New thermo mechanic fatigue test installation

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Introduction

For thermo-mechanical fatigue testing of heat-resistant and refractory low-alloy steels, specialized facilities are used. Such an installation in which the fatigue cycles are applied independently to the specimens in the temperature range of + 200°C ... + 1000°C in order to determine the non-isothermic oligocyclic fatigue curve, which is a characteristic of the material, used in the design codes of the thermo-mechanically required equipment, is presented further. This installation improves the mechanical fatigue cycle system.

Material and methods

The main technical characteristics of the installation are:

- A loading system with mechanical fatigue cycles based on an electromechanical mechanism consisting of a drive with an electric DC motor, belt drive, worm gear reducer, and a ball screw transmission;
- This solution ensures the test of the specimen with axial loads in the oligocycle range (with frequencies lower than the frequency having the value of 0,1 Hz); through the adopted solution of the system, ball screw, avoid the possibility of axial play in both directions of tension (traction-compression);
- Control of the thermal cycles (heating - maintaining - cooling) and processing of the force signals, diametrical deformation and temperature of the specimen is done by means of a computer with interface (distinct analog numeral converter and analogue converter).

The construction scheme of the installation (figure 1) consists of a rigid frame with three sleepers (one mobile-19 and two fixed ones - 1 and 2), two guiding columns and two columns of displacement (pos. 3 and 4) aligned with the upper clamping end 7 of the test specimen 5 ant the force dose 18 is interleaved. The diametrical deformation is measured with the diametric deformation transducer 6.

Mechanical fatigue cycling system consists of the stepper electric motor 11 with reversible rotation, belt transmission 10, worm gear reducer 9 and ball screw transmission 8 which actuates axially (upwards or downwards) the lower grip 7. The installation further comprises an inductive system 12 for measuring the movement of the lower gripper.

The axial fatigue test (traction-compression) test system can provide command in three distinct ways: with force control 18 (with force control 18), with deformation control (from the diametric deformation transducer 6) and control displacement (from inductive displacement transducer 12). On the calibrated portion with the minimum outside diameter of the specimen 5, a thermocouple (chromium-aluminum) is welded in points to receive the temperature signal.

The control of the mechanical and thermal fatigue cycles as well as the acquisition of the temperature, force, diametrical and displacement signals is carried out by software, by a personal computer 15, 16 via an interface. The amplification of the force signals, the diametrical deformation and the displacement is accomplished by means of an amplifier bridge 14, and the recording of the voltage-strain hysteresis loop is done on the personal computer monitor.

