

Control system of a multifunctional tester for electronically protected documents

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Abstract: Introduction of electronic protection into documents makes it necessary for the documents to undergo multicriteria tests, and results in a growing need for the development of specialised testers, an example of which can be constituted by a multifunctional testing device. The article presents a control system for a tester which realises the following tests: stamping, writing in, abrasion in an electronically protected document. The authors also describe the structure of hardware used and the structure of tests the devices can realise. Additionally, behavioural analysis with the use of UML activity diagrams is presented as well as technical parameters of the control system developed and its possible areas of application in a series of testing devices.

Keywords: product testing, RFID systems, document protection, impact load, abrasive load, UML activity diagram

1. Introduction

Contemporary electronically protected documents, such as ID cards or passports, include electronically saved data stored inside the RFID (Radio Frequency Identification) systems [1, 2, 3, 4]. RFID labels are integrated circuits in a flip chip casing that with a flat aerial printed on an elastic film are soldered to the inlay. Such a set, also known as a RFID label, is prone to damage resulting from loads occurring at the time the document is used. Requirements concerning quality and parameters of electronically protected documents are clearly specified, in the case of passports, by formal legal regulations of the International Civil Aviation Organization (ICAO) [5, 6]. One of such requirements includes, i.e. document's resistance to mechanical loads occurring at the time of leafing through, stamping, writing in or spherical and uniaxial bending.

At the Institute for Sustainable Technologies – National Research Institute a series of testing devices for electronically protected documents was designed, and the testers that have so far been developed include a tester for spherical bending, leafing through, two sided bending, alternate twisting [7, 8], and the most complex of them all – a multifunctional tester. The devices developed are intended for fatigue resistance tests, including in particular: positive pulsating quasi-static bending (spherical bending tester), two sided oscillatory symmetrical changeable quasi-static and low-cycle bending (leaf

through tester), one sided and two sided changeable quasi-static and low-cycle bending (two-sided bending tester), two sided oscillatory symmetric and asymmetric changeable quasi-static and low-cycle twisting (alternate twisting tester). The multifunctional tester generates three types of impact connected with the manual filling in of the document and abrasion. The loads are realised with the use of a dedicated triaxial spherical manipulator system.

One of the main assumptions at the time of designing the series of testers was that the devices needed to remain unified, and hence a universal control system had to be developed. The main components of the aforementioned system include the following: a set point module with an ascribed operator panel, and a regulation module constituted by a PLC controller allowing for an easy and fast extension of the system. Functions of the executive set and the measuring element are played by dedicated elements whose selection is connected with requirements towards a given testing device. The developed control system is cheap, universal, easy to be extended and modified, which means that it can be used for the entire series of testing devices.

2. Structure of the control system

The Twido PLC controller (Fig.1), which plays the role of the regulator, is the main element of the control system. It is programmed in three languages: LD, IL and Grafset [9]. It is characterised by a modular structure, which allows the controller to be expanded. An additional advantage of the controller is its cheap price, which decides on the low costs of the entire system. The PLC controller is equipped with digital inputs and 12-bit analogue inputs and outputs. Due to its modular structure, the PLC controller can also be equipped with an Ethernet communication module, which can significantly improve its functionality (possibility of superior control), but will boost its costs at the same time as well. The XBTN user panel by Magelis [9], with a backlit LCD screen and a Modbus communication interface, is also included in the control system.

The executive set in the control system developed is composed of an adjusting element and an executive element. What plays the role of the adjusting element are the grip and the head respectively, whereas the executive element is composed of two systems of stepper motor controller (fig. 2) of CMMS-ST type, a stepper motor

controller of EMMS-ST type [10], and an independent DC motor. The applied stepper motor controllers are characterised by the possibility to be configured according to user needs, with consideration of types and parameters of cooperating elements, including motors, encoders, or gears.

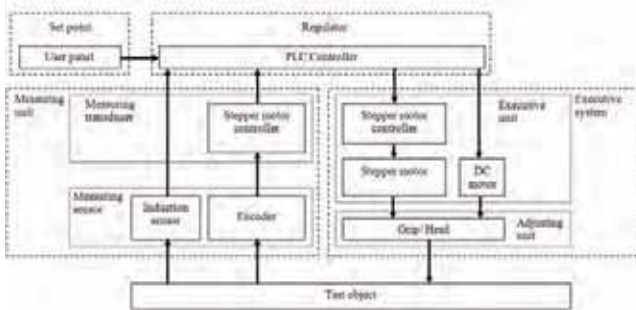


Fig. 1. Draft of the control system
Rys. 1. Schemat systemu sterowania

Moreover, in the controller configuration mode, the user can choose the communication interface with a superior PLC controller out of such interfaces as: digital and analogue inputs and outputs interface, CANopen interface, DeviceNet, Profibus DP, RS485, DeviceBus [10].



