Mirosław NESKA
Institute for Sustainable Technologies – National Research Institute, Radom

QUASI-STATIC AND LOW-CYCLE SYSTEM FOR THE APPLICATION OF SMALL LOADS IN TESTING DEVICES

Key words

Control system, quasi-static load, low-cycle load, bending, torsion.

Summary

The article presents the control system for the initiation of quasi-static and low-cycle bending and torsional loads that is intended for fatigue endurance tests in which the maximum value of the load imposed is calibrated electrically or mechanically.

The components of the developed system are presented together with examples of the practical application of the system in testers for printed objects.

Introduction

The manufacture of different kinds of materials and goods requires various tests to be conducted so that the appropriate level of production is sustained and a competitive product obtained. Thus, the materials and goods are subject to a number of tests performed on testers that check and determine the endurance [1], thermal, moisture resistance and other parameters of every object tested. For the majority of goods including, inter alia, metal, wood or ceramics, the most common tests conducted are the endurance tests [2]. The testing devices used in these cases are the universal machines for endurance testing [3] that are characterised by a wide range of the forces applied, which on the other hand, meets the requirements of the tests in small load conditions. Products subject to small load tests are usually tested on specialised devices that guarantee that the forces applied are maintained with great accuracy and in small measurement ranges [4, 5].

The loads the objects can be subject to can be divided into two categories, which are constant and time changeable loads. The duration and the character of the stresses applied determine the kind of fatigue resistance. Depending on the number of cycles and the character of changes of the load imposed, the following types of fatigue stress can be distinguished: constant (plus, minus), fluctuating (plus, minus), pulsating (plus, minus), two-sided and oscillatory. Additionally, with reference to the number of cycles, fatigue resistance of the tested object is also determined by the Wöhler curve that separates the fatigue resistance into three areas of quasi-static, low-cycle and high-cycle endurance [6].

This article presents the control system for fatigue resistance tests of goods subject to quasi-static and low-cycle bending and torsional loads. The system is particularly intended for the testing devices.

1. System structure

The system developed is composed of the control module, the measuring element and the executive system (Fig. 1).

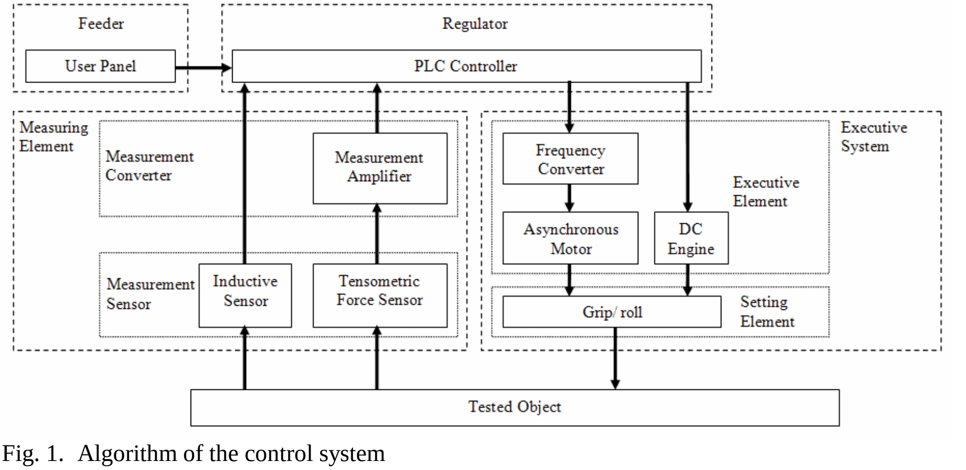

Fig. 1. Algorithm of the control system

The basic element of the system developed is the PLC controller (Twido) by Schneider Electric, which plays the role of the regulator. The main advantages of this controller, apart from its competitive price, include the modular structure that allows for its extension resulting in a greater flexibility of the entire system. The controller used in the system developed is equipped with digital an analogue inputs and outputs with a 12 bit resolution [7] and the control panel – the feeder. The PLC controller applied, due to its modular structure, can be additionally equipped with a Ethernet communication module, which can play the role of either the local controller for the external main control system or the role of the network controller for the monitoring of the condition of the entire system connected by the Ethernet connector.

