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TEST STAND FOR THE EXAMINATION OF STEEL CYCLIC PROPERTIES UNDER THE CONDITION OF TEMPERATURE CHANGES

Key words

Mechanical fatigue, thermal fatigue, service loads, control of fatigue specimen.

Abstract

In this study, a stand for tests of technical objects under the conditions of thermal and mechanical fatigue is presented. Temperature and load changes and the interrelations between them cause difficulties in controlling and recording basic parameters of fatigue tests in laboratory conditions. The article presents the design and creation of a system for temperature change control and adjustment during fatigue tests under the conditions of thermal loading. The test stand was built through the modernization of a standard strength-testing machine.

Introduction

Assessment of fatigue life of technical objects operating in higher temperatures is a research problem of many scientific centres [1, 2, 3, 8].

This issue is of particular significance in the electric power industry where the need to carry out overhauls involves huge costs. Therefore, careful planning plays a very important role in the engineering process. Although the issue connected with fatigue damage to technical objects used under conditions of thermal and mechanical loads has been dealt with by many authors, it is still far from being solved [4, 5, 6]. Most solutions do not take into account the need for temperature control [7, 9] at all, or the temperature control of the object under test fatigue [8] is not very precise.

The assumption that a steady state occurs under the conditions of simultaneous impact of thermal and mechanical loads provides the basis for currently used methods for the calculation of structural components fatigue life. This assumption appears to be true only for some materials. Based on literature analysis, it is possible to say that the phenomena of a material cyclic weakening or strengthening accompany cyclic strains takes place early under the conditions of isothermal loads. The material properties obtained under such conditions (e.g. in the form of a cyclic strain diagram) can be described by classic dependencies used in the field of low-cycle fatigue in normal ambient temperatures. The above has been presented in Figure 1 in the form of a plot.

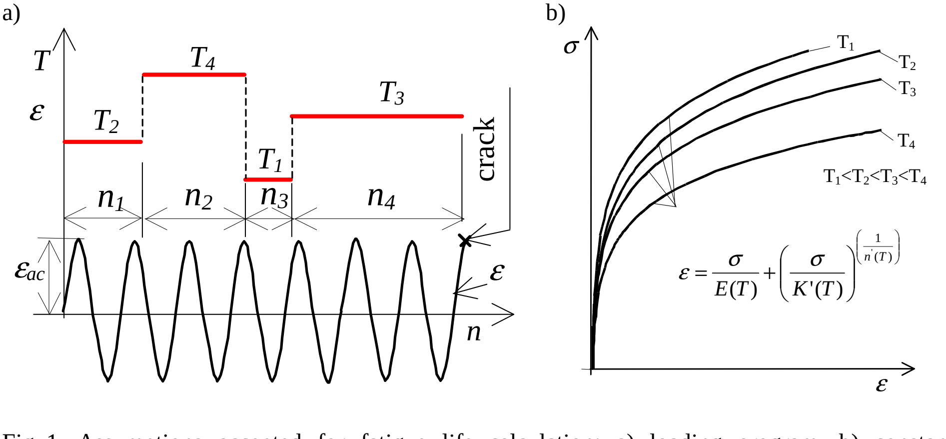

Fig. 1. Assumptions accepted for fatigue life calculation: a) loading program, b) constant amplitude tests

There is, however, a problem connected with the accuracy of the description. This is due to significantly higher complexity of a mathematical approach to the material strain process under thermal and mechanical loading, as compared to low-cycle fatigue in constant temperatures, it is necessary to use simplifications.

Temperature and load changes as well as their mutual relations cause difficulties in the control and adjustment of the basic parameters of the fatigue tests in laboratory conditions. Significant thermal inertia of the loaded components makes it impossible to image programs with, e.g., irregular temperature changes (Fig. 1). Failing to account for this fact in calculations often causes inconsistence between the results obtained from fatigue tests and those from calculations. In this case, it is electronics and computers that can be used to assist in the control of testing conditions, monitoring, and recording of the most important parameters.

The major goal of this study is to design and develop a control system for temperature changes during fatigue tests under the conditions of thermal loading. Another goal of this research is the modernization of the test stand whose main element is a strength-testing machine.

1. Description of the test stand

Tests performed under the condition of constant amplitude isothermal loading accompanied by temperature changes were carried out on an INSTRON 8502 strength-testing machine. In order to provide irregular loads, a software was developed to enable external control and recording of the strength-testing machine results using a computerized standard GPIB interface. A schematic of the machine control and utilization of the considered software is presented in Figure 2.

