Experimental Equipment for Studying Mechanical Properties of Materials under Multiaxial Loading with a Wide Temperature Range

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A great amount of work carried out for investigating physical and mechanical aspects of strength of materials gave rise in recent decades to a number of theories orderly enough which describe or explain the macroproperties of actual hard bodies at various temperatures.The necessity to experimentally ground these theories predetermines the development of new procedures for testing materials.

It is common knowledge that great methodical difficulties arise in investigating the regularities of deformation and failure of the materials subjected to composite stresses.These difficulties are substantially increasing in case the tests are conducted under high and low temperature conditions.Most of available facilities fit,in principle,for conducting tests within a wide range of temperatures allow to bring about biaxial stresses in the material of flat and tubular samples.

To drawbacks in the procedures based on testing flat samples(bend of wide plates /1,2/,tension of wide sample with transverse recess /3/,biaxial tension of cross-shaped sample /4,5/,one-sided loading on spherical or elliptical samples by uniform pressure and rigidly pinched the contour /6,7/,tension or compression of samples in the form of a rigidly rimmed plate /8/)should be referred:a narrow range of realized ratios between basic stresses and impossibility to load the sample with the tensor turning axes /3/,non-uniformity of stress and strain conditions of the sample working zone /9/,low reliability of the formulae used for determining internal stresses.

In the light of the above drawbacks,of a particular interest are the tests of thin-walled pipes subjected to the action of combined loads (axial force,torque and internal pressure).Following this scheme one can realize an arbitrary uniform flat stress and arbitrary process of changing it in time.However,the traditional designs of test equipment made according to the above scheme proved unfit for testing purposes at high and,especially,at low temperetures.Placing the sample in cooling liquid /10,11/ or in furnace /12/makes it practically impossible to ensure simultaneously stable temperature conditions in testing and reliable operation of the deformation measuring system.

In the units type CHT/13,14,15/developed by Institute for Problems of Strength of the Academy of Sciences of the Ukrainian SSR the problems of thermoregulation and tensometry were complexly solved:the required thermal conditions were maintained by a specil thermoregulator positioned in the sample internal cavity,and measurements of longitudinal,lateral and angular deformations of the pipe working part were made on the base 20-25 mm by means of a special electromechanical tensormeter /15/.

The universal unit CHT-5(see Diagram in Fig.I)comprises a hydraulic test machine I,high-pressure devices 2,vacuum working chamber 3,heating system 4 and cooling system 5

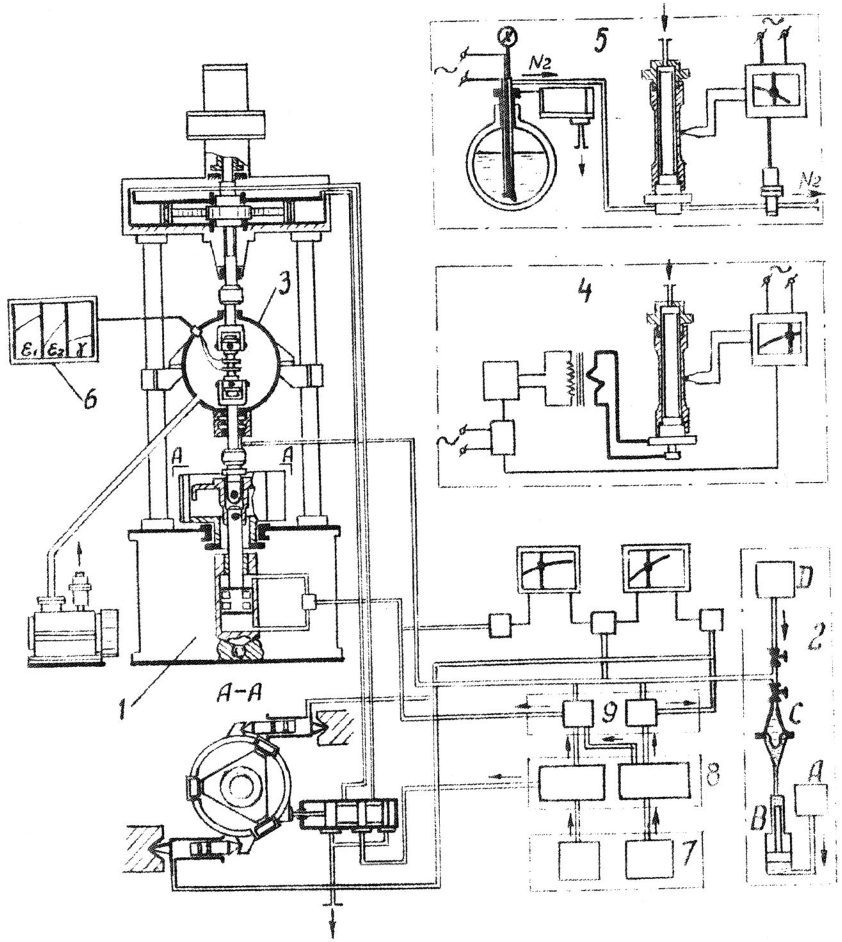

Fig.I. Sketch of the universal unit CHT-5

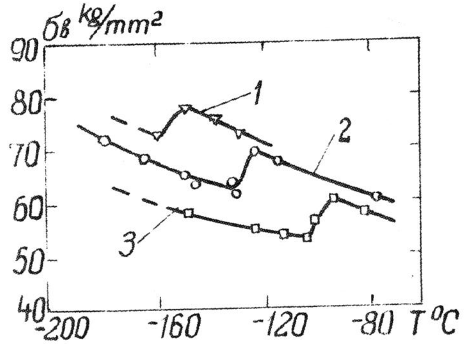

Fig.2. The results of carbonic steel tests.

I - K = -2

2 - K = 0

3 - K = +I

of the sample,and deformation measuring system 6.Loading the tubular sample with axial force (up to 5000 kg) and torque (up to 45 kgm) is effected on the side of lower gripper by means of the hydraulic cylinder provided with a floating pistdn,and the pair of plungers.Axial and angular deformatioms are selected in step on the side of upper gripper with the aid of the follow-up system.Pressure in the sample internal cavity is effected during low temperature tests by liquid (petroleum ether,isopentane),in testsunder high temperature conditions - by inert gas.

The machine hydraulic drive consists of two invariable displacement pumps 7 and control and regulating apparatus 8.The high pressure liquid device comprises a multipiston pump A,hydraulic actuator B increasing oil pressure up to 1500 atm,and separating chamber C (which separates oil from working liquid developing pressure in the sample).

The working pressure in gas medium is effected by the compressor D.Sample loading with changes in loads is effected in comliance with predetermined programs by means of hydromechanical ratio pressure controllers 9.

Due to working chamber 10 it is possible to conduct the tests in media of inert gas or vacuum ensuring good thermoinsulation of the sample and protecting it from icing and oxidizing.Used for thermoregulation is a flow type liquid nitrogen cooler and heater in the form of Silit resistor accommodated in a thick-walled case.Temperature equalizing along the entire working part of the sample is effected by using special devices /15/ ensuring reliable thermal bridge between the thermoelement and the sample.

Practically the thermoregulating system allows to set any temperature within the range from -180 to +1000°C and maintain it with accuracy ± 2°.

A great deal of experimental work /16,17/ was done on the units type CHT.To illustrate an example Fig.2 presents the results in testing carbon steel with high phosphorus contents at three ratios of basic stresses.The character of dependence of ultimate strength on temperature indicates that in transition from pure shear to biaxial uniform tension the temperature for transition of steel to brittle state increases by over 50°.

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