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Design and Manufactoring of a Laboratory Stand for Testing Accelerated Tensile Creep of Plastics According to ASTM D6992

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***Abstract*—The article discusses stages of design and manufacturing of a laboratory stand for accelerated tensile creep of plastics according to ASTM D6992. All components necessary for accurate operation of the laboratory stand will be examined: jaws, deadweight system,loading weights, linear strain measurement system and control, test temperature control and monitoring, test data storage and management. The aim of the article is to create flexible systems that allow the stand to be used for other similar test standards and materials. The main task in the design and manufacturing of the stand is to create reliable equipment with a high accuracy degree, automated loading of a control program, as well asability to store a large volume of data for the purpose of creating a database and comparing test results. The mathematical model for calculating equivalent years is directly integrated for easier processing of experimental results. The stand is designed and manufactured for testing 2 samples simultaneously , which facilitates comparison of data from different polymer blends.The stand is calibrated according to its three main quantities - linear strain, temperature and deadweights.The calibration results are presented to assess accuracy of the laboratory stand systems. The stand fully meets the requirements defined according to ASTM D6992. The accuracy of the calibrated quantities allows precise calculations of accelerated creep data on a wide range of materials. Design and manufacturing steps may also be used with other standardized and non-standardized creep tensile testing methods of plastics, as well as other laboratory equipment needs with similar systems and goals.**

Keywords — creep, lab equipment, test methods, design equipment, stepped isothermal method, plastic tests, tensile creep test.

I. Introduction

Creep is a process of slow increase in plastic strain over time at constant temperature and force loading[1]. The loading is carried out in the elastic strain zone[2]. Depending on used test standards , the exam can end without failure or with failure. The test is extremely relevant for heat-resistant materials and characterizes durability of selected material[3].Creep is characterized by 3 stages - undetermined creep, determined creep and creep with a constantly increasing speed[4].The increasing strain at a constant load at a certain temperature is expressed graphically with so-called creep curves. Depending on the applied temperature, there are low-temperature and high-temperature creep [5].There is not enough data to establish the entire creep process of materials, which makes research related to the process very relevant. Creep testing of materials is a long-term method, the duration of which depends on the functional purpose of the structure - it may reach up to 10,000 hours[6].

In practice, there are also theoretical calculations of strain by creating mathematical models based on sample data[7]. Creep testing of materials is widely used for various types of materials - polymers, metals, etc[8]..

Plastics are widely used in automotive, mechanical engineering, construction, etc., and the requirements for their characteristics are increasing. Plastics are tested experimentally for tensile, creep, impact toughness, compression, bending, etc[9]. The test specimens differ depending on used standards.

II. Materials and Methods

Based on the ASTM D6992 standard, the test stand was designed and manufactured to test plastic films for accelerated creep[10]. The requirements of the accelerated creep standard are:[11]:

- The jaws should not allow slippage or excessive stress on test specimens

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- The universal machine should be equipped with a dead-weight system
- Measurement and control strain values
- Time measurement
- •Temperature measurement and control, temperature hysteresis should be less than 2 degrees;
- •Guaranteeing standardized atmospheric testing conditions
- Management and storage of experimental data.

The designed two identical sets of jaws are for testing two samples with a width of 80 to 100 mm and a sample thickness of maximum 3 mm, a length of up to 250 mm. The jaws contain 3 holes for samples gripping so that it does not buckle or bend and one for gripping to base. All holes are 8.5 mm in diameter. The samples are intended to be gripped with 3 standardized M8 bolts. The lower jaw is designed on one side to grip the sample, and on the other to grip the deadweight systems. The jaw thickness is 6 mm.

The entire mechanical system is freely hanging, hooked at the upper end. The mechanical system consists of 3 clamps, two sets of jaws, a sample, a spacer and a deadweight system. The mechanical system is accompanied by a linear strain measuring system.

The loading system consists of a deadweight mount weighing 2.5 kg. The axis is designed for standard weights of 2.5 kg, 5 kg and 10 kg and can be loaded up to 80 kg.The selected maximum weight is sufficient for a wide range of plastics. For materials with higher creep resistance, the width of the specimens can be reduced.

