High Temperature Deformation and Fracture Behavior of Metals under High Strain Rate Conditions

Prepared under Navy
Bureau of Naval Weapons
Contract NOw 63-0502c

Progress Report No. 5
1 January to 1 March 1964

by

J. M. Dhosi
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New England Materials Laboratory, Inc.
Medford, Massachusetts

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I INTRODUCTION

~~Work was continued on~~ evaluation of the high strain rate deformation behavior of cast Udimet 700, hot pressed beryllium and arc melted tungsten. As previously outlined, the work is aimed at the determination of optimum hot working parameters of hard to work materials with special emphasis on the as cast condition. The results show that this can be achieved by testing ingot material at various strain rates, stresses and temperatures. Samples are taken from various critical ingot areas and therefore different specimen axis.

II EXPERIMENTAL TECHNIQUES

High strain rate tests were performed on a modified constant load creep-rupture machine. The equipment has been described in detail in a previous progress report.

Equipment Modifications

In the performance of the testing, there became apparent the requirement or at least the desirability for certain modifications in the equipment. Most important among these were the following:

1) In the performance of extremely short time tests (rupture lives in the range of 0.1 seconds or less), the necessity for extremely fast loading times is obvious. Modifications of the loading valve mechanism, removal of a connection restriction in the pneumatic feed line, and the introduction of a secondary feed line have reduced the time required to achieve full load from 0.05 seconds (which had been felt to be adequate) to 0.03 seconds. Oscillographic recordings indicate that there is still no overload or cyclic characteristic in the loading. The design of a much larger (by an order of magnitude in area) loading valve, based on an entirely new concept, has been completed and it is expected that this will result in a further reduction in loading time.

2) For the sake of flexibility, there has been added the capability for adjustment of loading time.

3) The application of extremely light loads implies the use of relatively low pneumatic pressures to be maintained in the system as a whole. The weight of the loading piston must therefore be sufficiently low as to be lifted to pre-test position by these low pressures. Re-design of the piston has dropped its weight from 3.5 pounds to 1.4 pounds resulting in a wider range (particularly at the low end) of available stress.

4) With the improvement of loading time, it was necessary to design a far more sensitive depressurization indicating device for the accurate determination and recording of both loading time and time to rupture. Such a device has been developed and incorporated in the equipment.

5) A capability for automatic reset in the event of power loss has been added.

6) The size of the loading frame has been increased somewhat to facilitate the use of the equipment with most any furnace or auxiliary recording equipment.

7) The incorporation of oscillographic and strain gauge load cell equipment makes more convenient the obtaining of accurate data concerning the operation of the machine.

III RESULTS AND DISCUSSION

A. Work on Udimet 700

More extensive testing was conducted on Udimet 700, using tensile specimens with the axis parallel to the ingot axis. In particular, the temperature range between 2100° and 2200° F was explored. The data are represented in Figures 1 and 2, representing the results in terms of stress as a function of the strain rate (1), reduction in area as a function of the strain rate (2). Considerable scatter can be observed, which is not too suprising with cast material. On the other hand, a very definite strain rate sensitivity of the ductility can be noted: both elongation and reduction in area decrease with increasing strain rate.

The ductility also changes quite markedly with the test temperature over a rather narrow temperature range. This is illustrated in Figure 3 where the ductility (reduction in area) is plotted as a function of the temperature with two selected strain rates. The maximum in ductility can be obtained between 2100° and 2125° F for both high and low strain rates, however, the peak values are very definitely achieved with the lower strain rates.

Further tests on Udimet 500 were conducted with specimens taken from the center of the ingot. The results of these will be discussed in the final report.

B. Work on Beryllium

A number of "fill-in" tests were conducted in order to complete the temperature, strain rate, ductility picture.

C. Work on Tungsten

Difficulties were encountered in machining tensile specimens from the as cast tungsten ingot. A set of samples have been prepared by now and the vacuum equipment is ready for the tests.

IV FUTURE WORK

The final contract period will be used for tests on tungsten specimens and the compilation of all the results. Conclusions are drawn with respect to recommended hot working methods. The value of the method for the evaluation of the forgeability of materials will be critically discussed.