Another module of the control system is the executive element composed of the setting and the executive elements. The properly profiled grips and rollers play the role of the setting element, whereas the frequency converter with the asynchronous motor or the DC engine plays the role of the executive element.

The frequency converter used is configured to work in a vector mode with a predefined frequency range and the external control option for the digital and analogue inputs and outputs. The control of the converter from the digital inputs and outputs enables the standby state to be confirmed, the rotation direction to be selected, and the asynchronous motor to be stopped in a controlled manner. The control from the analogue inputs and outputs, on the other hand, allows for the determination of the level of the work frequency of the converter that in turn enables the control of the level of the rotational speed of the controlled asynchronous motor. The rotational movement of the controlled asynchronous motor is transferred onto the grip or the roller by a crank mechanism with the use of a proper shift, guaranteeing that the assumed torque and speed of the setting element are achieved.

The DC motor used in the developed solution plays the role of a precise positioning system in which the direction of rotations and the load torque of the motor are controlled.

In the solution developed, the measuring element is composed of measurement sensors and a measurement convertor. The inductive sensors and the tensometric force sensors were used as the measurement sensors of the control system, whereas the measurement amplifier is used as the measurement converter. The signals from the inductive sensors are used for the control of the work of the executive element, which is aimed at the determination of the cycles of work of the setting element and the activation of emergency states of the entire system.

The signals from the tensometric sensor are fed through the measurement amplifier onto suitable analogue inputs of the control system. The tensometric force sensor and the measurement amplifier are used for the electric calibration of the force applied onto the object tested.

2. System parameters

In the solution designed, the regulation object is constituted by the stress application process in the test object that is placed in special immovable or partly movable grips on one side and movable grips or rollers on the other and subject to cyclically changeable loads. The regulation system used maintains a constant value of regulation, which is possible thanks to the fact that the output signal remains at the same predefined level (in the form of rotational speed, force or torque) no matter what the external interference to the regulated value exists [8]. The developed system for the application of cyclically changeable stresses is characterised by the following working parameters: maximum load torque at the asynchronous motor shaft of up to 1.28 Nm, motor speed ranging between 11.0 to 33.6 rpm, the number of work cycles between 1 to 9999, the maximum value of the stress applied at the time of electric calibration of 50 N, and the maximum load torque at the DC engine shaft of up to 2.5 Ncm. In the developed control system, the signalling of the following emergency alarm conditions is possible: errors in the asynchronous driver, power loss, an excess of the measurement range of the force value at the time of electric calibration, an excess of the maximum load torque of the DC engine, or the appearance of the moment of destruction of the object tested.

Additionally, the developed solution assumes the possibility of external communication via the Ethernet network (data transfer speed of 10 or 100 Mbit/s).

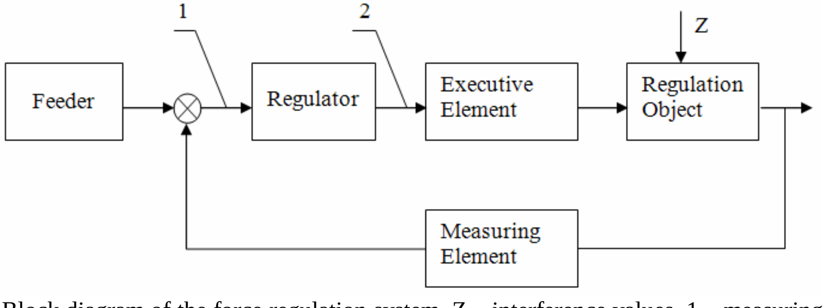

Fig. 2. Block diagram of the force regulation system. Z – interference values, 1 – measuring point for Ch1 channel, 2 – measuring point for Ch2 channel

In the control system developed, the tensometric force sensor and the measurement amplifier are characterised by the following technical parameters: a measurement range of the sensor of 0 to 50 N, a sensor sensitivity of 0.5010 mV/V, total error less/equal 0.2%, an amplifier supply voltage of 24 V DC, and an analogue output of the feeder with the voltage of 0 to 10 V. The electric calibration of the force applied in the developed regulation system consists in the application of the required stress, its measurement and stabilisation directed at the development of the input signal for the executive element and a simultaneous elimination of any interference to the regulation object (Fig. 2). The stabilisation of force at the time of the measurement is dynamically realised with an overshoot lower than 5%. The regulation time (tR), after which the predefined condition is obtained, is connected with the dynamics of the load change (Fig. 3).