The measuring system consists of incremental lines with a resolution of 5 microns and a displacement speed of 100 mm/s. The attachment to the mechanical system is carried out using standard ball joints.

To ensure atmospheric conditions during the test, the chamber is insulated except for ceiling. The lab stand door is designed for observing the samples during the test, for this purpose it has a transparent double glazing. To ensure uniform temperature distribution, the stand has two centrifugal fans with a power of 20 watts. Two conical air ducts are used for turbulent air movement. To maintain the temperature,two heaters with a power of 500 watts, controlled by a solid stage relay, are used. To maintain the temperature in the range of ± 0.2 degrees,classic pit control is used. The entire stand with all adjacent systems is shown in a CAD model in fig. 1.

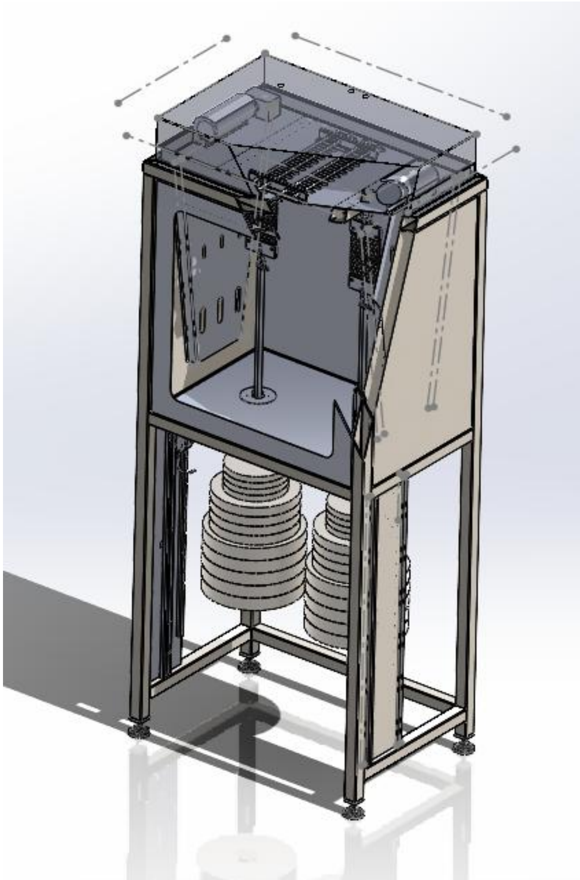

Fig. 1. CAD model of the designed stand.

For measuring the test duration, storing and managing the data, an industrial PLC controller and an HMI panel are used (Fig. 2)[12]. The processed data are recorded in two places - on an SD card and a USB flash drive to prevent the loss of experimental data. In case of a temporary power outage, a UPS with a capacity of 1600 VA is provided. When operating at full power of the stand (1100 watts), this is enough to power the stand for 20 minutes.

Fig. 2. HMI - GT2107-WTSD and PLS-FX5U-32MT/ESS.

The interactive interface provides the ability to store five preset programs. This way, the most frequently used test programs can be quickly launched. There is an option to re-adjust the preset programs for greater flexibility of the laboratory equipment.The home screen contains the following features,fig.3,4:

- Start and stop the program
- Select the test program

- Select language
- Date and time
- Real-time temperature and strain measurement.
- Remaining time until the end of the test
- Consumed electricity power
- Indication of data recording in the flash drive and SD card on parallel..
- Graph of linear strain and equivalent years

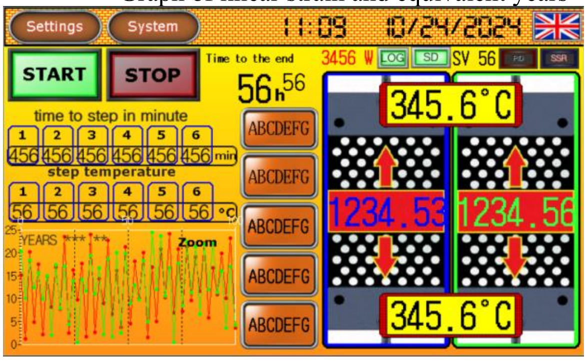

Fig. 3. Home screan.