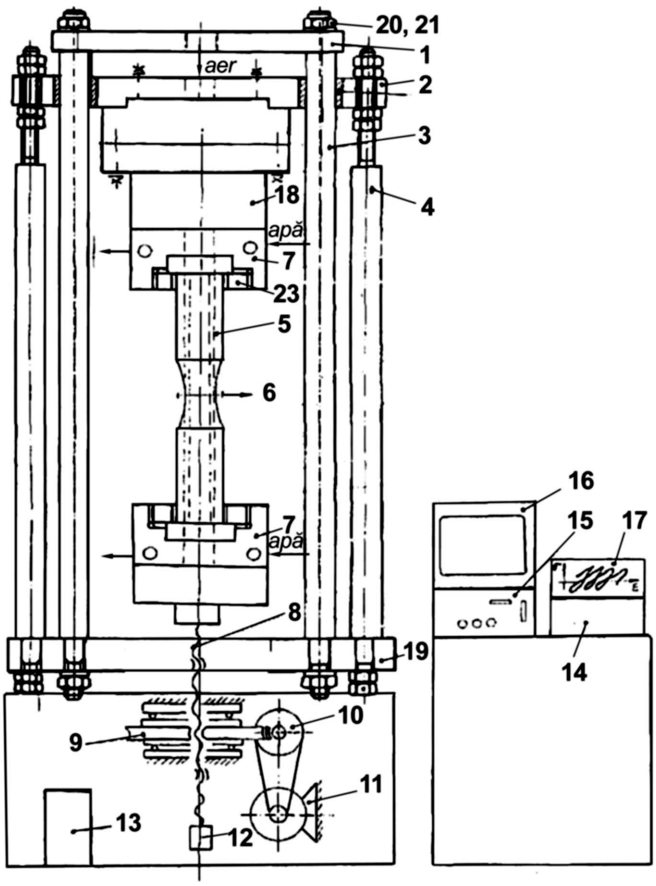

Figure 1. Thermo mechanic fatigue test installation

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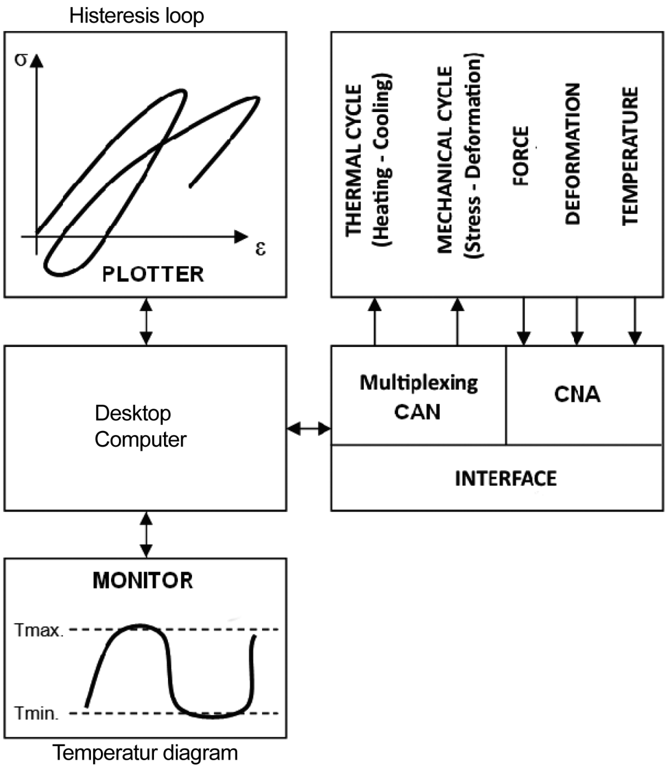

Figure 2. The block diagram of the control, signal acquisition and hysteresis loop tracing

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The thermal cycles applied to the specimen may be:

- in isothermal mode (T = const);
- in zigzag: heating from minimum temperature Tmin to maximum Tmax, followed by cooling to Tmin, etc.;
- semi-trapezoidal: additionally with maintaining at maximum temperature T_{max} with tmain maintenance time (during the maintenance period at T_{max} there is a relaxation of the creep stresses);
- trapezoidal: additionally with maximum temperature hold T_{max} hold time tmain1 and with minimum temperature hold T_{min} hold time t_{main2}.

The operating principle of the installation is that of loading the hollow cylindrical specimen, with thermal and mechanical fatigue cycles independent of each other; The thermo-mechanical fatigue test can be hard (mechanical deformation control) or soft (with force or tension control). Combinations of thermal and mechanical cycles are independent of isothermal and non-isothermal olygocycle fatigue loading:

- isothermal oligocyclic fatigue;
- non-isothermal oligocyclic fatigue (thermo-mechanical fatigue):
  - in phase;
  - in phase opposition.

Results

The test group receives the command for the soft heater semicircle from the personal computer via a CNA channel (analog-to-digital converter) interface to the thyristor power control system of the heating element of the test specimen. Heating is achieved by radiation from a 1kW halogen lamp. The test group receives the computer command semi cycle from the computer via other CNA channels of the interface to the coil control system of a pneumatic distributor that allows the air (or inert gas) access to the calibrated portion of the test specimen. The maintenance order at T_{max} (or T_{min}) temperatures is given by software with the appropriate adjustment of the heating element.

The test reaction (feedback) is performed by controlling the temperature by means of a cromel-aluminum thermocouple spot welded on the calibrated portion of the test specimen, the signal of which is received by a thermocouple adapter, which in turn releases an electrical signal in the range of 2-10 V usable through a channel of the numerical analog converter of the interface by the computer. The installation allows heating up to 1000 °C with a rapid response and with a maximum measurement error of ± 1%. The control of the mechanical cycles of the specimen is made from the computer via the interface to the electrical system which drives the electric motor of the DC in both directions of rotation, allowing it to be applied to both traction and compression. The stress control and control is done either at hard stress (deformation control, by taking diametric deformation signals and transforming them into axial deformation) or at soft stress (control of force or voltage at the dose).

Signals of force and diametric deformation are taken over by a channel of the amplification bridge in the +10V range. The calibration graphs of the two measuring transducers are input into the computer memory, the intermediate values being obtained by linear interpolation. On the computer monitor 14 you can see the temperature, force (voltage) and axial deformation (total or plastic) variations. On the computer monitor, the hysteresis loop 17 of elasto-plastic deformation σ-εx for the prescribed cycles.

The test can be stopped automatically when the voltage amplitude value in the current stress cycle decreases to a value of 50% of that in the first load cycle, or by the console command when the calibrated portion of the specimen shows macro-cracks with a minimum length approx. 10% of the diameter of the calibrated portion of the test specimen. The solution chosen for the heater half-cycle with a halogen lamp makes it possible to achieve very high speeds. 100 °C / sec and has the following advantages:

- power directly from the network;
- sufficient power for the 1 KW lamp for heating up to 1000 °C and thus low power consumption;
- high reliability and relatively low cost;
- easy and quick replacement in case of damage;
- standardized execution and availability.

The program system that drives the entire test process ensures the following functions:

- Acquisition of temperature, deformation and mechanical stress values;
- Real-time temperature adjustment according to the cyclical profile imposed by the operator;
- dialogue with the operator to start and stop the test block, setting the test parameters and other commands;

- display during the test of measured and calculated data in numerical and graphic form (temperature variation diagram, hysteresis loop, etc.);
- storing the main data generated during the test for further processing;
- Statistical calculations of the experimental results;
- drawing the hysteresis loop of elasto-plastic deformation;
- editing the test report.

Conclusions

The thermo-mechanical fatigue loading system in the presented solution can be used to perform the thermo-mechanical fatigue tests in order to obtain the characteristic oligocyclic fatigue curve determined and used by installation designers under the conditions of thermo-mechanical stresses required for the calculation of the lifetime of the construction or of the equipment subject to the specialty analysis. Also, this material characteristic (resistance to non-isothermic oligocyclic fatigue) is required for the design of equipment specific to the analyzed field

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