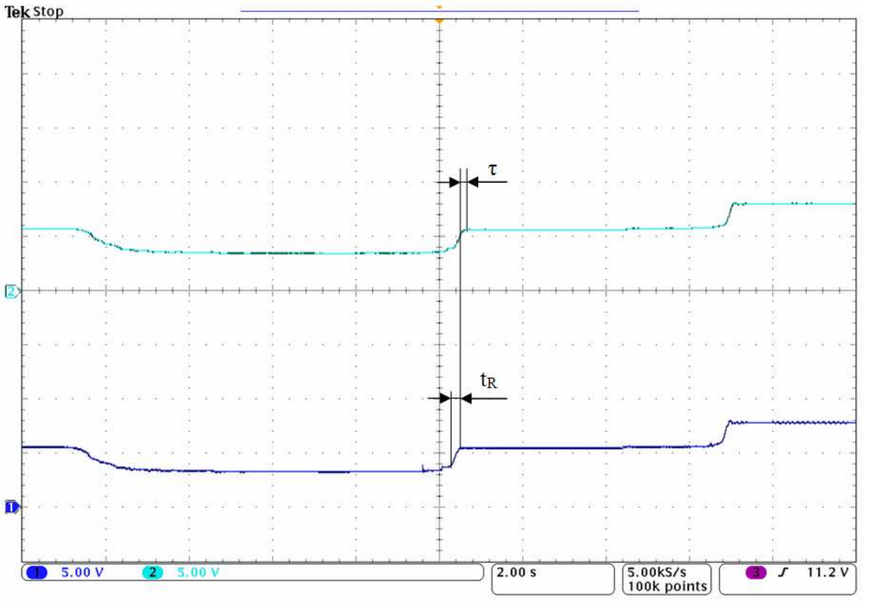

Fig. 3. Oscillogram from the force measurement and regulation. Ch1 – input voltage function of the regulation system (measurement amplifier voltage), Ch2 – output voltage function of the regulation system

The output function of the regulation system is obtained with a delay (τ) caused by the averaging of the ten last measurement results supplied onto the input of the regulation system. The averaging method used results from the empirical analysis that indicated that the averaging of the ten last measurements is the very moment when the elimination of quick impulse interference takes place. The delay between the input and the output function of the regulation system results from the filtration and signal processing in the regulator.

The achievement of the stress determined at the time of calibration is signalled on one of the digital outputs of the PLC controller (Fig. 4). This load is then used to activate the appropriate signalling device.