Fig. 4. Measured linear strain.

Fig. 5 shows the set up test programs screen.Each program may consists of 6 temperature steps, dwelling time and sample length,used for further calculation of elongations in percentages. According ASTM D6992, the minimum duration of each step is 10,000 seconds, and the minimum duration of the entire test is 60,000 seconds. The set up of test programs is as flexible as possible, while at the same time facilitating creation and management of large databases[13]. Data storage and management is very important, as it allows comparison of different plastic blends, as well as results from different test parameters[14]. The graphical presentation of data facilitates the comparison of experimental samples in real time.

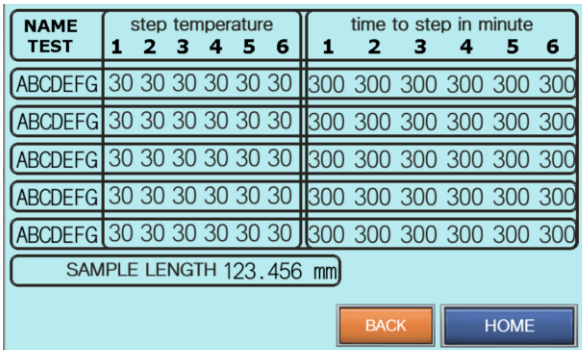

Fig. 5. Test programs set up.

In the system menu fig.6, the recorded data every 5 minutes for the deformation, the actual temperature, time and date are displayed.

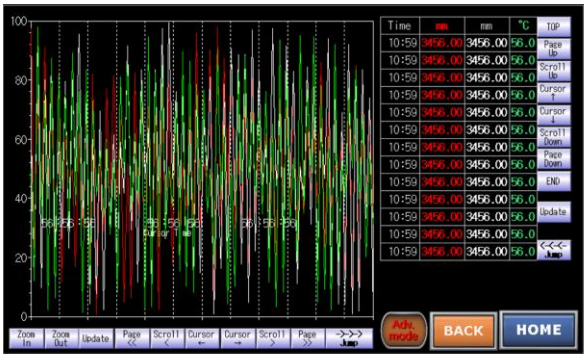

Fig. 6. System menu.

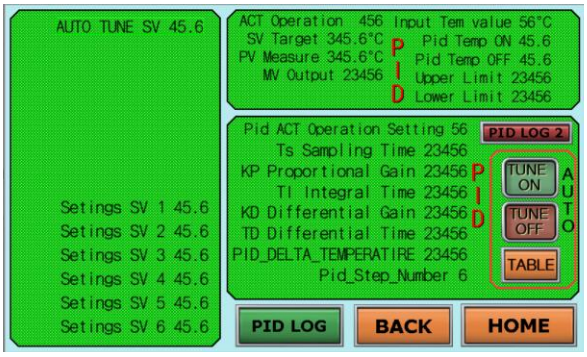

Fig. 7. PID control.

The system is equipped with PID control system and has the ability to auto-tune at any given step. The functional purpose of using a PID control system is to receive input data from the temperature sensors, calculate the difference between the actual and desired setpoint, and adjust the outputs. PID control is most often used for the following variables-voltage,speed, temperature,flow rate, pressure, etc[15].Temperature is a fundamental parameter and its accurate adjustment leads to adequate experimental results.The auto-tuning data is automatically recorded in the menu shown in Fig. 8, and there is also the ability to manually adjust the control parameters

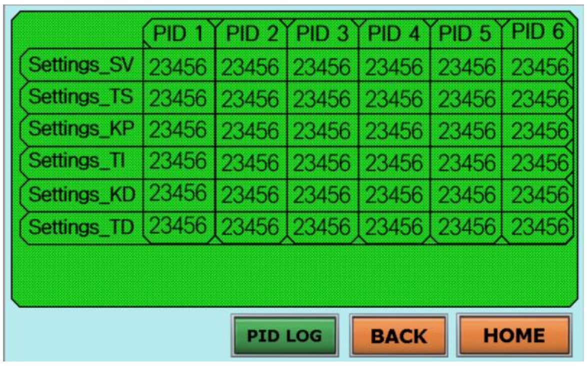

Fig. 8. Auto-tuned data.

