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IMPROVEMENT OF A MICROTENSILE MACHINE

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

Modifications of the loading system and traveling optical system of a microtensile machine are described. The motor-driven load micrometer permits constant-rate loading, the recording of stress-strain data, and a significant increase in output of test results.

The original traveling microscope is replaced with an optical unit that offers an extensive range of magnifications and the use of optical measuring and photomicrographic devices. Improved observation and measurement of transparent specimen materials can be conducted by employing standard, polarizing, or dark-field microscopy. The improved accuracy in measurement of specimen dimensions provides more accurate test results. The original precision of the instrument and its chief characteristic of high extension sensitivity are maintained.

INTRODUCTION

In recent years, intensive studies of the mechanical properties of whiskers and thin films have been in progress. Such studies have necessitated the development of mechanical instruments capable of applying loads and detecting subsequent strain in microscopic materials. Machines of various designs have been described by several investigators (refs. 1 to 4); however, the microtensile machine developed by D. M. Marsh is one of the few commercially available instruments specifically designed for microscopic materials (refs. 5 and 6).

The Marsh machine is based solely on mechanical and optical principles. It employs a torsion balance to apply loads to the specimen and a mirror-autocollimating telescope system to detect extensions. Operation of the instrument, as originally designed, is completely manual. Automation of the loading procedure and development of a method of recording stress-strain behavior would enhance facility of operation and increase the output of test results. Additional changes would prove helpful, particularly in the case of detailed observation and measurement of transparent specimens.

Modifications were designed to add the following characteristics to the instrument:

(1) Automatic application of axial tensile loads at constant rates

(2) Capacity for recording stress-strain behavior of test specimens

(3) A traveling optical system offering the following improvements:

(a) Variable specimen magnifications ranging from 23.6 to 750 diameters

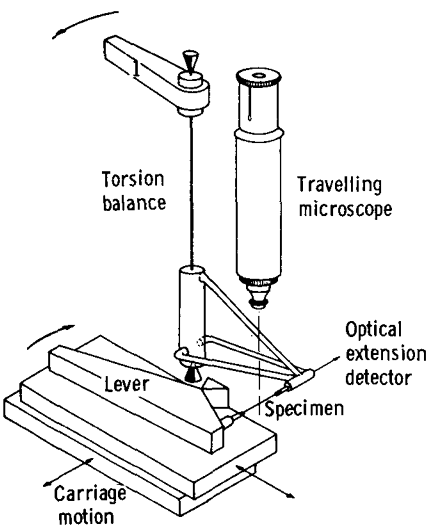
(b) Controlled-intensity incident and transmitted illumination

(c) Use of optical measuring and photomicrographic devices employing standard, polarizing, or dark-field microscopy

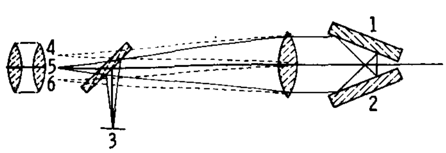
REVIEW OF DESIGN PRINCIPLES

A schematic diagram of the loading system is shown in figure 1(a) (from ref. 6). The system consists of a torsion balance that offers extensive load coverage through use of interchangable, calibrated torsion wires. The balance is controlled by a load micrometer, which is coupled to the torsion head arm (fig. 1). Movement of the arm transmits torque to the inserted wire and thus exerts an axial tensile load on the mounted specimen. The loads involved are within the range 10^{-5} to 0.45 kilogram.

Extension is detected by a mirror autocollimating telescope system, the operation of which is shown in figure 1(b). Light, focused through a graticule at 3, is received by two mirrors, 1 and 2. In the null position, the mirrors are at 45° to each other. The light is reflected along paths shown by the continuous lines and returns to the telescope to form a single central image at 5. When load is applied to the specimen, the resultant extension upsets the null condition; the reflected light paths diverge to form images at 4 and 6. The null position is restored by merging the graticule images into coincidence. Actual extensions are measured on a sensitive micrometer acting through the reduction lever system illustrated at the base of figure 1(a).



(a) Loading system.



(b) Basic principles of extension detector.

Figure 1. - Diagram of microtensile machine elements (ref. 6).