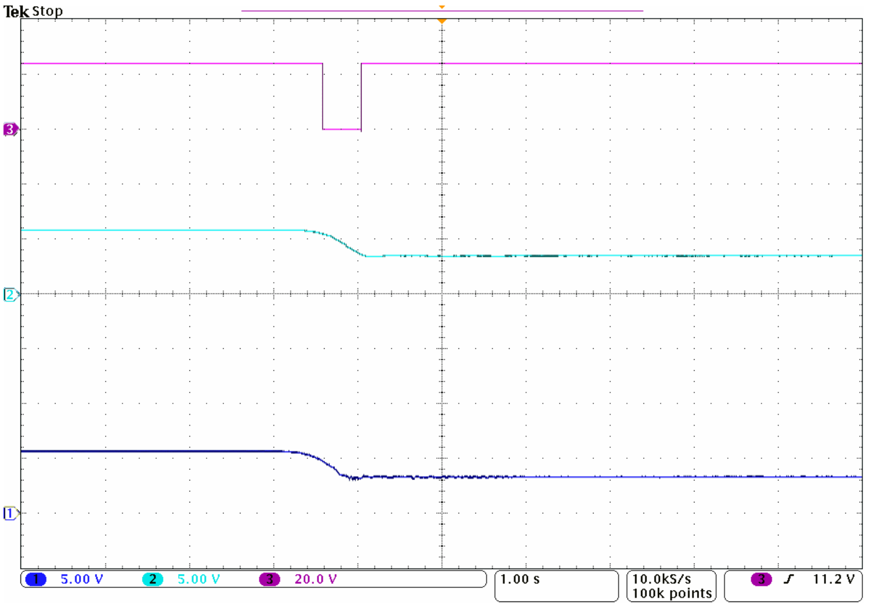

Fig. 4. Oscillogram from the measurement and regulation of force with the signal in the digital output of the PLC controller Ch1 – input voltage function of the regulation system, Ch2 – output voltage function of the regulation system Ch3 – digital signal function in the output of the regulation system

In the developed regulation system, the control of the load torque for the DC motor is possible on the basis of the measurement of the value of the current according to the following dependency:

$$M = c_m \Phi I \tag{1}$$

where:

c_m – constant connected with geometrical parameters of the DC motor,
Φ – magnetic flux,
I – DC motor armature current.

The exemplary tests were carried out for the DC shunt motor in which the rated torque amounts to 2.5 Ncm. The characteristics of the torque load of the DC motor were determined based on the measuring points (Fig. 5). The function of the torque in the function of the current confirms the fact that for the nominal current value and the torque the $M = f(I)$ of the DC shunt motor dependency is very similar to the linear one.

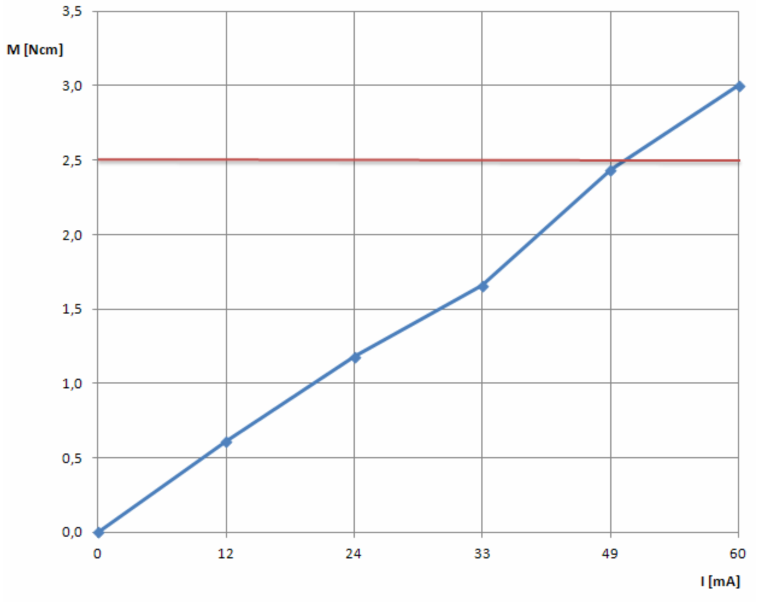

Fig. 5. Graph of the load torque of the DC motor

3. Application of the system

The developed system allows for the tests of endurance to fatigue caused by quasi-static and low-cycle bending and torsion to be conducted. The system can apply stresses of different characters including, inter alia, fluctuating, pulsating, two-sided and oscillatory (symmetric and asymmetric) loads. The designed control system was used in three different kinds of devices for the application of quasi-static and low-cycle small stresses that are cyclically changeable. These devices allow for the realisation of the following fatigue endurance tests to be conducted: two-sided, oscillatory symmetric, changeable quasi-static and low-cycle bending (Fig. 6), one-sided or two-sided changeable quasi-static and low-cycle bending (Fig. 7), two-sided oscillatory symmetric or two-sided asymmetric quasi-static and low-cycle bending (Fig. 8).