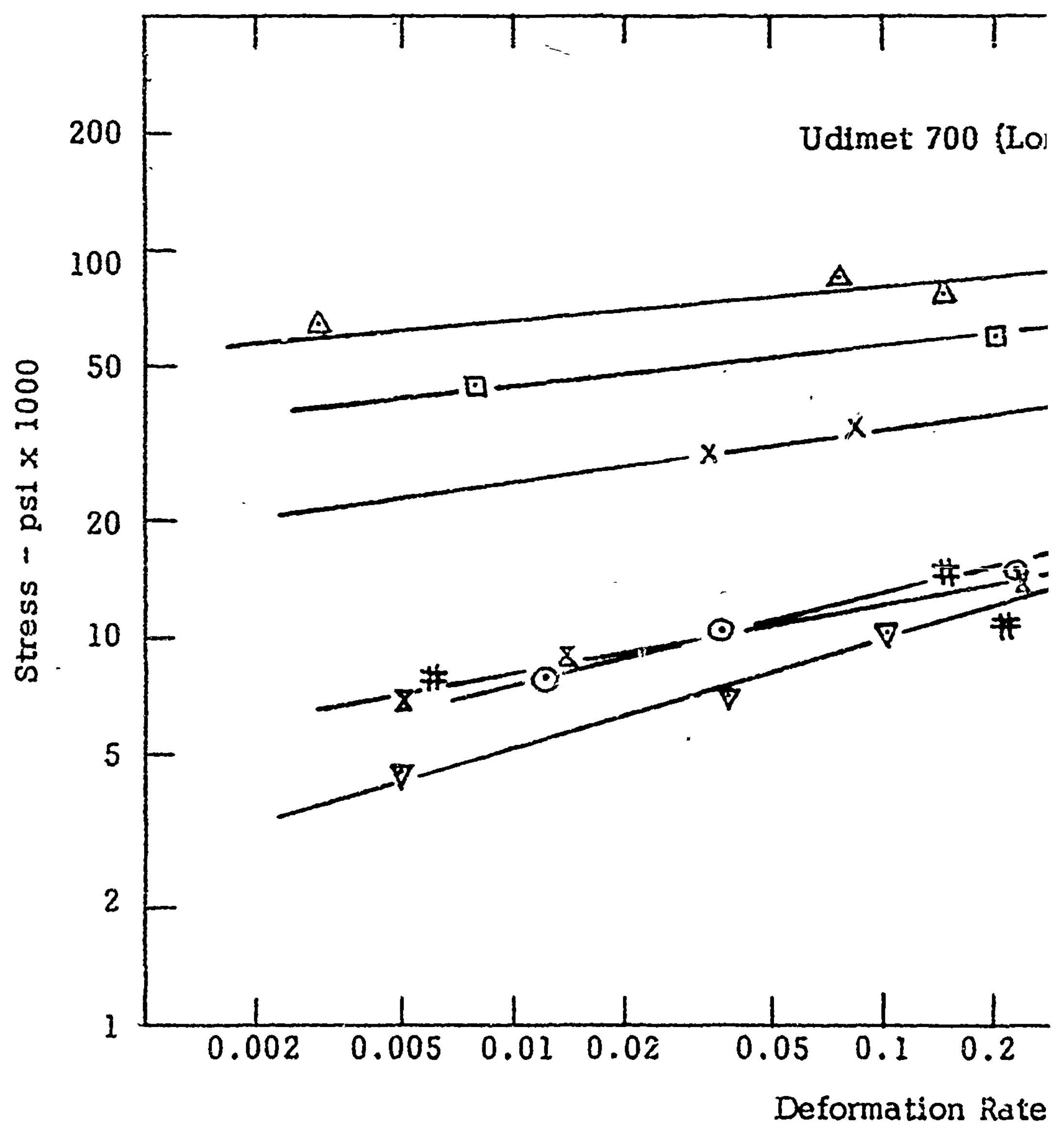
