Metallurgist, Vol. 50, Nos. 7–8, 2006

# EXPERIMENTAL UNIT FOR STUDYING THE PROCESSES INVOLVED IN DEFECT FORMATION IN STRIP-TYPE HIGH-TEMPERATURE SUPERCONDUCTORS

**I. P. Miroshnichenko, I. A. Parinov,**
**E. V. Rozhkov, and A. G. Serkin**

UDC 537.312.62

*The proposed experimental unit will make it possible to perform tests of short and long high-temperature superconductors (HTSC) in strip and wire form and to quickly evaluate their required mechanical characteristics with improved accuracy, thus giving the unit an advantage over similar existing units. The unit will also make it possible to offer a new range of services in regard to the comprehensive testing of HTSC and other new materials.*

The current rate of industrial growth makes it important to develop new technologies that will reduce not only energy costs, but also the costs incurred in making, testing, and certifying products. In this context, the development of technologies for making and testing high-temperature superconductors (HTSC) is now an important problem [1, 2].

The future wide use of HTSC – materials and components – in power generation, electronics, transport, aerospace, medicine, and other sectors of the economy will create a large demand for experimental units that can be used to test them. Hundreds or thousands of such units may eventually be needed.

To meet this challenge, we have developed a unit to perform experimental studies on the identification and accumulation of damages from the bending of superconducting single- and multi-strand strips of Bi-2223/Ag. We also obtained estimates of the defect content of the specimens after loading. No small units of this type are currently made anywhere else in the world. The closest similar unit is an experimental system developed to evaluate the aging of HTSC wires made of Bi-2223 during mechanical loading. That system was designed jointly by Pirelli Cables and Systems (in Italy) and the American Superconductor Corporation (U.S.) [3]. However, this unit uses neither laser systems nor acoustic-emission techniques to evaluate the displacements and strains that occur in such wires under mechanical loads. Thus, the results obtained with it are likely to be less accurate than the results obtained from the unit being proposed here.

A basic diagram of the unit is shown in Fig. 1. The unit's load-bearing structure consists of a stationary main base *1* and a stationary auxiliary base *2* that are rigidly connected to one another by four posts *3*. The small testing machine *4* of the unit is located on main base *1* along with an elastic element *5* with four extensometers *6*; a special beam *7* is rigidly attached to the element, a piezoelectric element *8* with a reflector *9* being affixed to one end of the beam and two ball-bearing supports *10* being installed on the other end. The test specimen *11* is placed on the supports just mentioned. Specimen *11* is loaded by an indenter/transducer *12*, which moves in the vertical direction along guides composed of a cylinder *13* and a bushing *14* with lapped surfaces. Indenter/transducer *12* is moved by the action of the lever *15*, which is brought into motion by testing machine *4*. The indenter/transducer is returned to its original position by a spring *16* when the load is removed. The displacement of indenter-transducer *12* is determined by the signal formed by extensometer *17*.

Nedelin Military Institute of Rocket Forces, Rostov; Vorovich Research Institute of Mechanics and Applied Mathematics, Rostov State University. Translated from Metallurg, No. 7, pp. 77–78, July, 2006.

 

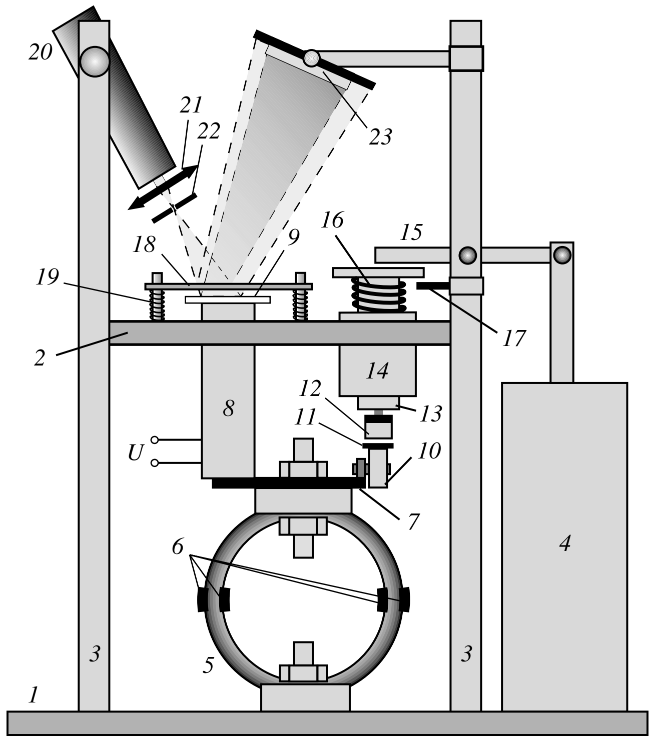


Fig. 1. Diagram of experimental unit.