Tests realised with the use of the developed devices enable the application of cyclical stresses onto the object tested, in which, in each and every work cycle, the force used changes from the zero level to the value determined at the time of calibration. This force value in a single work cycle oscillates between the plus and the minus value. The calibration process in the devices developed is realised mechanically or electrically. The main task of the control system is to monitor the speed of the oscillating load, count the number of work cycles, calibrate the loads, apply and control the torque in the precise grip positioning system, and to monitor the emergency conditions. The control system enables, from the external user panel, the setting of such parameters of the undertaken process as speed and the programming of the number of cycles.

a)

b)

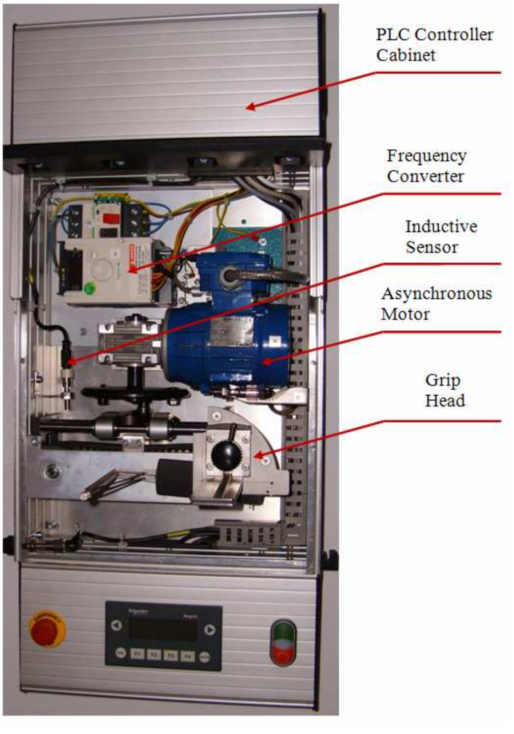

Fig. 6. Tester for document paging: a) en tire device, b) location of elements of automation

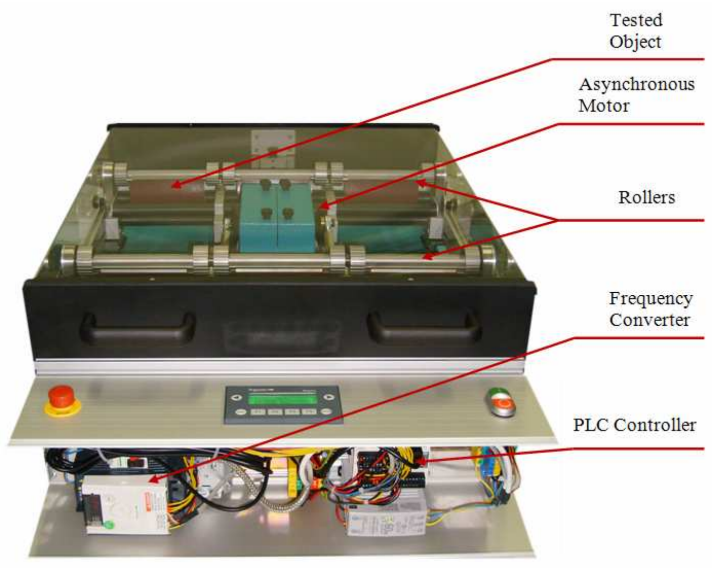

Fig. 7. Tester for two-sided bending of documents with elements of automation

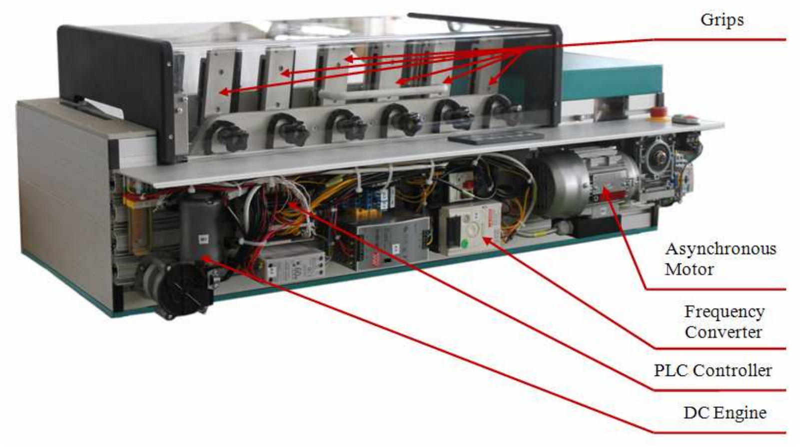

Fig. 8. Tester for alternate twisting of documents with elements of automation

Summary

The advantages of the developed control system include its simple structure and low production costs, as well as the universal character that allows for the application of the system in different testing devices. At the same time, the solution also ensures good functional parameters and maintains good metrological parameters.