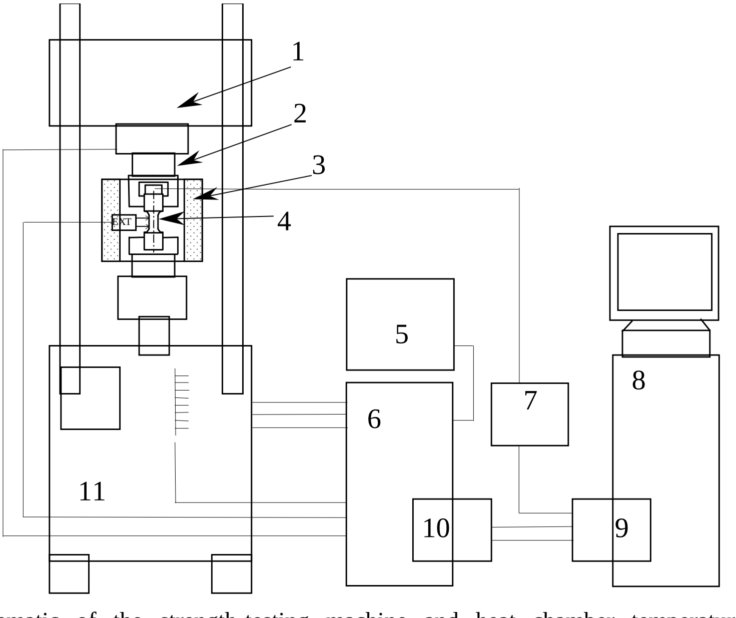

Fig. 2. Schematic of the strength-testing machine and heat chamber temperature control: 1) Strength-testing machine [MW], 2) load cell, 3) Heat chamber, 4) Tested specimen, 5) Control panel, 6) Proportional-integral-derivative computer control, 7) Chamber heat controller, 8) Computer PC controlling and recording data from particular channels, 9) Cards used to couple the system of control and regulation, 10) Data on displacement, load and strain from the hydraulic actuator channel, 11) Machine body

Maintenance of the desirable temperature is of key importance for strength tests of materials in an elevated temperature. In a standard chamber mounted on a hydraulic strength-testing machine, the temperature is measured and controlled on the heat chamber walls (Fig. 2). Such measurement does not show the temperature of a tested specimen. In order to measure the real temperature of the specimen, an additional, independent temperature converter was mounted directly on the specimen (Fig. 2). The major disadvantage of such a solution is a lack of automatic temperature control of the specimen as during fatigue tests, when both the load and temperature should be controlled. In order to monitor and adjust temperature changes in time, a system consisting of a standard Instron SLF chamber and Czaki temperature converter model EMT-200 with TP 203 was designed and built.

The test stand uses an EMT-200 temperature-measuring meter (Fig. 3). It is a multi-task microprocessor temperature meter providing the possibility of being connected with many other temperature sensors. It has two programmable versatile alarms that control the transmitters.

a)

b)

Sensor type	Range [^{0}C]
B PtRh30-PtRh6	400…1800
R PtRh13-Pt	200…1600
S PtRh10-Pt	200…1600
N NiCrSi-NiSi	-100…1300
K NiCr-NiAI	-100…1200
J Fe-CuNi	-100…1000
T Cu-CuNi	-100…230
PT100[1]	-100…850
Ni100[1]	-60…180

Fig. 3. Temperature measuring meter EMT-200: a) view, b) parameters

The meter signals when the temperature range has been exceeded and reports failures. After being connected with logging program, it is possible to read and set or program each parameter using an interface or keyboard. It has an easy to handle, four-task double display. It is equipped with memory capable of 300 measurements. Through the connection of the meter with a printer (with series input RS-232), it is possible to create an uncomplicated system of temperature recording. Measurement of the EMT-200 type is commonly performed with interface RS-232, and a connection to the computer should be done according to the following RS-232 pin diagram (Fig. 4).

