2289

THE TRUE STRESS-STRAIN PROPERTIES OF
BRITTLE MATERIALS TO 5000° F

Report To

U. S. ATOMIC ENERGY COMMISSION

MASTER

DO NOT

OKO-388

SOUTHERN RESEARCH INSTITUTE

2000 9th Avenue S.

Birmingham 5, Alabama

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U. S. ATOMIC ENERGY COMMISSION

Southern Research Institute
Birmingham, Alabama
March 9, 1961
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THE TRUE STRESS-STRAIN PROPERTIES OF BRITTLE MATERIALS TO 5000° F

FOREWORD

This is the tenth monthly report on Contract No. AT-(40-1)-2694 for the development of a system for the evaluation of the true stress-strain properties of brittle materials at temperatures up to 5000° F. There are three general areas of development in this program: (1) to heat the specimen radiantly with an external source with minimum temperature gradients within the gage length, (2) to grip and load the specimen with true uniaxial loading, and (3) to measure strains in specimens to 5000° F optically.

SUMMARY

Additional runs on the zirconia-coated graphite have established that the ultimate strength of this material is 30% to 100% greater than reported in the literature. This greater strength is apparently obtained because (1) the gas bearings eliminate all bending moments in the specimens and (2) the radiant heating provides more even and measurable temperatures.

The ultimate strength of one pyrolytic graphite specimen was found to be over 33,600 psi at 4000° F. This is very high strength even for pyrolytic graphite.

The resistance heated furnace performance is proving very satisfactory. Work has restarted on the induction heated unit, which will probably be necessary to accommodate the strain analyzer.

The gas bearings have been dismounted, cleaned, plated, and are now being reinstalled.

The designs of the grips are receiving continued attention to provide the maximum alignment and versatility.

Some limit switches are being added to the load frame to provide protection from overtravel.

The preliminary model of the strain analyzer is being assembled and components ordered as the design continues to develop.

PERFORMANCE DATA

During the month, additional runs at temperatures up to 4000° F were made to confirm operating techniques and to uncover any difficulties in the operation of the system. No serious difficulties have been encountered, but a few minor modifications have resulted.

In a preliminary run on pyrolytic graphite, a specimen was machined from a 4" x 4" x $\frac{1}{4}$ " thick flat bar and pulled with the gas bearings in operation. The ultimate strength was plus 33,600 psi at 4000° F. The specimen broke slightly out of the gage length where the temperature could have been 100° F colder so that the ultimate could be somewhat higher. During the loading, there were some sharp (but small) inflections in the load-time curve, indicating that the material may have been breaking by layers. Because of its extremely high strength for a graphite, a more precise study of this material would seem desirable and may be made at a later date when the evaluation program is established and the material is available.

Additional tensile pulls were completed during the month on the zirconia-coated graphite specimen as described in the last monthly report. With the gas bearings in operation, a large increase is evident over the reported ultimate strength of similar graphites at temperatures up to 4500° F (see Figure 1). Observe that the true ultimates are from 30% to over 100% (over the temperature range) greater than those reported for systems not using gas bearings. Also, the data scatter is considerably reduced to perhaps 10%.

FURNACE

Additional runs were made with the tubular furnace at 4000° F and lower. These runs further established the ability of the furnace to perform satisfactorily over a range of temperatures.

Braces to support the heavy power leads to the resistance element are being fabricated. These braces should facilitate alignment of the furnace and specimen.

Figure 1. Ultimate Tensile Strength for GBH Graphite with Rockide Z Coating.

With the addition of the supports to the power leads, the tubular resistance furnace, including its power supplies and related equipment, will be in good operating condition, lacking only the modifications necessary for the implementation of the strain analyzer.

Preliminary work should begin soon on the induction furnace using a graphite susceptor, which will radiantly heat the specimen. Previously, 1" carbon rods have been heated to 4800° F with very small power settings on the 25-KW generator. In the past few months, the work on a heating source has been channeled to the resistance furnace because it showed immediate promise as a reliable unit. Barring any complications that might arise in adapting the strain analyzer to the furnace, the tubular furnace can be considered completely successful. However, much remains to be learned about the induction heated furnace. A concentrated effort should produce a performing unit despite the multitude of problems.

