Mirosław NESKA, Andrzej MAJCHER, Jan PRZYBYLSKI
Instytut Technologii Eksploatacji – PIB, Radom

LOW COST CONTROL SYSTEM FOR SETTING LOW CONSTANT AND CYCLICALLY ALTERNATING LOADS

Key words

Control system, fatigue tests, force adjustment control system, stepper motor system.

Summary

The article is dedicated to a low cost system for setting input functions in material tests in low, constant and periodically alternating loads. The paper presents all elements of the created system, the results of verification, and an example of system application for a paper-testing machine.

When compared to the classic systems for this type of task, the developed system is characterised by a simple and cheap construction, and it also allows one to obtain good functional and metrological parameters, which enables it to be applied in testing machines, especially for testing the fatigue resistance of such materials as plastics, film, paper, and textiles.

Introduction

Currently manufactured products frequently and repeatedly undergo tests concerning external load forces, including stretching, squeezing, shearing, bending, or twisting [1]. The loads the products are subject to can be of constant (static) or periodically changeable. The time and the character of changes of an imposed load determine the kind of tested fatigue resistance. Taking into consideration the number of cycles and the character of changes of the imposed load, the following types of fatigue loads are identified: constant (<0, >0), variable single-sided (<0, >0), pulsating (<0, >0), double-sided, and oscillatory. Additionally, with regards to the number of cycles, the fatigue resistance of a given product is specified by the Wöhler curve, which divides fatigue resistance into three resistance areas – quasi-static (number of cycles from ¼ to $10^3 \div 10^4$), low-cycle (number of cycles between 10^4 and 10^5), and high-cycle (number of cycles varies from 10^5 to 10^7).

In tests where alternating loads are set in specific time frames, programmable execution systems for the realisation of a required load are used. Hydraulic, pneumatic, and electric actuators are used in this type of device [2]. The use of actuators is connected with structural restrictions that are the result of the load value, which is predefined. The structure of a hydraulic press can be a good example. Due to the possibilities of high-precision force application with varied periodic changeability, the application of electric actuators offers greater control opportunities.

The article presents a control system for fatigue resistance tests on products subject to low bending, static, and periodically alternating loads. Three types of electric drives were considered as the executive elements: direct current motors (DC motors), stepper motors, and servomotors. Although DC motors are characterised by the great linearity of mechanical features and relatively small mass moment of inertia, which is considered to be an advantage of the designed load system, they require the application of adequate braking systems [3]. One of the best solutions in load systems is to use servomotors as executive elements, because they allow one to realise various characteristics of the load imposed [4]. The disadvantage of the application of this solution in low load systems is mainly economic. Thus, the application of stepper motors in the aforementioned load systems is by far the best solution, because it offers functionality comparable to that given by servomotors, but significantly reduces the costs of the solution [5].

1. Structure of the system

The stepper motor has been used as an executive element in the designed low load system (Fig. 1). The developed system is composed of the control module, measurement elements, and the executive set.

The Twido PLC controller, which plays the role of the regulator, is the main element of the control module. It is characterised by a modular structure that allows the controller to be expanded. The PLC controller is equipped with digital inputs and, *inter alia*, two outputs of the impulse generator which enable the impulse control at a frequency lower than 7 kHz [6]. Additionally, the PLC controller is equipped with 12-bit analogue inputs and outputs and the operational panel – the programming device. Due to its modular structure, the

PLC controller can also be equipped with an Ethernet communication module that allows the developed control system to communicate with the subordinate external control system.

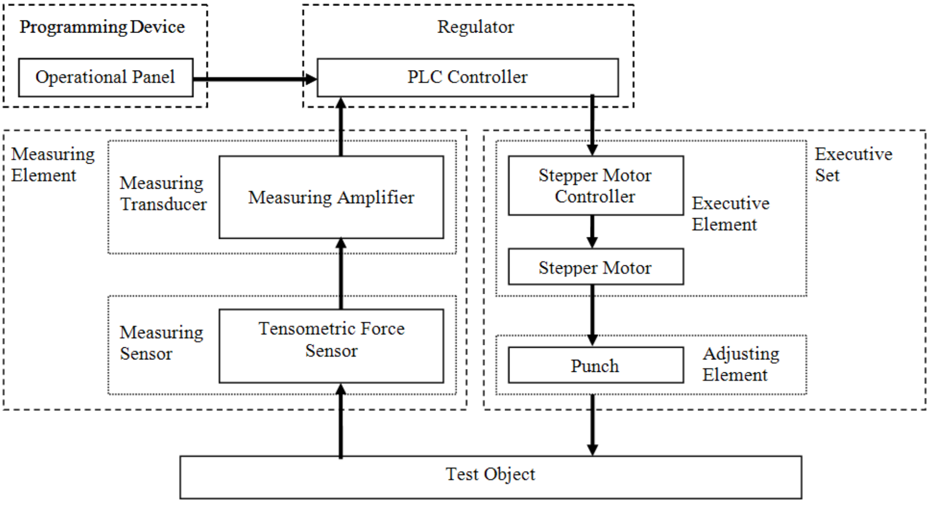


Fig. 1. Functional scheme of the control system

The executive set of the designed system is composed of the adjusting element (the appropriately shaped punch) and the executive element (the stepper motor controller with the 1.8° step two-phase stepper motor). The stepper motor controller applied is by the possibility to select between 200 – 3200 steps and the possibility to choose the operating mode. There are three operating modes in the motor controller – one operating mode with a step signal from the external impulse generator, one with one predefined operating frequency, and the frequency set for the internal generator by the voltage change in the analogue input of the stepper motor controller. The rotational movement of the motor is, in the executive set, transferred with the use of worm gear onto the punch, which puts pressure on the required base.