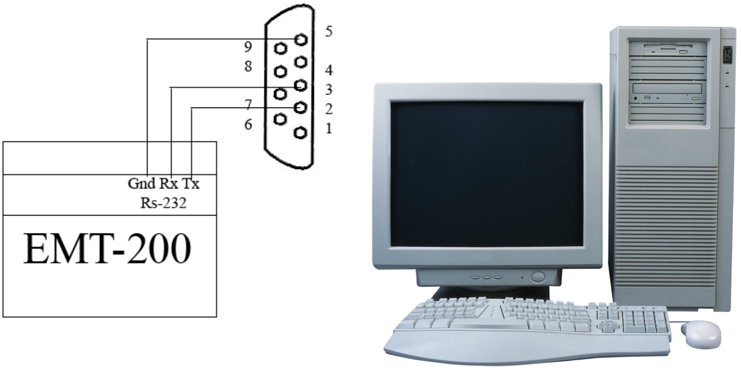

Fig. 4. EMT-200 temperature meter RS-232 pin diagram

The Eurotherm 3216 temperature controller is also equipped with a display providing current information on the course of a given process, which provides a precise and universal input for the process and temperature measurement (Fig. 5).

Fig. 5. Eurotherm 3216 controller

The controller is equipped with a system that was patented by Eurotherm- Instant Accuracy. It provides precise and accurate control and measurement of the process temperature with the use of a standard measurement input (TC, RTD, we. linear – mV, mA). CT input can be used for the measurement and control of load current in the output circuit of the heating element (error detection and signalling of the alarm state). It provides the possibility of communication in standard Modbus – RS 232 – RS 485. The configuration of the controller is simple; therefore, the controller can be easily adjusted to the one's own needs. The idea of the proposed solution is presented in Figure 6. It involves application of the temperature meter and controller.

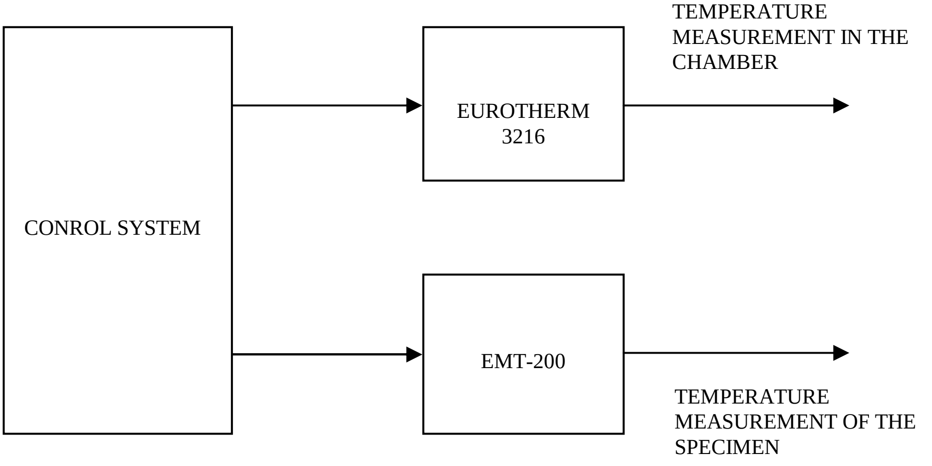

Fig. 6. Idea of the solution

The control system was built based on a standard PC class computer equipped with two RS-232 ports. One of these ports was used for communication with the temperature converter and the second with the chamber controller. Communication with both devices runs in a two-direction mode. For the EMT-200 temperature converter, it runs according to the algorithm demonstrated in Figure 7.