GAS BEARINGS

All new components, including the gas bearings, have been disassembled and are being thoroughly inspected. There is no evidence of undue wear and all components seemed to have performed satisfactorily. There was evidence of foreign matter entering the gas bearings from the high pressure piping and nitrogen cylinders. This could cause clogging of the bearing orifices and electric arc-over between the bearing surfaces. Recall that the power to the heater can short out to ground across the faces of the gas bearings if the specimen touches the heater tube. The addition of a filter in the gas line to remove the solid particles should eliminate this problem.

The flat gas bearing was originally intended to be used only to provide design information and was therefore fabricated from untreated 4150 steel. Now that it has been modified and made a permanent part of the system, it is being cadmium plated to protect it from corrosion.

During the next month, inspection and adjustment of the system will continue. Also, small modifications will be made that should allow quicker setup time and enhance the operation of the system.

GRIPS

The grips to be used in the final system are not being used at present. They will be incorporated in the system at a later date when specimens are machined specifically for use in the final system. A study is being made to determine the feasibility of modifying these grips to allow their operation inside the heater tube of the 5000° F furnace. This would allow a reduction in the length of the specimens from 10" to about 5", resulting in easier machining and less material cost for the specimens.

LOADING SYSTEM

Limit switches are being added to the load frame to prevent the upper crosshead from traveling too far up and shearing the pin in the positioning drive. Later on, limiting devices will probably be added to the mechanical drive to limit the movement of the drive both up and down. Further refining of the equipment will proceed as time permits and the needs become evident; however, the major effort will remain to improve the technical performance and reduce the time required for each evaluation.

OPTICAL EXTENSOMETER

Servo Design

The previous progress report described the plan to measure fine motion by using a movable aperture in place of the rotating plate. The fine motion measuring system, called the Aperture Servo, replaces the Parallel-plate Servo of earlier reports. With selection of this method of obtaining fine motion control, it became possible to determine the specifications for a suitable drive-motor and gear-train.

An experimental procedure was planned and a test rig assembled to permit obtaining static and dynamic parameters for the aperture positioning mechanism. Measurements give the effective values for the polar moment of inertia, viscous damping, mechanical time constant, and starting friction. For these measurements the positioning mechanism was lubricated for minimum viscous damping, and operated

without the aperture attached. Nevertheless, the results are adequate to determine the torque requirement for the motor and are being used to determine the suitability of commercially available servo components. The dynamic design will later require correction of these values to account for the additional inertia of the aperture and the increased starting friction caused by the aperture.

As an aid in over-all planning, an electrical functional diagram was drawn for the extensometer system and will be augmented or corrected as needed.

Mechanical Design

Detail drawings of about 80% of the mechanical components have been completed and shop orders submitted for their fabrication. Purchase orders have been submitted for the procurement of some commercial components used in the mechanical design.

The chopper assembly has been designed and incorporates a synchronous motor rigidly attached to each chopper. The chopper will produce a slightly unsymmetrical function but is not expected to introduce an appreciable error.

The design of the aperture assembly is complete. It incorporates the fine focusing mechanism of a Bausch and Lomb microscope and will be servo-operated. The aperture and focusing mechanism will function as the fine-range strain-following mechanism.

Several changes were made in the final design of the lens tubes in an effort to eliminate stray light. If the stray light is not reduced considerably, it will be necessary to incorporate additional optics in the region between the aperture and photocell. Final design of components in this region will depend upon the outcome of stray light evaluation using parts now being fabricated.

Details of the mounting base for the mechanical components are complete to date, but minor alterations are contemplated as the servo components are selected.

Assembly of the mechanical components will begin as soon as parts are available from the shop. In the meantime, design and selection of additional components will continue.

ACKNOWLEDGMENTS

The furnace and loading frame phases of the work are being performed by Paul T. Howse, Jr. Frank J. Digesu is developing the gas bearing. The optical strain analyzer is being developed under the direction of Albert L. Thomas, Jr., Head of the Instrument Development Section. The mechanical design of the analyzer is being carried out by Norman L. Francis and W. O. Watkins. Alvin N. Bird, Jr., is responsible for the optical design. The servo system analysis is being done by Mr. Robert R. Bairnsfather.

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Birmingham, Alabama

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