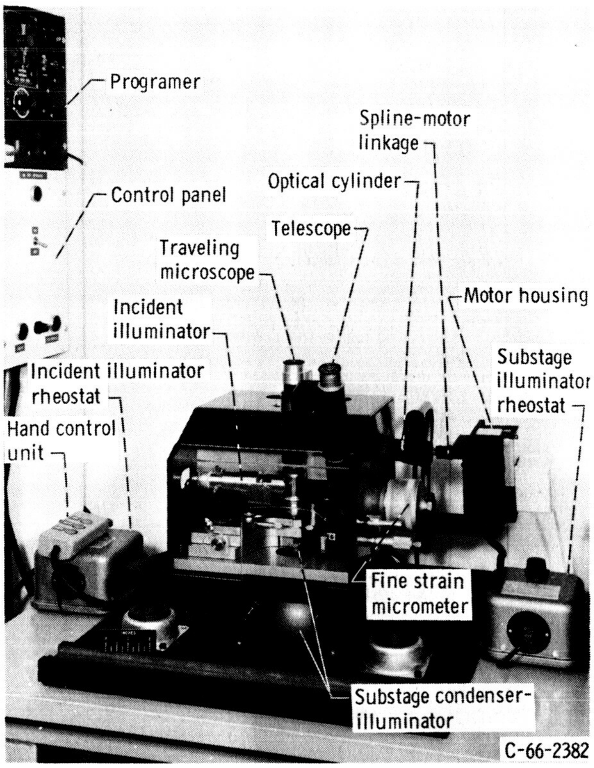


Figure 2. - General view of microtensile machine as modified.

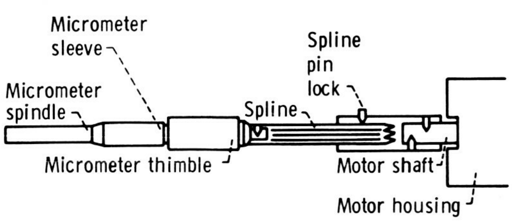


Figure 3. - Sketch of motor-micrometer linkage.

TABLE I. - CAPACITIES AND LOADING RATES OF TORSION WIRES

Torsion wire	Capacity, kg	Load rate, kg/min
1	7.60×10^{-4}	2.92×10^{-5}
2	4.22×10^{-3}	1.62×10^{-4}
3	9.40×10^{-2}	3.61×10^{-3}
4	4.50×10^{-1}	1.73×10^{-2}

MODIFICATION OF LOADING PROCEDURE

The loading procedure was modified to render the instrument capable of recording stress-strain data and to enhance facility of operation. Specimen-loading procedure was changed to permit automatic application of load at constant rates. The modified instrument is shown in figure 2.

The thimble of the load micrometer is coupled to the shaft of a reversible synchronous motor by a spline (fig. 3). For current tests, the thimble is rotated at a constant speed of 1 rpm. Each revolution advances the micrometer spindle 0.5 millimeter. The actual load applied to the specimen depends upon the load capacity of the torsion wire inserted in the balance. Therefore at constant speed, load rate varies directly with the capacity of the wire. Table I summarizes the capacities and load rates of four calibrated torsion wires. The constant speed of 1 rpm satisfies the present requirements of the instrument; however, the load rate of each wire can be varied through use of a controlled variable-speed micrometer drive.

The synchronous motor drive may be operated either manually or automatically. The hand control unit (fig. 2) controls the motor drive directly. It contains on (load) and off and reverse (unload) switches. As the load micrometer rotates, extension determinations are made by successive presetting of selected extensions. The event signal is actuated when the extension detector indicates null (that the preset extension has been reached).

Automatic operation is achieved by switching a programer into the control circuit.

The load micrometer can be programed for specified load-delay or on-off cycles. The programer (fig. 2) consists of a timer equipped with a time-delay circuit and is actuated by the hand control unit. The load phase of the cycle can be extended over intervals ranging from 1 to 60 seconds and thus permits specimen loading at predetermined increments. Such load increments are a function of torsion-wire capacity, load interval, and load-micrometer motor speed. The delay (or off) phase of the cycle is controllable within the range 1 to 10 seconds. This phase permits measurement and recording of specimen extensions.