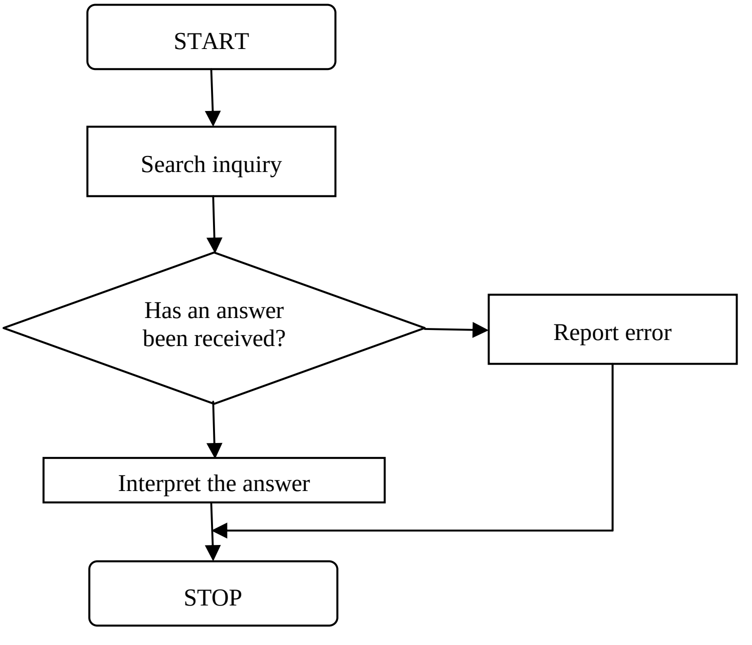

Fig. 7. Algorithm of temperature reading from EMT-200

The control system sends a search inquiry in ACSI format to the converter in the form of "01T?[CR][LF]", where "01" is the device address. The inquiry is answered by the device as follows: e.g. "+0036.2[CR][LF]" and the parameters of CTHE Communication are "2400,8,n,1".

The communication with the chamber controller runs on mBus RTU RS-232 protocol with transmission parameters "9600,8,n,1". The controller has three sites for setting of temperature, denoted as SP1, SP2 and Remote SP. The first two have a limited number of recordings (entries). In connection with this, “Remote SP” should be used for setting a given temperature. The basic set of registers and their addresses used in the software are shown in Table 1.

Table 1. A set of basic registers of Eurotherm 3216 device

Denotation	Description	Address MODBUS
PV.IN	Current temperature (viewer copy)	1
Rm.SP	Remotely applied temperature	26
L-R	Switching the temperature applied from a local point to a remote point 0 – local point SP1 lub SP2 1 – remote point Rm.SP	276

The entire system is controlled by a Komora v.1.0, which controls the chamber in such a way that the desired temperature applied to the specimen is maintained throughout the process. The main window of the program is depicted in Fig. 8.

The menu displays the following temperatures:

- Temperature of the chamber walls, which denotes current temperature of the heat chamber walls;
- Assigned temperature, which denotes the temperature to be provided for the chamber heating system;
- Temperature set on the specimen, which is the temperature desired for the specimen; and,
- Specimen temperature, which is the current temperature of the specimen.

In the screen displays two diagrams: the first one with temperature programmed in time, and the second one with the specimen’s current temperature. The configuration menu contains settings of parameters of the RS-232 communication ports through which the program controls the heat chamber and the temperature sensor. The button: *Konfiguracja temperatur* (temperature configuration) is used to set the specimen temperature and its heating time. In Figure 9, there is an example of a table depicting the temperature change program and its corresponding theoretical course.

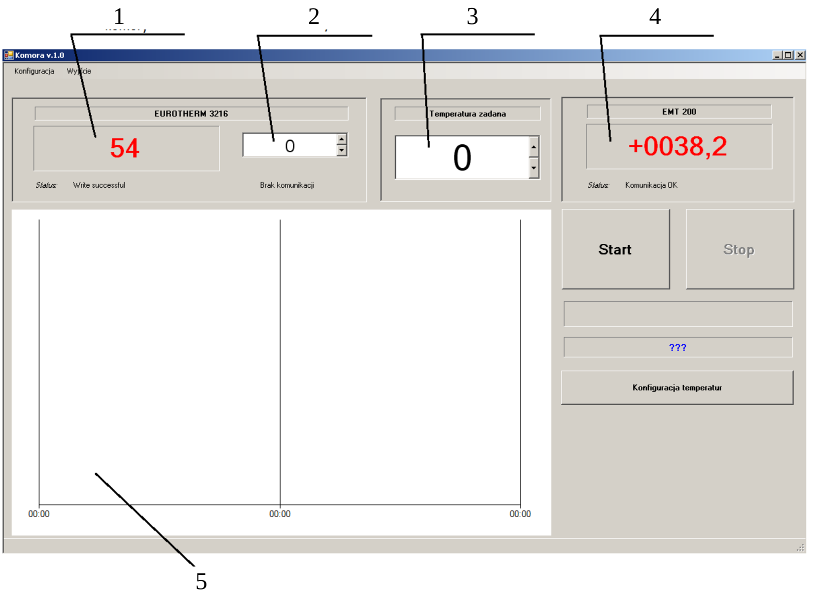

Fig. 8. Contact window of the specimen control program (1 – temperature of the chamber walls, 2 – expected chamber temperature, 3–expected object temperature, 4 – actual object temperature, 5 – chart window)