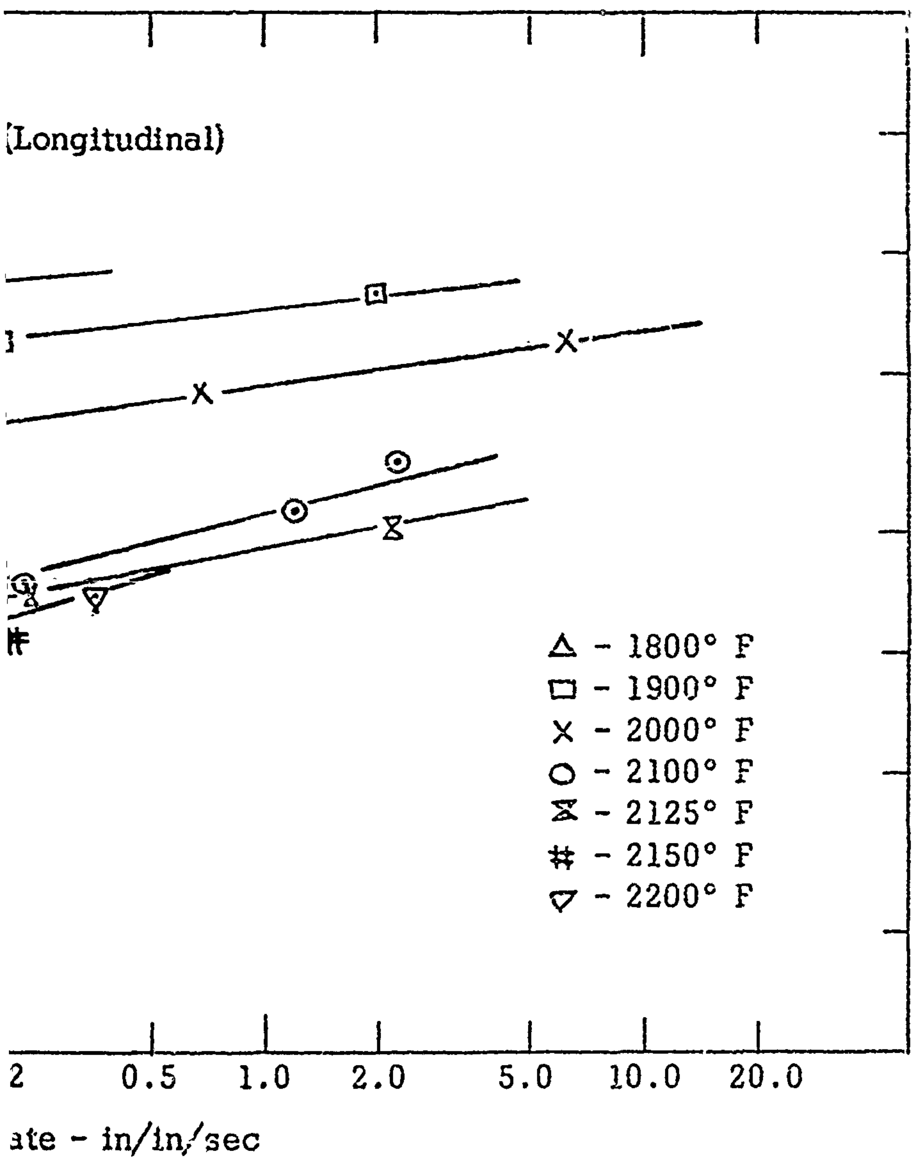


