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SHOCK CHARACTERIZATION OF TOAD PINS

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The purpose of this program was to characterize Time Of Arrival Detectors (TOAD) pins response to shock loading with respect to risetime, amplitude, repeatability and consistency. TOAD pins were subjected to impacts of 35 to 420 kilobars amplitude and approximately 1 ms pulse width to investigate the timing spread of four pins and the voltage output profile of the individual pins. Sets of pins were also aged at 45°, 60° and 80° C for approximately nine weeks before shock testing at 315 kilobars impact stress. Four sets of pins were heated to 50.2° C (125° F) for approximately two hours and then impacted at either 50 or 315 kilobars. Also, four sets of pins were aged at 60° C for nine weeks and then heated to 50.2° C before shock testing at 50 and 315 kilobars impact stress, respectively. Particle velocity measurements at the contact point between the stainless steel targets and TOAD pins were made using a Velocity Interferometer System for Any Reflector (VISAR) to monitor both the amplitude and profile of the shock waves.

INTRODUCTION

The TOAD pin (Time Of Arrival Detector) is currently under consideration for use as a diagnostic for accepting electroexplosive devices. Although the TOAD pin has been in use for many years, it has not been extensively studied to determine its behavior under abnormal conditions or over a range of stress inputs. This report describes a gas gun test program designed to fully characterize a specific TOAD pin (Dynasen Model CA-1135). The gas gun is employed because it provides reliable and well-measured stress levels over a wide range of amplitudes.

EXPERIMENTAL TECHNIQUE

The intent of this program is to perform tests in which four pins will be loaded simultaneously by the identical stress pulse, in conjunction with a VISAR (Velocity Interferometer for Any Reflector) measurement to provide accurate waveshape information. The results gained during the experiments allow achieving the five objectives of the TOAD characterization program: 1. Determine the response of the pin (risetime and pulse shape) over the range of stress 35-420 kbar. 2. Evaluate pin-to-pin consistency. 3. Assess the behavior of the pin when initially heated to 50.2° C. 4. Artificially age the pin and study possible degradation in performance. 5. Artificially age the pin, heat to 50.2° C and assess the pin behavior.

The experimental configuration used for this program is shown in Figure 1. The impactor material (typically stainless steel) is mounted onto the sabot and is chosen to give the desired stress level in conjunction with the stainless steel target material and the desired impact velocity. The stress wave from the stainless steel target is transmitted into the TOAD pins. The pins are held in a Vespel™ fixture. The diameter of the pin placement was approximately 0.30" which minimized the uncertainty in the stress wave arrival time. Resistance measurements were made both after assembly of the target and as mounted before a test to assure intimate contact of the pins and stainless steel targets. In this manner, the incident shock wave should contact all four pins at nearly the same instant (within 6 ns across the 0.3" diameter of the four pins). A polymethyl methacrylate (PMMA) window allows the laser beam in the VISAR system to be placed slightly offcenter, providing room for the Vespel fixture.

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TABLE Shot Matrix and Results

Shot Number	Configuration	Impact Stress kbar	Particle Velocity mm/μs	Comments	Spread at 10V ns
559	SS/SS	35	0.169	Baseline	26
565	SS/SS	50	0.246	Baseline	12
562	SS/SS	160	0.703	Baseline	11
561		167	0.729		10
563	SS/SS	315	1.24	Baseline	6
564					12
576	WC/SS	420	1.56	Baseline	7
567	SS/SS	315	1.24	Aged at 45° C	10
566	SS/SS	315	1.24	Aged at 60° C	7
570					12
568	SS/SS	315	1.24	Aged at 80° C	5 (33)
571					7
572	SS/SS	50	0.246	Heated to	44
573				50.2° C	51
574	SS/SS	315	1.24	Heated to	12
575				50.2° C	16
592	SS/SS	50	0.246	Aged and	5 (25)
593				Heated	15
590	SS/SS	315	1.24	Aged and	35
591				Heated	45

RESULTS AND ANALYSIS

Table 1 lists the conditions for the test matrix along with the results of the TOAD pin response for this program. The test conditions listed include the shot number, the test configuration which includes the impactor and target materials, the impact stress, the measured particle velocity in the PMMA window and a comment on the category of the test. For these "baseline" tests, the impactor material chosen was primarily 304 stainless steel with the exception of the highest impact stress shot where tungsten carbide was used. The impact stress values ranged from a low of 35 kbar to a high of 420 kbar.

Figure 2 plots the spread in the time response of the TOAD pins at increasing impact stress. The spread decreased with increased impact stress for all conditions. The spread in the response was smallest for the baseline condition and increased with aging, heating, and aging and heating.

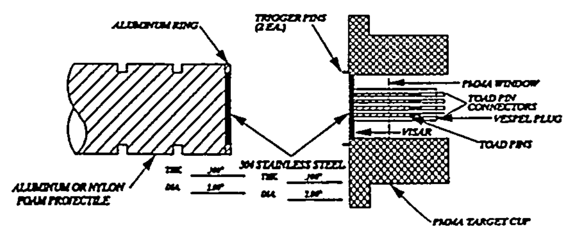

FIGURE 1. Schematic of the Projectile/ Target Configuration

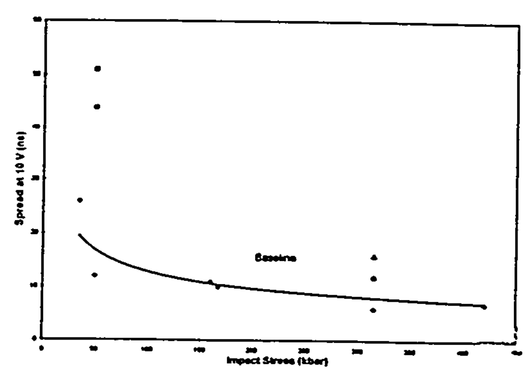

FIGURE 2. Pin-Response Spread at 10V versus Impact Stress

Figure 3 plots the voltage-response time to reach 10 volts at increasing impact stress. It was observed that the time became shorter as the impact stress increased. This result can also be described in the terms of risetime. The higher the applied impact stress, the faster was the resulting risetime.