A beam splitter *18* is secured to auxiliary base *2*. The position of the splitter *18* is recorded when the unit is adjusted, and the splitter is then fixed in position by means of special spring-opposed supports *19*. A radiation source *20* is mounted on the posts along with a convex lens *21*. The diaphragm of three-dimensional filter *22* is located in the focus of the lens. A photodector *23* is also mounted on the posts.

Specimen *11* is mechanically loaded in a three-point loading scheme using small nonstandard testing machine *4*. The specimen freely lies on both ball-bearing supports *10*. The loading is done by indenter/transducer *12*. Regulators provided for the switching-and-control element can be used to assign and smoothly change the rate and direction of the loading. The force that is developed is measured by means of four transducers *6*, while the deflection is measured with transducer *17*. The displacement is measured with a holographic interference system. Indenter/transducer *9* receives acoustic emission (AE) signals, and the parameters of those signals are analyzed by the AE block of the switching-and-control element. A matching block then converts the analyzed signals in an analog-digital converter and the output signals from the converter are subjected to final analysis in a microcomputer.

As noted above, one of the distinguishing features of the unit developed here is the use of an interference gage to measure displacement. The gage operates in the following manner: the coherent monochromatic radiation from laser *20* is converted into a divergent beam after passing through short-focus convex lens *21*, the diaphgram *22* being located in the focus of this lens. One part of the beam is reflected by beam splitter *18*, while the other part strikes the reflector *9* secured to piezoelectric element *8*. The piezoelectric element is rigidly affixed to the elastic element *5* of the gage that measures the loading force. Beam splitter *18* and reflector *9* are adjusted so that the beams reflected from them are sent to photodetector *23*. An interference pattern is formed in the plane of the photodetector in the form of rings of different inclination. The nature of this pattern is due to the interaction of the coherent, spatially coincident beams – the reference beam (formed by the splitter) and the measurement beam (formed by the reflector). The output signal of photodetector *23* is recorded and analyzed in the microcomputer. Piezoelectric element *8* is designed to establish the zero of the gage. This is done by feeding the gage a signal whose voltage has been stabilized within a 30-V range of values.

The gage incoporates design features that distinguish it favorably from standard laser interferometers. The simplicity of the overall design and the small number of optical elements make it possible to reduce losses in intensity and alleviate distortion of the wave front of the interference beams. The interference pattern is formed in the plane of the photodetector beyond the limits of the holographic photosensitive plate, on the same side as the optical axis of the light flow that is being reconstructed. This makes it possible to freely position the detector and the radiation source in space and simplifies the recording of the information. The quality and reliability of the interference measurements are improved by using a system that corrects the readings through integral recording of the intensity of the optical field of the interference pattern [4]. Use of the given method also makes it possible to check for the effects of other factors on the measurement results or to change the test conditions in general.

The interference gage being proposed here for measuring small displacements can be used to directly receive acoustic signals (such as AE signals) and analyze their spectral composition in order to study different stages of the processes involved in fracture and evaluate the damage content of structural materials and elements as they are loaded and undergo creep.

The proposed experimental unit makes it possible to test shortwave and longwave HTSC – strips and wires – and to evaluate the required mechanical characteristics faster and more reliably. This is an important advantage over existing units. The new unit can be used to offer a new range of services in regard to the systematic testing of HTSC and other new materials.

The unit was awarded a silver medal at Archimedes-2004 – the VII International Exhibit of Commercial Products in Moscow.

This study was supported by the Russian Fund for Basic Research (Grant No. 06-08-96623).

## REFERENCES


1. I. A. Parinov, *Macrostructure and Properties of High-Temperature Superconductors* [in Russian], RGU, Rostov-on-Don (2004), Vol. 1.
2. I. A. Parinov and E. V. Rozhkov, “Acoustic emission study of the damage to HTSC strips in bending,” *Mekh. Komp. Mater. Konstr.,* **10,** No. 3, 355–365 (2004).
3. L. J. Masur, J. Kellers, F. Li, S. Fleshler, and E. R. Podtburg, “Industrial high temperature superconductors: perspective and milestones,” *IEEE Transactions on Applied Superconductivity,* **12,** No. 1, 1145–1150 (2002).
4. A. G. Serkin, “Use of an integral estimate of optical field intensity in measuring displacements by holographic-interference methods,” *Izv. Vuzov, Serevo-Kavkazskii Region, Tekh. Nauk,* No. 4, 9–13 (2005).