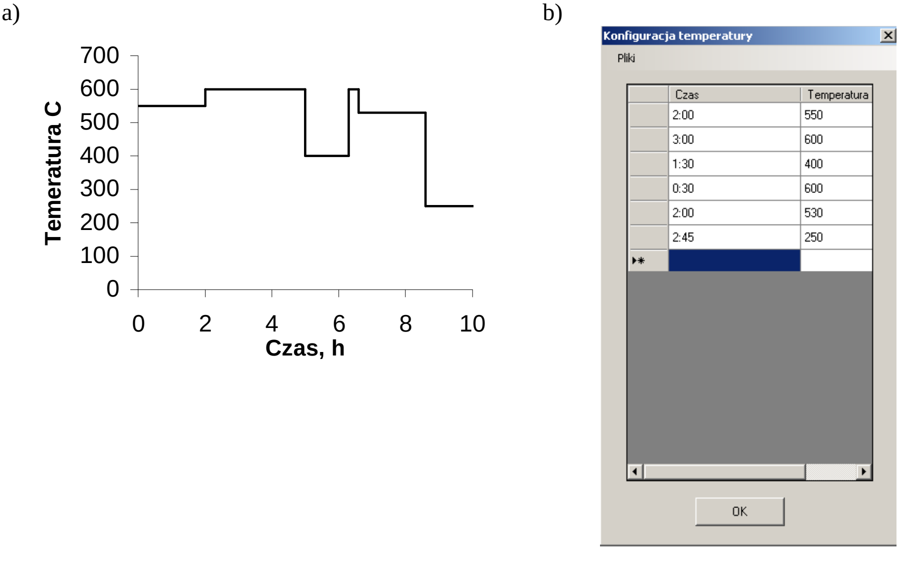

Fig. 9. Temperature change program: a) diagram, b) configuration menu

Data from the table can be saved in a file and entered again. Entering or saving changes into the temperature change table makes the temperature change history diagram display in the window in the programmed time (Fig. 10).

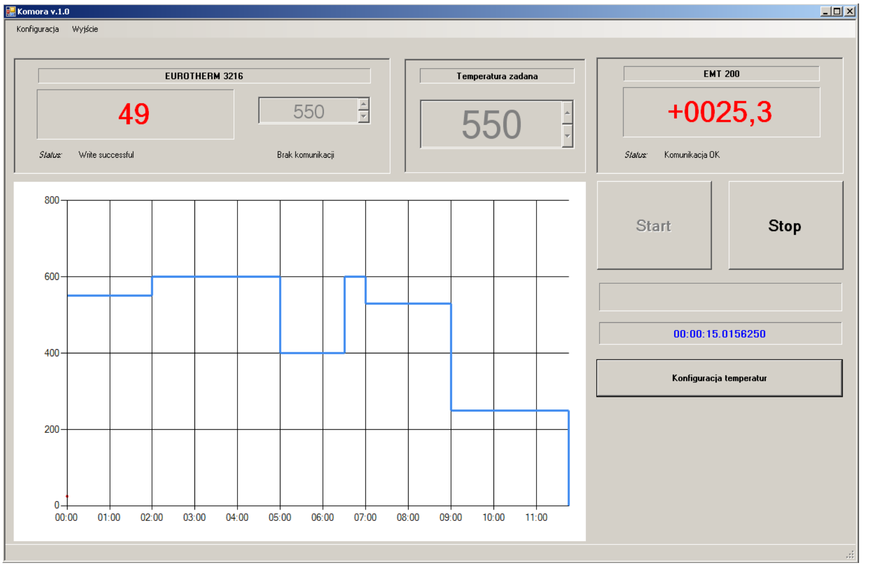

Fig. 10. Diagram of temperature changes

Pushing the "Start" button activates the temperature control on the specimen according to the flowchart presented in Figure 11. The input quantities are applied temperature and the temperature of the specimen.

