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Progress Report

for

ENVIRONMENTAL TESTER DEVELOPMENT

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to

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by

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Project Aim: The inventor proposes to refine the design of the environmental tensometer and build and test a second generation prototype of the diagnostic device. The suitability of the apparatus will then be tested in a laboratory setting.

Project Objectives:

The primary objective is to further develop the environmental tensometer toward commercialization by making key technical refinements, improving the controlling and data-logging software, and testing the system in a potential customer's laboratory.

Progress:

Progress has been made in Tasks 1 (completed), Task 2 (one half completed), Task 4 (one half completed) of the original work plan. In the following paragraphs a detailed description of the work completed on the second prototype is explained in detail.

A second prototype of the Environmental Tester, a device capable of tensile tests of fibers in controlled environments and at high temperatures, has been designed and is currently being fabricated. The first prototype includes six integrated systems; the testing system, the furnace system, the vacuum system, the mass flow control system, and the computer data acquisition and control (CDAC) system.¹

The First Prototype

A schematic of the testing and furnace systems of the first prototype is provided in figure 1.² The testing system consists of a position measuring actuator and a force transducer to measure the load. The actuator is mounted on a steel plate that is held above the baseplate by steel rods. The furnace system consists of a cylindrical furnace that is supported by a steel plate that is attached to the same steel supports that ultimately support the actuator. The temperature is monitored by two thermocouples: an S type thermocouple that is placed inside the tube of the furnace near the test specimen, and a K type thermocouple that measures the ambient temperature in the test chamber at a user determined location.

A schematic of the remainder of the device is provided in figure 2. The vacuum system consists of a bell jar that surrounds the testing and furnace systems, a baseplate onto which the testing and furnace systems are mounted, a vacuum pump, and a pressure gauge. The mass flow control system of the first prototype includes four controllers for different gases (Ar, CO, CO₂, and O₂), and a controlling power supply. The support system consists of a steel top mounted on a frame with mounts to level the steel top and isolate it from vibrations. The sixth system is the data acquisition system, which includes a computer, a data acquisition board, a backplane and signal conditioners.

The Testing System

It was found that the steel rods that supported the furnace and motor in the first prototype underwent thermal expansion as the furnace system reached the testing temperature, and a substantial dwell time was necessary to allow the furnace and testing systems to equilibrate so that accurate testing could begin. The steel rods will be replaced with fused silica rods for much lower thermal expansion in the second prototype, and connectors utilizing a Teflon seal will be used to join the rods and the steel plates above and below them. Also, the support for the furnace system will be uncoupled from the support for the actuator, as shown in the front, top, and side views of the testing and furnace systems in figures 3, 4,

¹ D.J. Pysher and R.E. Tressler, "An Apparatus for Mechanically Testing Single Filaments at High Temperature in a Controlled Environment or Vacuum" (Center for Advanced Materials, The Pennsylvania State University, University Park, PA.)

² Figures 1 and 2 are modified versions of figures in the above reference.

and 5. The silica rods and four connectors to seal them to the steel have been received. The force transducer has also been received.

The Furnace System

The furnace system in the first prototype included a stationary furnace with a narrow tube along the center. The operator must carefully insert the test specimen into the tube and attach the bottom mount of the specimen to the force transducer. The furnace in the new prototype will have a clamshell design and will slide out of the way when not in use. The mechanism which will allow it to slide, open, and close is illustrated in figures 6, 7, and 8. A vertical rod with a square cross section will function as a mechanical opening device and a stop. This stop will be fixed to a subplate (figure 6) that will be between the baseplate and a linear slide to which the furnace is mounted. The furnace will be mounted to two arms (shown in figure 8), which will be mounted to a pedestal (figure 7) that will be connected to the moveable piece of the slide. The arms will be held together by a pair of springs. When the furnace is moved forward, the stop rod will combine with features of the two arms to temporarily open the furnace so it does not disturb the fiber during movement. Additional features on the furnace arms (shown in figure 8) will allow the furnace to close when it is in the testing position, and provide an indication to the operator that the furnace has been moved to the appropriate location.

A custom furnace will be built by the Earth and Mineral Science Machine Shop. A preliminary design has been completed and the necessary materials to build the furnace have been procured.

The furnace system in the first prototype also included two thermocouples, one for the ambient temperature and one for the testing temperature. The second prototype will include an additional S type thermocouple to monitor the temperature of the furnace elements. The new furnace will have a maximum safe operating temperature of at least 1450C, and the additional thermocouple will monitor the heating elements to insure that this temperature is not exceeded.

The Vacuum System

The vacuum system in the first prototype includes a Pyrex bell jar that has an outer diameter of 18 inches and a height of 18 inches. The operator is required to manually remove the bell jar in order to load the test sample, and replace the jar if a controlled environment is required for the test. The second prototype will include a system to lift a taller bell jar (18 inches outer diameter by 24 inches high) with a pair of screw jacks connected to a gearbox and motor. The motor, gearbox, and screw jacks have been received. The stainless steel disc for the baseplate has been machined with the necessary holes for the vacuum feedthroughs, and has had the upper side ground to improve its appearance and to prevent the outgassing of rough features.

Also, the vacuum system of the first prototype included a Pirani gauge to measure the pressure. This gauge has an output which is dependent on the molecular weight of the gas. The second prototype will include a readout with a calibration that can be easily switched between argon and nitrogen (air), and an additional readout that can be programmed to display the pressure for a different gas combination at the discretion of the user. The Pirani gauge and tube have been received, and the extra readout has also been received.

The Support System

The support system will have several modifications. To improve stability and portability, the support frame will be reinforced with gussets and an undercarriage, and will include casters at the bottom. The jacks, motor, and gearbox will be mounted on a shelf that is attached to the undercarriage, as in figure 9. The steel sheet above the frame will be increased in thickness from 1/4" to 3/16", will have additional holes to accommodate the jacks, and it will have small holes to accommodate the feedthroughs in the baseplate. Instead of small holes for the feedthroughs, the sheet on the first prototype has one very large round hole that is almost the size of the baseplate. The feedthrough accommodation will be changed and the thickness increased because the sheet on the current prototype has warped over time under the weight of the test chamber, baseplate, and bell jar.

The material for the support frame has been received and the frame is under construction. The isolation and leveling mounts have also been received, as well as the 3/16" stainless steel plate. The undercarriage has been constructed and the casters have been mounted to it.

Mass Flow Control and Data Acquisition

The mass flow control and data acquisition systems will remain largely unchanged. The data acquisition board in the first prototype has a 12-bit digital-to-analog converter, while the second prototype will use a 16 bit digital-to-analog converter.

Conclusion

The redesign of the Environmental Tester is complete. Most major components of the testing system have been ordered and have been received. The same is true of the vacuum and support systems. The furnace construction will begin soon after performance testing of the SiC heating elements. The mass flow control and computer data acquisition systems will not be radically different from their counterparts on the first prototype, but they require further planning.

Figure 1

Figure 2

Figure 3

Figure 4

1"

feedthroughs

slide

furnace

quartz rods

bell jar

● Figure 5

Figure 6: Subplate with stop rod

Figure 7: The Pedestal

Figure 8: top view of furnace and arms

**Figure 9: schematic of new support system
with bell jar lift**