The measuring element in the developed system is composed of a tensometric force sensor and a measuring amplifier. Technical parameters of the force sensor are as follows:

Measuring scope between 0 to 500N,
Sensitivity of 1.0341mV/V, and
A total error of 0.2%.

The technical parameters of the amplifier, on the other hand, are as follows:
A transducer power supply voltage of 24VDC, and
A transducer analogue output voltage between 0 – 10V.

2. System parameters

The adjusting element in the developed system consists of the physical process taking place within the test object (the loaded element) that is placed on the elastic cushion inside the closed casing. The adjusting system applied maintains the constant value of the controlled variable, independently of the interference affecting the controlled variable and resulting from the changeability of parameters of the element subject to loading and the base of the test object.

The developed system for setting low periodic loads is characterised by the following working parameters:

Load scope between 0 – 400N,

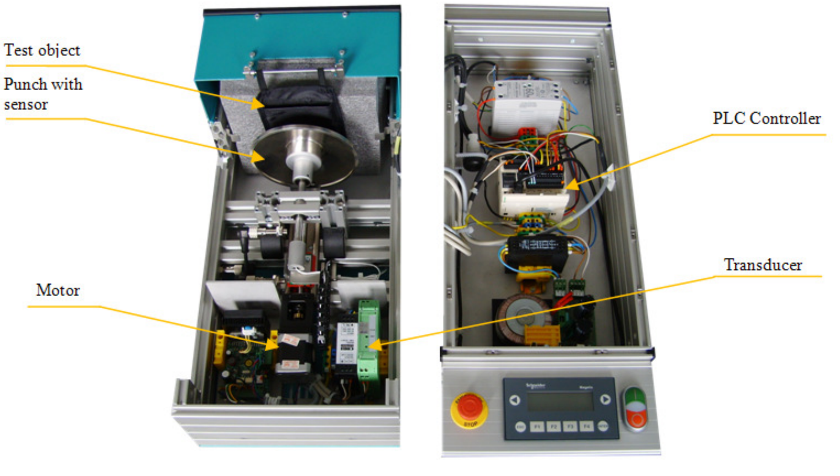
Load distribution of 0.1N,

Executive element speed scope between 0.6 – 2100 r/min,

Single motor step angle value scope from 0.1125° to 1.8°, and

The possibility of external communication through an Ethernet network (data transmission speed 10 or 100 Mbit/s).

The developed system enables one to test fatigue resistance to static, quasi-static, and low-cycle bending. Moreover, the system can set alternating loads of a different nature, such as single-sided alternating loads, pulsating loads, double-sided loads, and oscillatory loads. The developed version of the control system for setting low loads is configured to test fatigue resistance to plus pulsating quasi-static bending, and it has been applied in the spherical bending tester shown below (Fig. 2).



a) *b)*

Fig. 2. Spherical bending tester with incorporated automation elements: a) top level, b) bottom level

This test consists in imposing a periodic force – in every work cycle the force imposed increases from zero level to a certain fixed value, then it is maintained for a specified period of time and finally the force is reduced to zero again. The single load cycle oscillogram below (Fig. 3) depicts this procedure. In the developed control system, the aperiodic course of the controlled variable with the value set at the level of 350 N (Fig. 4) with over-regulation not exceeding 5% were obtained. The regulation time (t_R), after which the condition set reached equals 19 seconds [7] and [8].

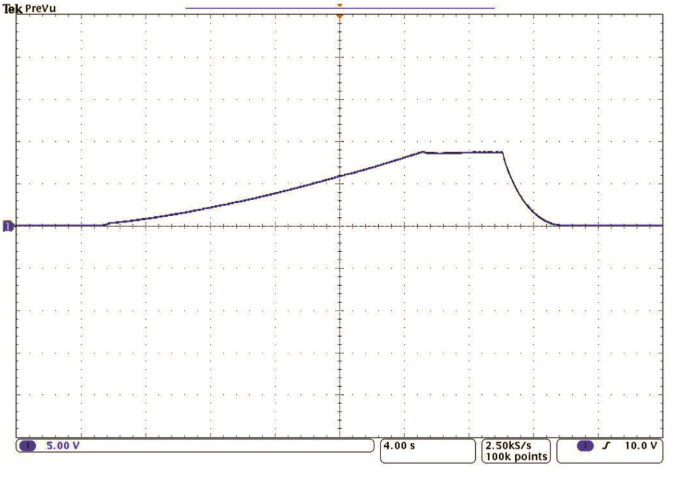


Fig. 3. Oscillogram of single cycle load of a tested object. Ch1 – measuring transducer analogue output voltage (5V/d, 4s/d)