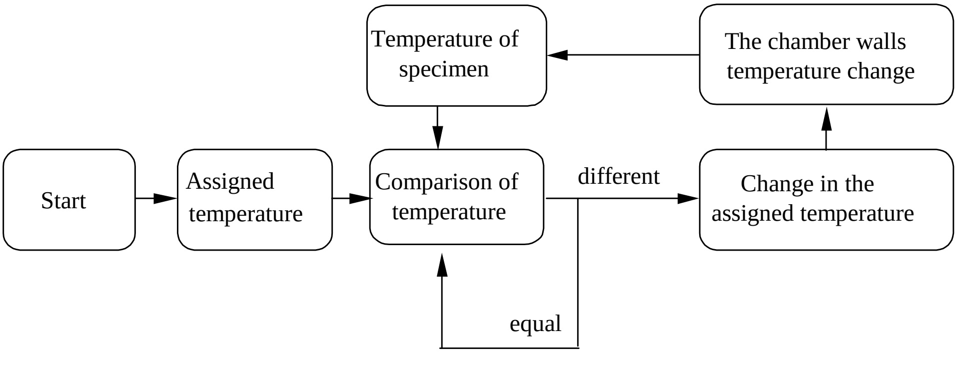

Fig. 11. Flowchart of the specimen temperature control

The program stops when the assigned heating time is complete or after pushing the "Stop" button. When the Komora v.1.0. program is switched off, the controller of Instron SLF chamber reaches the value of the previously programmed temperature.

Conclusion

The goal of this study is to provide a specimen with temperature control to be used during fatigue tests. Due to significant thermal inertia of the system (specimen, chamber, and apparatus), it is not possible to introduce irregular temperature changes into the specimen. Temperature changes occurring while heating are demonstrated in Figure 12.

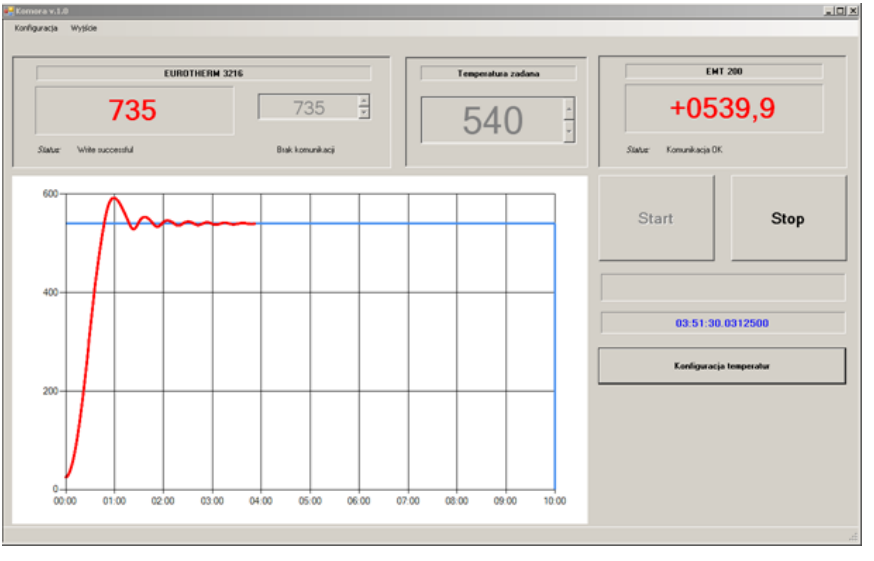

Fig. 12. Temperature changes of the specimen during heating

Stabilization of the temperature at the pre-set level occurs after approximately 30 minutes, which is after the moment the specimen starts heating up above ambient room temperature. While planning fatigue tests, it is necessary to account for the time needed to stabilize the temperature before starting up the specimen loading. Since fatigue tests last longer, the specimen temperature control, despite the system inertia, fulfils its function perfectly well.

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Stanowisko do badań właściwości cyklicznych stali w warunkach zmian temperatury

Słowa kluczowe

Zmęczenie mechaniczne, zmęczenie cieplne, obciążenia eksploatacyjne, sterowanie próbą zmęczeniową.

Streszczenie

W pracy przedstawiono stanowisko do badań w warunkach zmęczenia cieplnego oraz mechanicznego. Zmiany temperatury i obciążenia oraz występujące pomiędzy nimi interakcje powodują, że w warunkach laboratoryjnych występują trudności w zakresie sterowania i rejestracji podstawowych parametrów prób zmęczeniowych. W artykule opisano projekt i wykonanie układu sterowania oraz kontroli zmian temperatury podczas badań zmęczeniowych w warunkach obciążeń cieplnych. Stanowisko badawcze zostało stworzone poprzez modernizację standardowej maszyny wytrzymałościowej.