Figure 1. Log stress as a function of log deformation r
temperatures.



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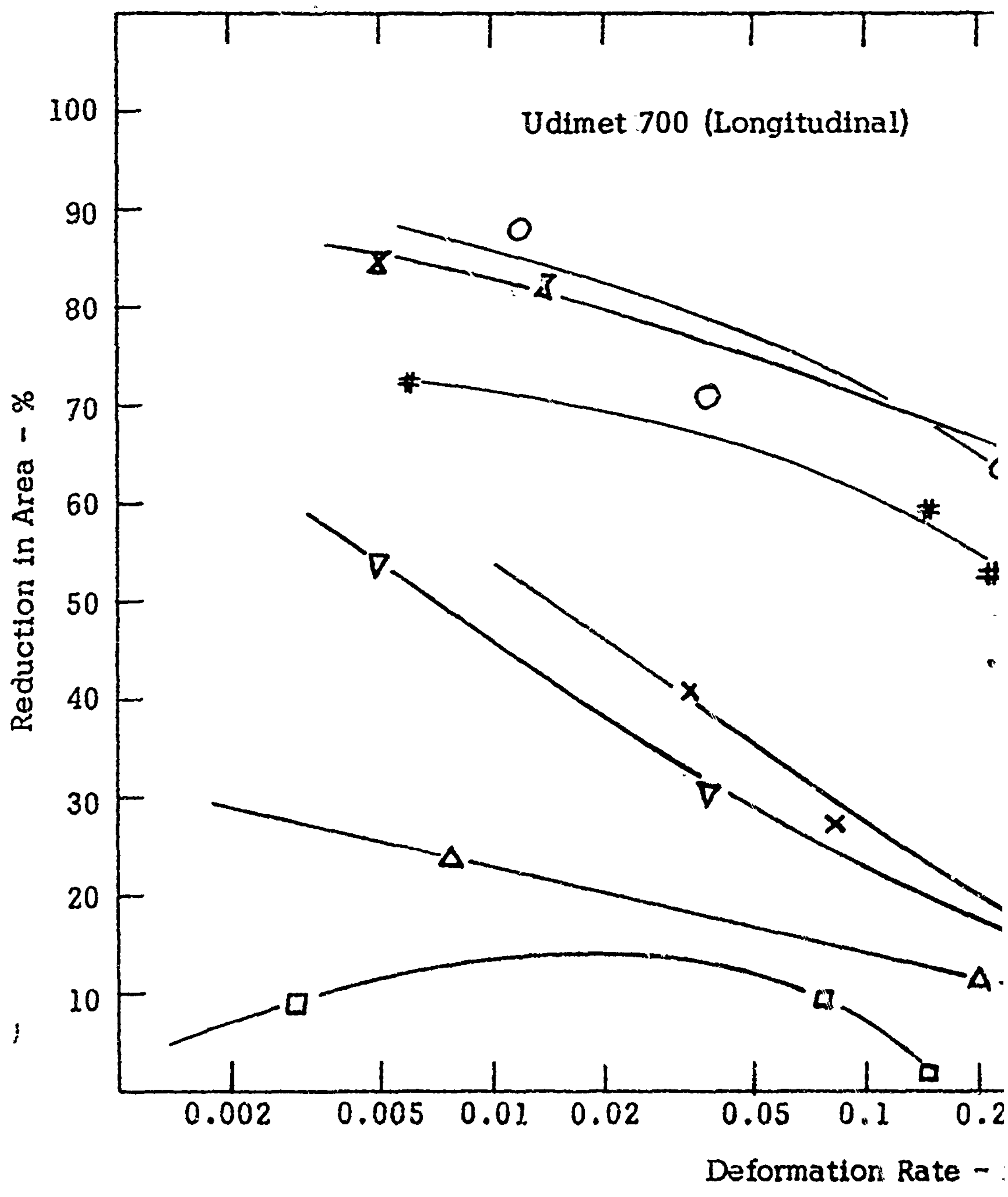
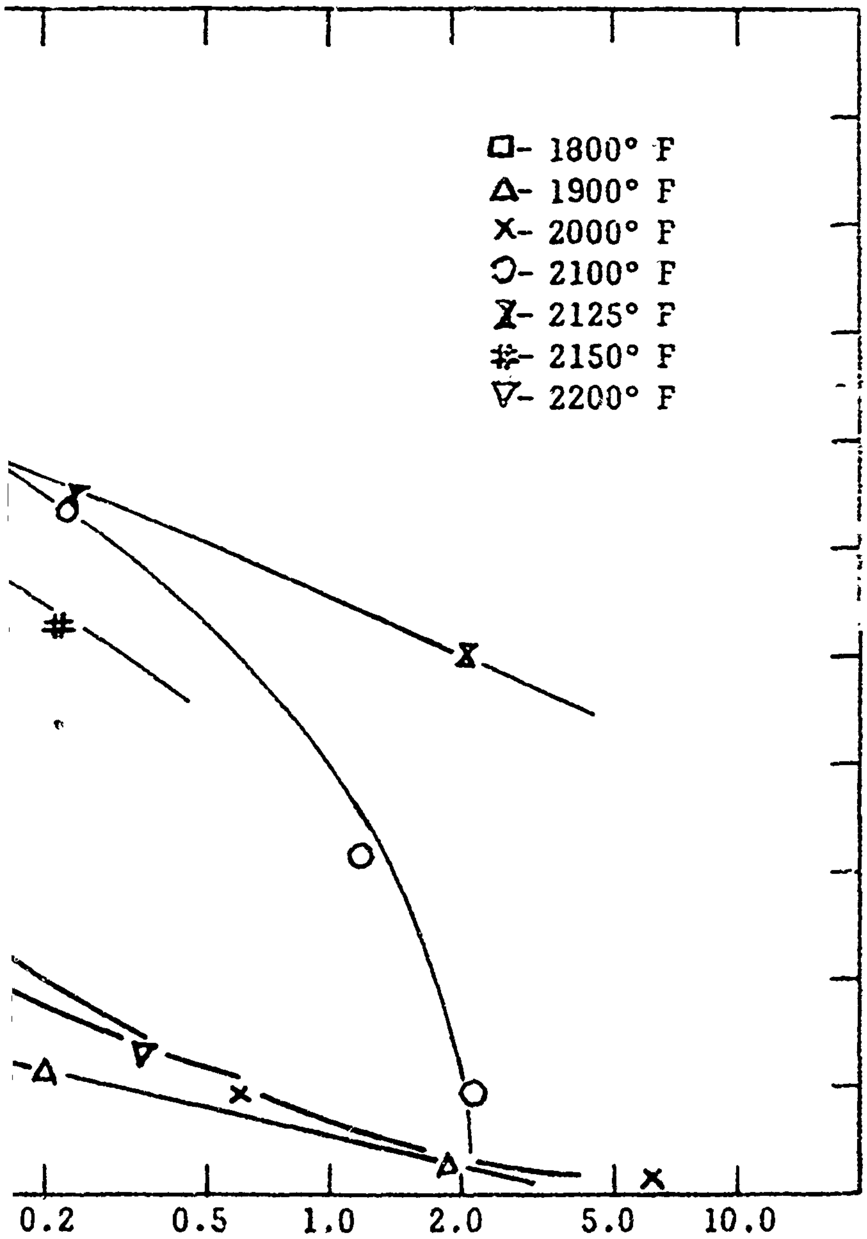


