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ELECTROMAGNETIC STRESS & VELOCITY GAGES

R. S. Wilson

DEVELOPMENT DIVISION

OCTOBER - DECEMBER 1971
P.O. No. 58-0038

MASTER

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The purpose of this project is to determine the applicability of the electromagnetic stress and velocity gages to systems employing small explosive drivers.

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DISCLAIMER

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ABSTRACT

The final results of a comparison of the stress profiles of the XMC 2361 and the MC 2453 drivers are reported. Difficulties with the velocity gage signal from the MC 2453 were overcome by using the complete driver assembly. Also reported are the results of an unsuccessful attempt to use the velocity gage to measure the particle velocity produced by these drivers in a PZT ceramic transducer.

DISCUSSION

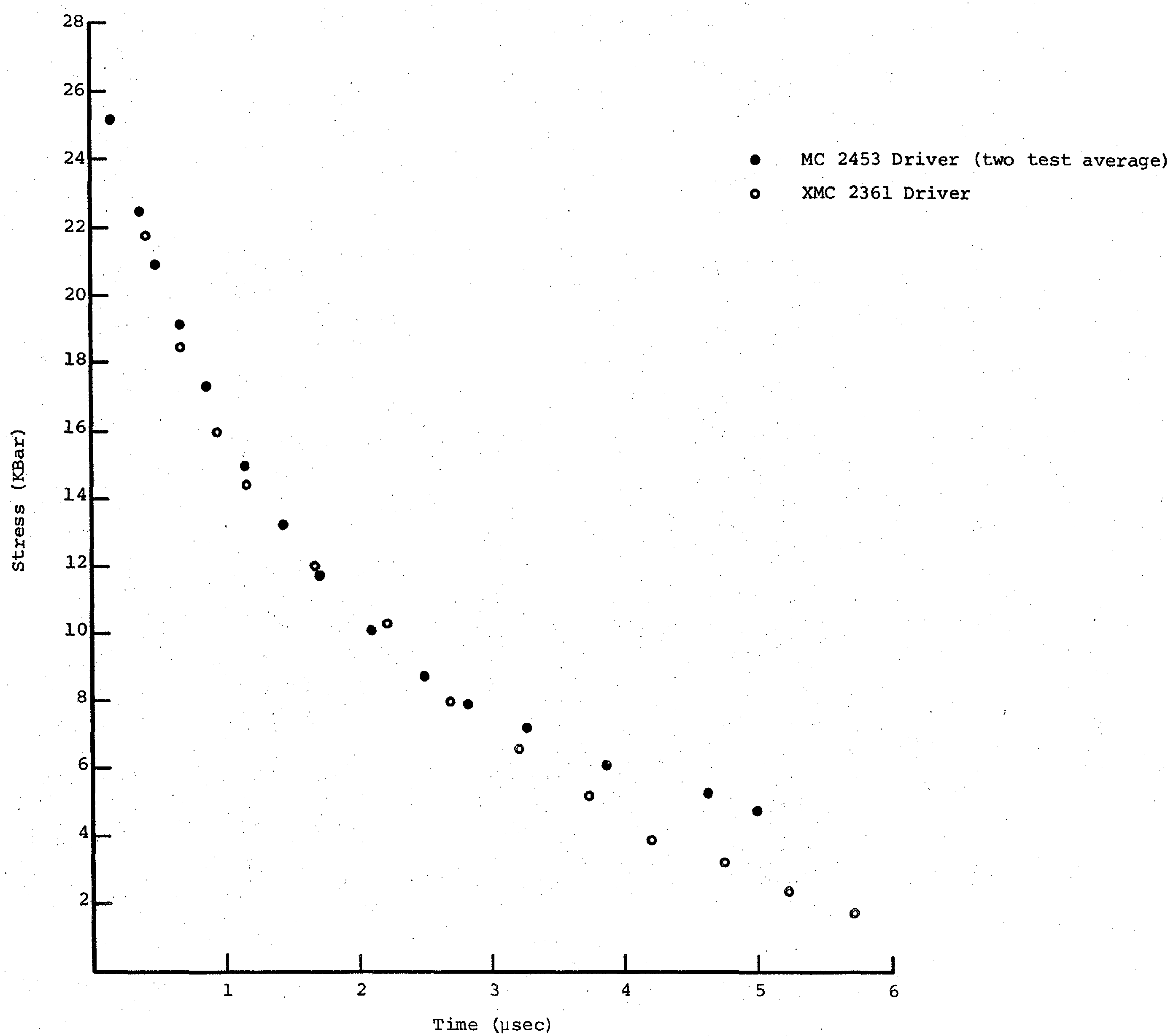
Last period an analysis of the MC 2453 driver sub-assembly's pressure profile was reported. A peculiar hump approximately 6 μsec into the particle velocity signal was found and was shown not to represent an actual increase in particle velocity but rather a magnetic signal probably created by the movement of the steel explosive container through the magnetic field.