The control system allows for monitoring of PID control every five minutes,so the system ensure correct tests.

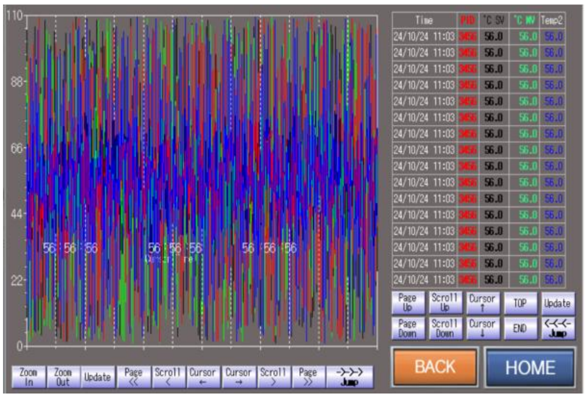

Fig. 9. PID control monitoring.

III. Results and Discussion

The laboratory stand for accelerated tensile creep of plastics was designed and manufactured,fig.10. The stand was tested with various blend plastics in order to validate the performance of its systems. No critical deviations were observed,the temperature is in the range $\pm 1^0$ from the nominal value both in short-term and long-term tests..All requirements of the standard ASTM D6992 have been met, while at the same time the designed and manufactured stand has flexible systems that allow testing of plastics with different force and temperature conditions.Within the scope of the applied specification is possible other gripping systems to be used. At the same time, the information system on the stand allows storage, comparison and management of a large volume of data, which is beneficial for engineering practice. All requirements for reliability, accuracy, and stability of the technical system have been met. In addition to creep testing, the stand can also be used for static load tests. The stand can be used for all types of creep testing defined in the standard, as well as for similar creep tests according to other standards. The stand is made according to all safety standards for electrical and electronic equipment. The autonomous power supply allows the stand to operate for some time during temporary power outages.

Fig. 10. Manufactured stand.

The stand was calibrated by accredited laboratory for its three main quantities - linear strain, temperature and deadweights.The weights were purchased calibrated[16].The results of the calibration of the linear strain are presented in a tab. 1.

Table.1 Linear strain calibration results in mm

Nominal value	Deviation	Uncertainly,U
0	0	0,02
50	+0,04	0,03
100	+0,06	0,03
200	+0,1	0.05
300	+0,13	0.05
400	+0,15	0.05
500	+0,16	0.05

The results of the temperature calibration are presented in a table 2.

Tab.2 Temperature calibration results

Stand temperature, C^0	35	40
Real temperature, C^0	34,97	39,65
Uncertainly,U, C^0	0,3	0,3

The reported expanded uncertainly of measurement is stated as the standard uncertainly,multiplied by the coverage factor k=2,which for the normal contribution corresponds for the coverage probability of 95%. The stand meets and even exceeds the requirements set out in the standard.

IV. Conclusions

The stand meets the high requirements for laboratory equipment - reliability, ease of use, automated setup and data logging, the ability to store a large volume of test results. The stand allows flexible operating conditions with a large range of measured linear strains, relatively high test temperature and load range, suitable for heavily loaded plastic structures. The design of the stand can be upgraded with the addition of a system for measuring dynamic loads (for example, cyclic fatigue tensile-compression) by designing a system for additional modules - a strain gauge sensor and a servo system. The main limitation of the stand is the temperature range of the tested material. The stand cover with the adjacent fans is designed as a subsystem that can be replaced with high-temperature fans, which will allow for the measurement of high-temperature creep. The stand can be used for close to standard test conditions, as well as for non-standard tests. The evaluations from the calibration of the stand showed excellent results.

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