Fig. 2. View on the arrangement of elements of the control system in the control panel of the multifunctional tester for electronically protected documents
Rys. 2. Widok rozmieszczenia elementów systemu sterowania w szafie sterowniczej wielofunkcyjnego urządzenia do testowania dokumentów z zabezpieczeniem elektronicznym

In the developed control system, the stepper motor controllers were configured in a way that enables their cooperation with properly selected stepper motors and gears, and as a communication interface, the interface with digital and analogue inputs and outputs was chosen. The control of a stepper motor controller realised from the level of digital and analogue inputs and outputs enables the realisation of determined and programmable working movements of the stepper motor. Suitable analogue inputs and outputs of the stepper motor controller enable the speed to be regulated and the current position of the stepper motor to be read. In the executive system the rotational movement of stepper motors, realised with the use of toothed gears, is transferred onto the working head,

which results in the shift of the head and impacts the test object.

Another element included in the executive system is a DC motor, whose rotational movement is, *via* chain drive, transferred onto the working grip.

In the developed control system, encoders and induction sensors were used as measuring sensors, and a dedicated measurement interface for stepper motor controllers was used as measuring transducers of shift sensors. Signals obtained from induction signals are used for the control of the executive element – for the positioning and cyclical operation of the working grip. They are also applied for the activation of emergency states in the control system.

Signals from encoders are transmitted to stepper motor controllers playing the role of measuring transducers, and then directed to appropriate analogue inputs of the PLC controller. Shift sensors together with stepper motor controllers constitute the measuring element of the control system, whose objective is to control the activity of the working head.

3. Tests realised by the control system of the device

The control system of the multifunctional testing device assumes that three types of tests can be realised in the case of electronically protected documents. These include the following: stamping, manual write in, abrasion (fig. 3). Each of the aforementioned tests can be realised as normative or programmable tests [5].

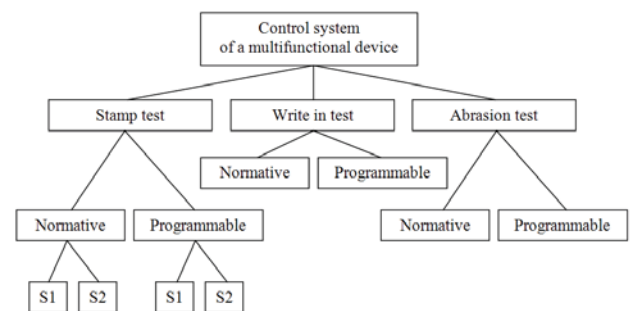


Fig. 3. Diagram of the structure of tests realised by the control system of the multifunctional testing device. S1 – stamp test realised with the use of a changeable head in a shape of a cylinder with 29 mm in diameter, S2 – stamp test realised with a changeable head in a shape of a cuboid with the size of the base of 178 × 123 mm

Rys. 3. Schemat struktury testów realizowanych przez system sterowania wielofunkcyjnego urządzenia. S1 – test stemplowania realizowany głowicą wymienną w kształcie walca o średnicy $\phi 29$ mm, S2 – test stemplowania realizowany głowicą wymienną w kształcie prostokąta o wymiarach podstawy 178 × 123 mm

Stamp tests can be realised with the use of exchangeable head S1 or S2 (fig. 4) that differ in weight.

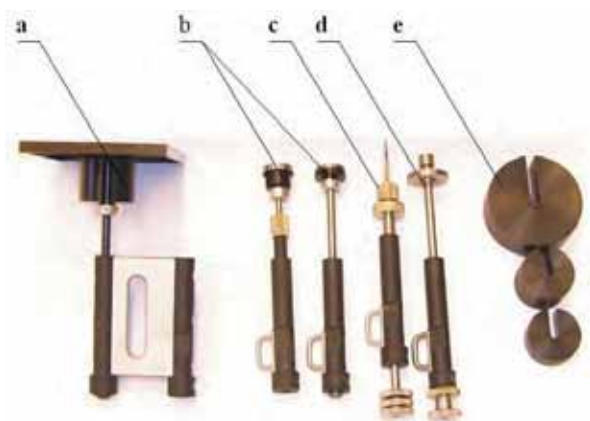


Fig. 4. Set of changeable heads of a multifunctional device: a – changeable head S2, b – two types of changeable head S1, c – changeable head with a ballpoint pen, d – changeable head for abrasion tests, e – set of loads for changeable heads