Figure 2. Reduction in area as a function of log deformat
temperatures.



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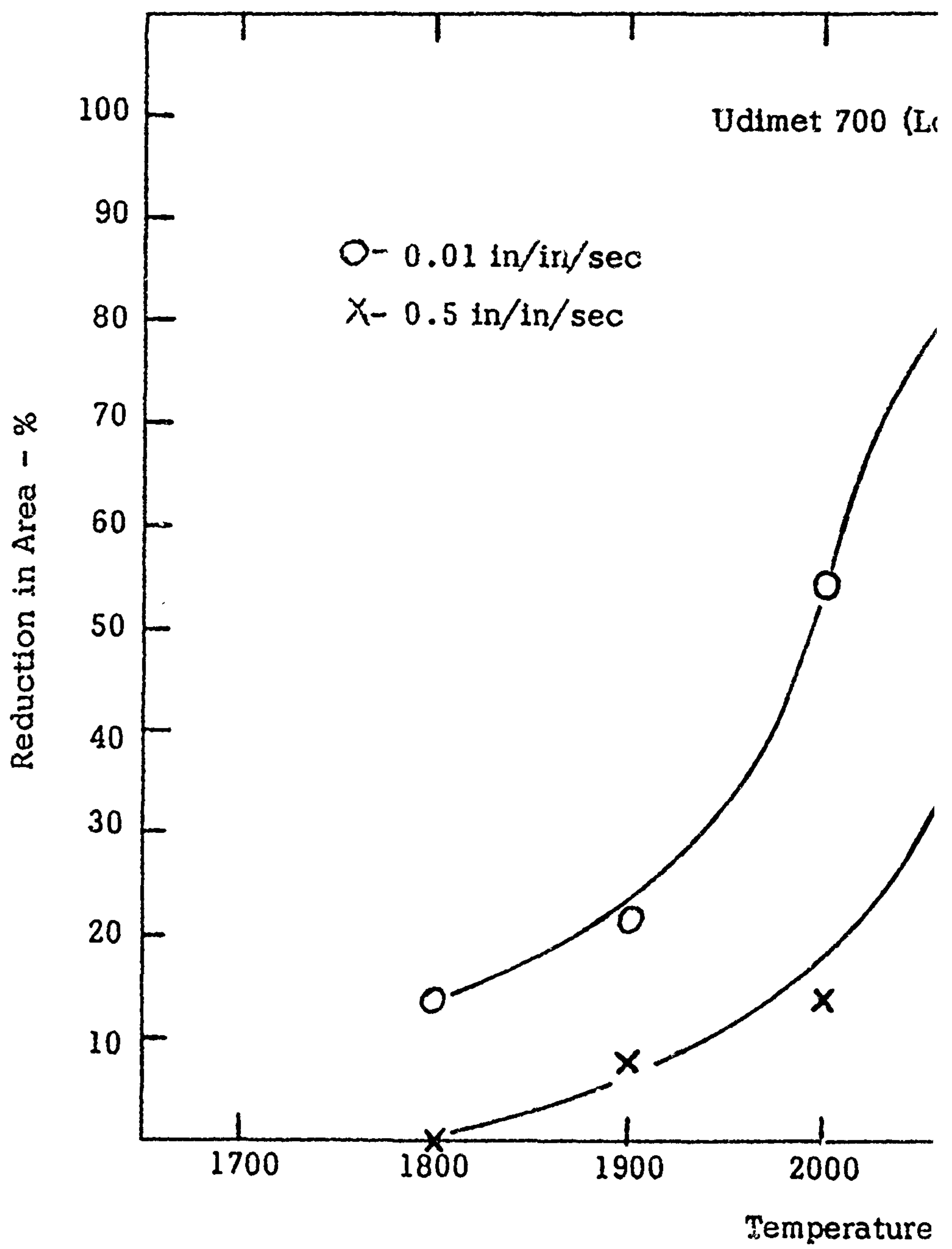
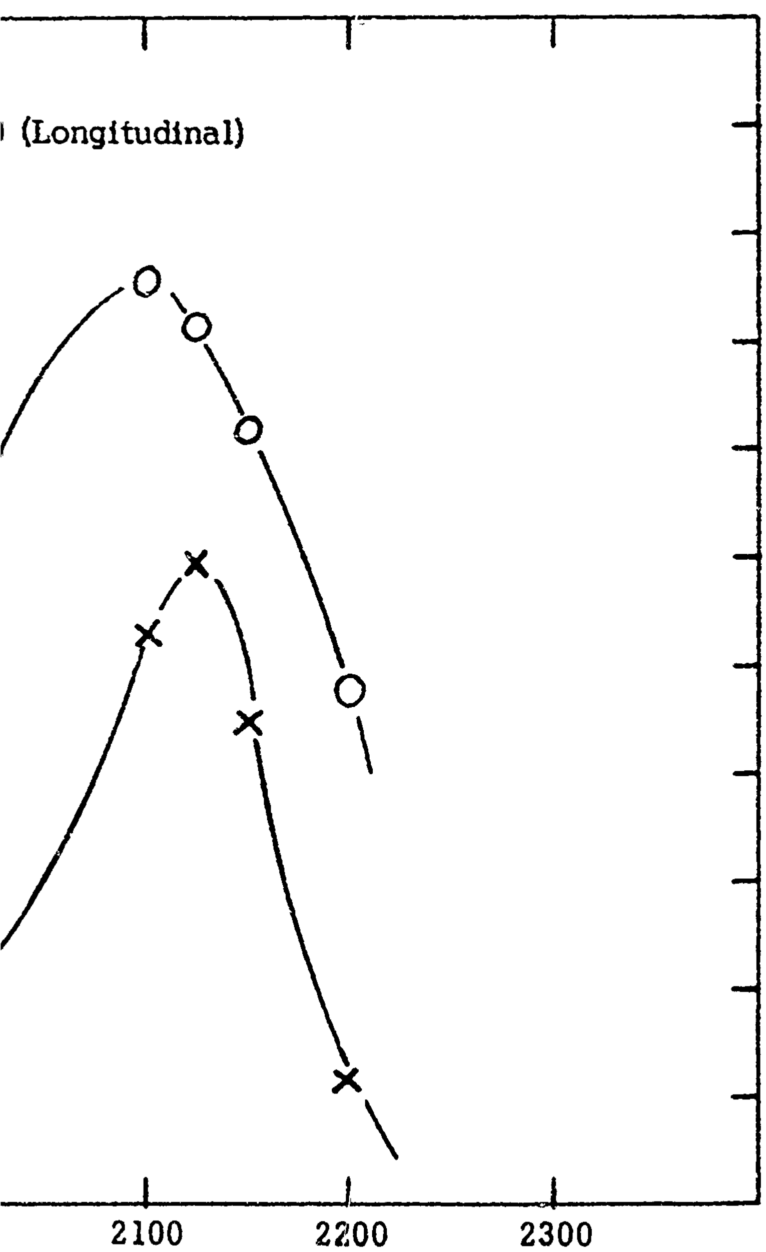


Figure 3. Reduction in area as a function of test
at two strain rates.



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