The motor-driven load micrometer has relieved much of the operator fatigue commonly associated with use of the tensile machine. It has also eliminated frequent abortion of tests caused by severe vibrations that resulted from manual operation of the load micrometer. The output of test results has been significantly increased.

DATA RECORDING

Tensile load is recorded by a photoelectric sensor that counts the revolutions of the load-micrometer thimble. Load is recorded on the chart of a high-speed recorder by impulses generated as an index mark on the thimble passes the sensor. A complete record of load is obtained since both the thimble and the chart move at known speeds.

The photoelectric sensor and the micrometer thimble are enclosed in an optical cylinder (fig. 2). The interior of the cylinder is coated with an optical black lacquer that dampens reflections from the sensor light source. The ends and hinged access port of the assembly are sealed with felt strips to prevent light leakage. Recording can thus be conducted under conditions of normal room lighting.

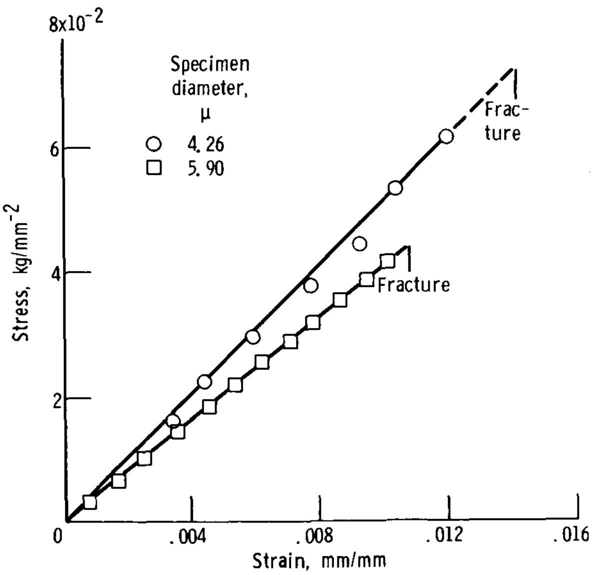


Figure 4. - Stress-strain diagrams of sapphire whiskers.

Time of specimen-extension measurement is also recorded on the chart through use of an event signal actuated by the hand control unit. The impulse generated is registered on the chart as an event mark, and respective extensions are recorded. The resultant record represents two related types of data, time of load and time of extension. Interpretation of the chart entails substituting the event marks for the respective extensions recorded and relating each with its corresponding load. Figure 4 illustrates representative stress-strain diagrams of two sapphire whiskers. Programed cycles of 30- and 60-second load intervals and delay intervals of 5 seconds each were employed.

TRAVELING OPTICAL SYSTEM

The original traveling microscope is replaced by an optical system that offers an extensive range of mangifications and the use of optical measuring and photomicrographic devices. Magnifications of 23.6 to 750 diameters can be obtained by employing dry objectives of long free-working distances.

The base plate of the tensile machine was modified to provide an aperture that accommodates a variable-focus substage condenser-illuminator equipped with a field diaphram. This illuminator is mounted immediately below the specimen anvils. Lateral movement of this substage unit can be coordinated with the normal movement of the traveling microscope. Addition of the illuminator allows detailed observation and measurement of the gage length of transparent specimens as well as accurate measurement of any transverse section along the entire gage length.

Controlled-intensity incident illumination is included in the system for observation and measurement of opaque materials. Combined illumination can be established by simultaneous use of both illuminators. The technique of combined illumination is often required for detailed surface and subsurface examination of transparent materials. Light intensity of both systems is adjustable to a color temperature of 3200° K, as required for color photomicrography, polarizing microscopy, or dark-field microscopy. Polarized light is available in each system.

The eyepiece tube of the microscope accommodates any standard ocular, conventional photomicrographic attachment, or the image splitting measuring eyepiece (ref. 7). The latter device is capable of measurements accurate to 0.125 micron. Use of the eyepiece as an accessory of the test apparatus permits accurate detection of minute dimensional variations in specimens being tested. Observation and measurement of specimens can be conducted through use of standard, polarizing, or dark-field microscopy.

Lewis Research Center,
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