Tests have now been made on the complete driver assembly and no hump was found in this instance. Apparently the exterior case of the complete driver effectively shielded this signal and prevented it from reaching the velocity gage.

Shown in Fig. 1 is the pressure profile for the complete MC 2453 driver. The correction for the offset baseline was made by the same technique discussed in the report of last period in connection with the driver sub-assembly. For comparison, a pressure profile of the XMC 2361 driver taken from last period's report is also shown in the figure. The pressure pulse of the MC 2453 is seen to reach a slightly higher peak value and to hold up somewhat longer than that of the XMC 2361. The mean peak pressure values of four different shots of each type driver, including two of the MC 2453 sub-assemblies, are very close to the values obtained from these two shots: 25.0 ± 1.9 KBar for the MC 2453 and 22.4 ± 0.8 KBar for the XMC 2361. Therefore, the profiles shown in Fig. 1 are considered to be very good representations of these drivers.

An effort was made to use the velocity gage technique to measure the pressure transmitted into a piezo-electric PZT ceramic transducer embedded in aluminum oxide filled epoxy. For this purpose the gage shown in Fig. 2 was designed.

To permit particle velocity measurements to be taken within the ceramic, a thin piece was cut off the end of the ceramic block; the copper foil sensing element was then placed over the end of the block and the thin piece bonded back on using Eastman 910 adhesive in as thin a layer as possible. Particle velocity measurements were also desired in the epoxy just above the epoxy-ceramic interface and for this purpose a thin piece of epoxy was formed and attached in the same manner as the ceramic piece. A sensing element was also included at the



28
26
24
22
20
18
16
14
12
10
8
6
4
2
Stress (KBar)
1
2
3
4
5
6
Time (μsec)
MC 2453 Driver (two test average)
XMC 2361 Driver