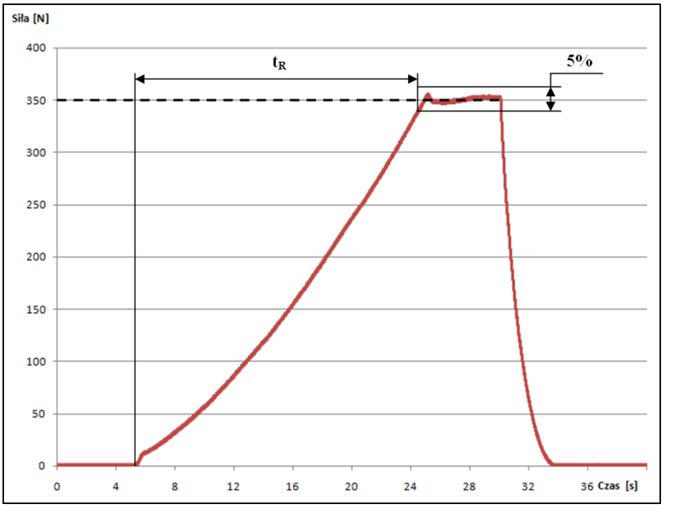


Fig. 4. Controlled variable course with set adjustment parameters. Data on the basis of the record from the oscilloscope

In the control system, there is also the possibility setting any number of load cycles from the operational panel level. As an example, the oscillogram of six load cycles was selected (Fig. 5). Moreover, there is also the possibility setting individual parameters of the single load cycle, which includes load speed, the maximum load force value required, the time needed to maintain maximum force, and the speed of removing the load force.

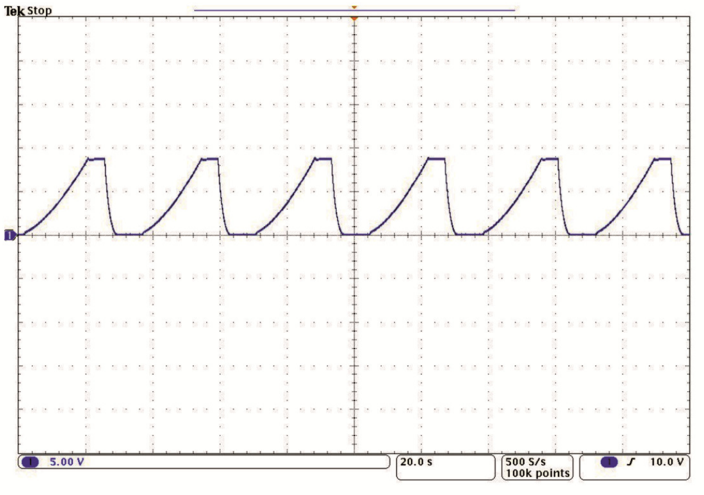


Fig. 5. Oscillogram of six load cycles of the tested object Ch1 – measuring transducer analogue output voltage (5V/d, 20s/d)

Amplifier output voltage measurement was conducted with the use of a MSO4054 oscilloscope, and voltages were measured with the use of a passive P6139A voltage probe.

Conclusions

The developed control system can work independently, or it can be applied in Distributed Control Systems (DCS) in which several control systems are combined into one. The solution significantly improves the functionality of a single control system by means of increasing the possibility of measurement data transformation and acquisition and adding the remote control function, which allows the external control over individual parameters of the control system.

The developed solution has been applied in the device for electronically tagged document testing, whose test methodology is described in one of International Civil Aviation Organisation (ICAO) procedures [9] and [10].

Another application area for the developed solution can be the systems for precision low load setting and tests. Devices for testing different kind of materials, including plastic [11], film, and paper, can be a good example.

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Reviewers:
Zbigniew GORYCA
Jan M. KOŚCIELNY

Niskokosztowy układ do zadawania małych obciążeń stałych i okresowo zmiennych

Słowa kluczowe

System sterowania, badania zmęczeniowe, układ regulacji siły, układ napędowy z silnikiem skokowym.

Streszczenie

W artykule opisano niskokosztowy układ do zadawania wymuszeń w testach materiałowych, w warunkach małych obciążeń stałych i okresowo zmiennych. Przedstawiono elementy składowe opracowanego układu, wyniki badań weryfikacyjnych oraz przykładową aplikację w testerze wyrobów papierniczych.

W porównaniu z klasycznymi układami realizującymi takie zadania opracowany układ charakteryzuje się prostotą budowy i niskimi kosztami wykonania, zapewniając jednocześnie uzyskiwanie dobrych parametrów funkcjonalnych i metrologicznych. Umożliwia to stosowanie go w urządzeniach testujących, szczególnie do badań wytrzymałości zmęczeniowej takich materiałów, jak: tworzywa sztuczne, folie, wyroby papiernicze czy włókiennicze.