The trend in voltage amplitude response was that the higher the impact stress the lower the maximum amplitude and the shorter the response width. Figure 4 plots the maximum amplitude of the voltage response of the TOAD pins at increasing impact stress. The digitizers were set for a maximum voltage output of 70 V in order to maximize the observation of response spread and risetime. Thus, all voltage responses above this value were "clipped". The voltage response at impact stresses below 315 kbar were clipped. However, values were obtained at 315 and 420 kbar impacts.

DISCUSSION

Baseline Tests

The results from these tests found that the voltage response had a faster risetime with increased impact stress level. These results reflect the loading curve profiles measured by VISAR. This loading curve profile is analogous to that seen by the TOAD pins in the intended application, in that both have stainless steel parts butted against the TOAD pins. The Hugoniot Elastic Limit (HEL) of 304 stainless steel has been reported [5] to be 2.3 kbar (0.066 mm/μs particle velocity in PMMA window). This value corresponds in amplitude with the inflection points in the loading curves shown in Figure 2. Therefore, it is probably the elastic/plastic nature of 304 stainless steel which is producing the loading ramp behavior.

Inspite of the loading ramp behavior, impacts of TOAD pins at 50 to 420 kbar impact levels produced voltage signal spreads at 10 V outputs of 12 ns or less. These results are very acceptable for the intended use of the TOAD pins. Therefore, the TOAD pins as currently designed and built satisfy the needed requirements.

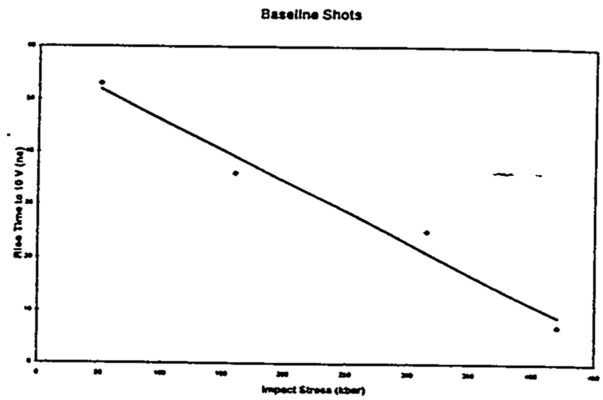

FIGURE 3. Voltage Risetime at 10V versus Impact Stress

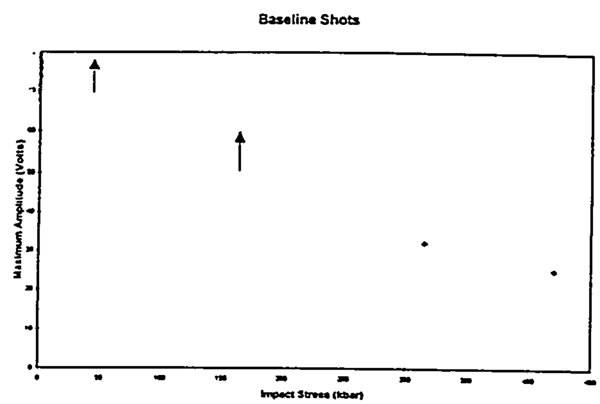

FIGURE 4. Maximum Voltage Amplitude versus Impact Stress

Aged Tests

The actual temperature used for the aging process had no experimentally measurable affect on the voltage response of the pins. Also, the process of aging the pins did not affect the spread of the voltage response between the four pins in a set. The process of aging the pins, however, did effect the voltage response by producing pins which responded with faster risetimes. The aging process had affected some physical property of the TOAD pin assembly. What exactly has changed is not known. However, it is unlikely that the piezoelectric crystal itself has changed at such low relative temperatures. The most likely change is within the conductive-epoxy potting compound. It could have further cured or perhaps outgassed. Again, the resultant spread of voltage response was not changed but the voltage-response profile was improved.

Heated Tests

Heating the pins at 50.2° C for two hours before impacting at a stress level of 315 kbar slightly increased the spread of the voltage response between the four pins, at least for one set with the other giving the usual 12 ns spread. The pins, when used in their intended application, do see a temperature history of 50.2 C for anywhere from 2 hours to four days. Therefore, the results from the present program may explain the good success of the TOAD-pin results in the application scenario.

Heating the pins at 50.2° C for two hours before impacting at a stress level of 50 kbar significantly increased the spread of the voltage response between the four pins in both sets. The reason for this result is not fully understood. There are most likely at least two contributing factors to this result. First, the loading history at these lower stress level tests is extended which decreased the risetime and could extend the response spread. Second, raising the temperature of the target to 50.2° C could change the alighnment of the target (not measureable at this point in the procedure) and increase the tilt angle thereby increasing the pin-response spread.

Aged and Heated Tests

The voltage response of the aged and heated pins was essentially the same as that response from the aged or heated pins. The same general conclusions can be made. The voltage-response profiles are sharpened (faster riseteimes) compared to the results from baseline tests. The pin-response spread is not significantly differenct from that of the baseline for the 315 kbar impacts. The spread increased for the 50 kbar impacts. The same reasoning applied to the aged or heated tests should apply to these tests on aged and heated pins.

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