Fig. 1

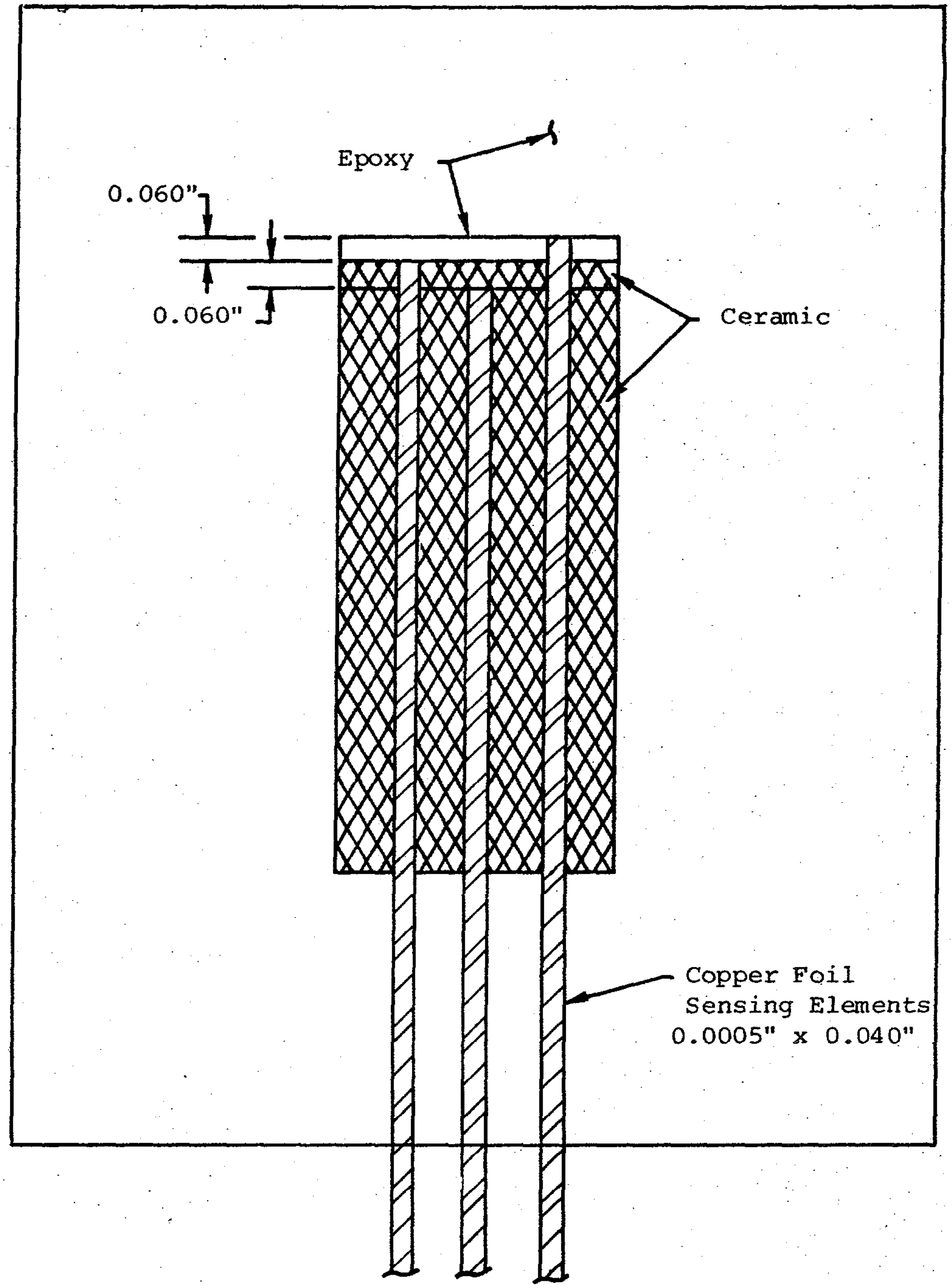


Fig. 2. Velocity Gage Design for the PZT Ceramic Transducer

interface, primarily because the opportunity to do so presented itself; it was not at all clear, however, what relevance a measurement at that position would have, other than providing a timing mark. The entire assembly was then potted in epoxy as described in earlier reports.

The ceramic transducer supplied for these shots had previously been electrically polarized and it was therefore necessary to depolarize them to prevent a high voltage from being generated when they were subjected to a shock wave. This was accomplished, before the ceramic was cut, by heating it to 240 C, 25 C above the Curie temperature, for 30 minutes, then cooling slowly to room temperature.

Three gages were built and mounted on a stand as previously described for the type 9 gage. Two were tested with XMC 2361 drivers, and the other with a MC 2453.

In all three tests, the gage signals were obliterated by high frequency (10-15 KHz) noise as soon as the shock wave reached the ceramic. The amplitude of the noise was of such a magnitude—as much as 2 volts peak to peak—that it was impossible to even make an estimate of the velocity signal, which is typically of about 0.3 volt amplitude. The noise on the signal from the sensing element in the epoxy was much less intense (the signal was free from noise until the shock wave reached the ceramic) and it was possible to see the basic shape of the velocity signal. This provided no new information, however, since measurements in epoxy had previously been made at this depth with this driver.

The amplitude of the noise from the ceramic was very large compared to the particle velocity signal but quite insignificant compared to the high voltage produced by a fully polarized transducer. It was therefore decided that it may not be feasible to depolarize the ceramic to the degree required for tests of this sort and that if any future velocity gage work is done with such materials, pieces which have not been polarized should be used. No such pieces were available for these tests, however, and the effort has been discontinued.

FUTURE WORK; COMMENTS; CONCLUSIONS

The electromagnetic velocity gage technique has been shown to be a practical, accurate, and relatively simple method for measuring shock wave profiles from small explosive drivers. With the appropriate gage configuration the technique can also be used to determine the equation of state of any nonconducting material in which the gage sensing elements may be placed.

The electromagnetic stress gage, however, could not be made to perform reliably in the type of test required here. The primary source of the trouble appeared to be the limitation imposed by the electromagnet on the size of the explosive driver. The small drivers produced shock waves which lacked the planarity required by the stress gage; they also attenuated significantly while tranversing in the inclined edge of the sensing element. The gage was shown, in a previous report, to be sensitive to both of these properties. It was found, however, that a multiple element velocity gage can provide much of the information which the stress gage was designed to give and, at the same time, it is both simpler to build and easier to analyze.

The following considerations should be borne in mind when work with either type gage is undertaken. The explosive driver should be as large as possible and preferably should be of a plane wave lens design; the sensing element should be of the smallest possible length which produces an acceptable output voltage, and, if a foil is used, of the narrowest width that can be conveniently handled; the thickness of the element in the direction of shock front propagation directly affects the rise time of the signal and therefore should be as thin as possible. However, no difference was observed between gages using 0.0005" thick foil and those using 0.004" diameter wire which could be attributed to this property alone. In fact, the fastest risetime obtained was with a gage having the thicker wire elements. The risetime was therefore limited by some other factor, most probably curvature of the wavefront. A further consideration, and one which caused some difficulty in this work, is the elimination of all materials of appreciable permeability from the driver and gage assembly. The least effect such materials would have is a perturbation of the magnetic field so that the field intensity at the sensing elements would not be accurately known. More damaging is the effect they can have on the gage signal if they are put into motion by the driver. Such an effect proved to be difficult to account for in the analysis of several types of shots made in the course of this project and it would be better by far to eliminate the permeable materials completely.