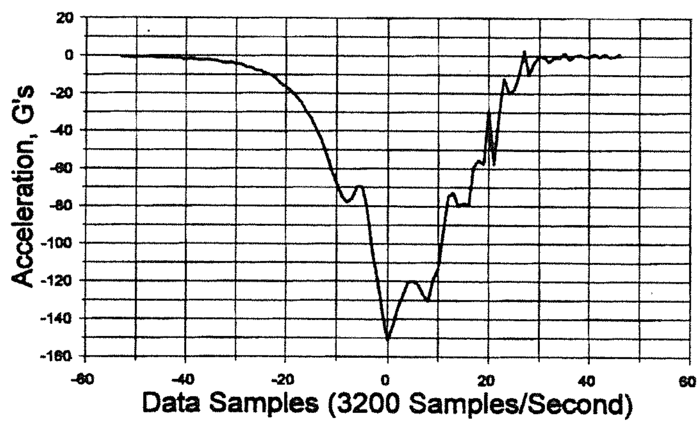

Figure 6: Vertical Shock Effects, 13,500 Pound UTS Kevlar Strap (Drop Weight = 19.14 Pounds)

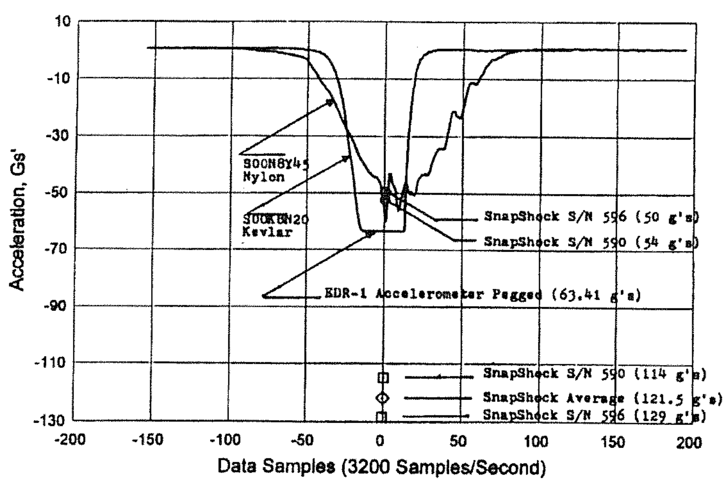

Figure 7: Comparison of Vertical Shock Effects for 13,500 Pound UTS Kevlar and 12,000 Pound Nylon Test Straps (Drop Weight = 20.12 Pounds)

A typical vertical shock profile using SAMI II is presented in figure 5. Since figure 5 represents two data frames, the effects of damping may be seen. It is noted that all values of damping of motion are in the same direction as the shock. This indicates an absence of internal spring forces in the Kevlar test strap. This would tend to validate the assumption that the Kevlar test bridle is inelastic. Figure 6 shows the shock caused by this vertical acceleration time history on an expanded scale. A vertical acceleration exceeding 150 g's was measured using the SAMI II.

A comparison of shock effects on 13,500 pound UTS Kevlar webbing and 12,000 pound UTS Nylon webbing is presented in figure 7. [4] This data shows the peak acceleration of the 13,500 pound UTS Kevlar strap was in the range of 120 g's. The 12,000 pound UTS Nylon webbing had a peak acceleration in the range of 50 g's. Figure 7 shows there is an oscillatory effect following the peak shock on the Nylon strap. This is caused by the greater elongation or stretching in the Nylon strap.

CONCLUSIONS

Properties of the rapid change in acceleration it its simplest form - or the Jerk - have been measured. There is little know measured data available for the third derivative - the Jerk. A simple economical method has been developed to measure the Jerk or peak acceleration for a free falling body. This may be attributed to recent advances in solid state electronics which has allowed increasingly complex solid state data acquisition systems to be built. Peak acceleration level exceeding 150 g's have been measured.

ACKNOWLEDGMENTS

The authors would like to thank the following persons for the assistance they provided in the course of this experiment. David Moltedo of NASA Goddard Space Flight Center/Wallops Flight Facility for designing and fabricating the instrumented platform; Vance Behr and Larry Whinery of Sandia National Laboratory for providing the Kevlar strap design; and David Guy of Accurate Auto Repair for providing the high-bay area in which to conduct the drop tests.

REFERENCES

1.van Valkenburgh, Paul; "Hitting the Wall", RaceCar Engineering Magazine; Surrey CR3 5QG England; 1994.

2. Hailey, C.; Measured Impact Accelerations for Over-Land and Over-Water Sounding Rocket Payloads; 13th AIAA Aerodynamic Decelerator Systems Technology Conference; May 1995.

3."Recovery System Design Guide"; AFFDL-TR-151; Wright Patterson Air Force Base, OH; December 1978

4. DeRichie, John M. and Clark, Randall T., "An Empirical Comparison of the Shock Effects on 13,500 # UTS Kevlar and 12,000 # UTS Nylon Webbing"; Presented at the Seventh Annual Richard A. Henson School of Science and Technology Undergraduate Research Symposium, Salisbury State University; April 1997.