The system enables quasi-static and low-cycle, small and cyclically changeable loads with the maximum value of the load torque of 1.28 Nm to be applied. Additionally, the system allows for the electric calibration of the applied stress in the range of up to 50 N. These parameters enable individual copies of goods and the entire groups of products to be tested. This is in the case of such materials as plastics, films or paper.

The developed system can work autonomously or with the use of the Ethernet network, and it can be connected with the system of testing devices, which allows for the remote control of the test results obtained.

With a small change in hardware and software configurations, the developed system can also be dedicated for high-cycle tests of low-loaded materials.

The developed solution was used in equipment for the testing of electronically tagged documents, whose research methods are defined by appropriate norms [9] and procedures of the International Civil Aviation Organisation (ICAO) [10, 11].

Other possible areas of application of the developed solution may include the devices for the testing of plastics [12], films, pulp, paper and printing products, as well as many different combinations thereof enhanced with electronic personalization systems, such as RFID systems (Radio Frequency Identification) [13].

The developed solution is particularly intended for tests carried out for pulp, paper and the printing industry, as well as electronically tagged document certification laboratories.

References

1. Turvey G.J.: Torsion tests on pultruded GRP sheet. Composites Science and Technology. 1998, 58 (8), 1343–1351.
2. Dietrich M.: Podstawy konstrukcji maszyn. Wydawnictwo Naukowo--Techniczne. Warszawa, 1995.
3. Official websites of: Zwick/Roell, Instron, Chatillon, ATS Inc., WMT&R Inc., Shimadzu, TestResources Inc.
4. Boers S.H.A., Geers M.G.D., Kouznetsova V.G.: Contactless and Frictionless Pure Bending. Experimental Mechanics, 2010, 50 (6), 683–693.
5. Neska M., Majcher A., Przybylski J.: Low cost control system for setting low constant and cyclically alternating load. Problemy Eksploatacji, 2011, 2, 289–296.
6. Kocańda St., Szala J.: Podstawy obliczeń zmęczeniowych. Wydawnictwo Naukowe PWN, Warszawa 1997.
7. Schneider Electric official website.
8. Nise N.S.: Control Systems Engineering. Third edition. J. Wiley & Sons, 2000.

9. PN-ISO/IEC 10373-1:2008. Karty identyfikacyjne. Metody badań.
10. Doc 9303 Machine Readable Travel Documents. ICAO Sixth Edition 2006.
11. Machine Readable Travel Documents. Technical Report: Durability of Machine Readable Passports Version 3.2. ICAO, 2006.
12. Broniewski T., Kapko J., Płaczek W., Thomalla J.: Metody badań i ocena właściwości tworzyw sztucznych. WNT, Warszawa 2000.
13. Wang F., Liu S., Liu P. : Complex RFID event processing. The VLDB Journal, 2009, 18 (4), 913–931.

Recenzent:
Andrzej KAPŁON

Quasi-statyczny i niskocyklowy układ do wywierania małych obciążeń w urządzeniach testujących

Słowa kluczowe

Układ sterowania, obciążenie quasi-statyczne, obciążenie niskocyklowe, zginanie, skręcanie.

Streszczenie

W artykule przedstawiono układ sterowania do wywierania quasi-statycznych i niskocyklowych małych obciążeń zginających i skręcających dedykowany do badania wytrzymałości zmęczeniowej obiektów w urządzeniach testujących, w których kalibracja maksymalnej wartości wywieranego obciążenia odbywa się w sposób elektryczny lub mechaniczny.

Przedstawiono elementy składowe opracowanego układu sterowania oraz zaprezentowano przykładowe aplikacje układu w testerach wyrobów poligraficznych.