Rys. 4. Zestaw głowic wymiennych wielofunkcyjnego urządzenia: a – głowica wymienna S2, b – dwa typy głowicy wymiennej S1, c – głowica wymienna z długopisem, d – głowica wymienna do ścierania napisów, e – zestaw obciążników głowic wymiennych

The test realised with the use of the S1 head has a normative character, whereas the one realised with the S2 head – programmable. The normative tests consist in the stamping of the entire page of the passport with single stamps located within 10.5 mm from one another. In the programmable test, on the other hand, the size of the stamping area, and the size of the stamp itself (up to the size of the working area of the test stand) can be individually set (fig. 5), and the stamp can, at the same time, be placed in any area in the test stand. In the stamp test realised with the use of the S2 head an entire page (or two neighbouring pages) of the passport can be stamped with a single stamp. Additionally, in this type of tests, the number of stamps can be individually selected.

The manual write-in test is realised with the use of a changeable head with a ballpoint pen, which can have either a normative or a programmable character. In a normative test, with the use of the ballpoint pen, double lines are made on the entire page of the passport. The lines are parallel or perpendicular and they are made every 1.5 mm. In the case of a programmable test, the area to be filled in can be selected and its size set individually; however, it cannot be smaller than 1.5×1.5 mm.

The abrasion test is realised with the use of a changeable head onto which a sheet of paper, which plays the role of an abrasive medium, is adjusted. The sheet adheres directly to the page of the document tested. The objective of the abrasion test is to check to what degree the tested object, particularly in the area for automatic data read-out, is resistant to mechanical abrasive wear. The abrasion test, as a normative test, consists in the abrasion of a clearly defined area of a tested object. The normative abrasion test is realised parallel to this area in an oscillatory cycle (there are 500 of such cycles). In the program-

mable abrasion test, on the other hand, the size of the test area can additionally be set in the range between 20 mm to the maximum width of the working area of the test stand, and any number of test cycles can be programmed.

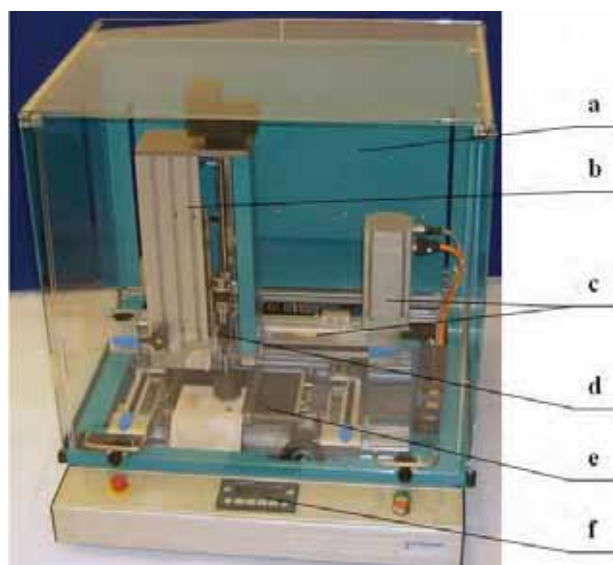


Fig. 5. Multifunctional device for electronically protected document testing: a – control panel, b – working head with DC drive and working grip, c – stepper motor and longitudinal movement gear, d – changeable head, e – test table, f – user screen

Rys. 5. Widok wielofunkcyjnego urządzenia do testowania dokumentów z zabezpieczeniem elektronicznym: a – szafa sterownicza, b – głowica robocza z napędem DC i uchwytem roboczym, c – silnik skokowy i przekładnia ruchu wzdłużnego, d – głowica wymienna, e – stolik na testowany dokument, f – pulpit operatorski

4. Behavioural analysis of the control system

Figure 6 presents a generalised control process of a multifunctional device for normative testing of electronically protected documents with the use of Unified Modelling Language (UML) [11, 12].

The control process is initiated once the ON button is pressed and information about system's readiness displayed on the user screen. Only then can the operator select the type of test to be performed, by pressing the F1, F2, or F3 button (respectively: stamping, write in, abrasion). The test selected can have either a normative or programmable character.

In the case of a stamp test (same procedure for tests realised with the use of the S1 or S2 head), the first task of the operator is to set the test (configure mechanical elements to be used, like changeable head, stand, documents) and then to define the test area by programming characteristic points P1 and P2 diagonally to the rectangular test area. The test setting is finished when all test parameters are characterised. After that, the stamping procedure is undertaken for the defined test area. Once the head is set in an initial stamping position m_1 , the

n number of stamps is performed in characteristic $m_1 - m_n$ points that are determined automatically for the test area defined. The stamp test lasts until the set number of stamps (n) is finished. Once the last stamp is performed, the head returns to its initial position, and the system changes over to standby, which is signalled on the operator screen.

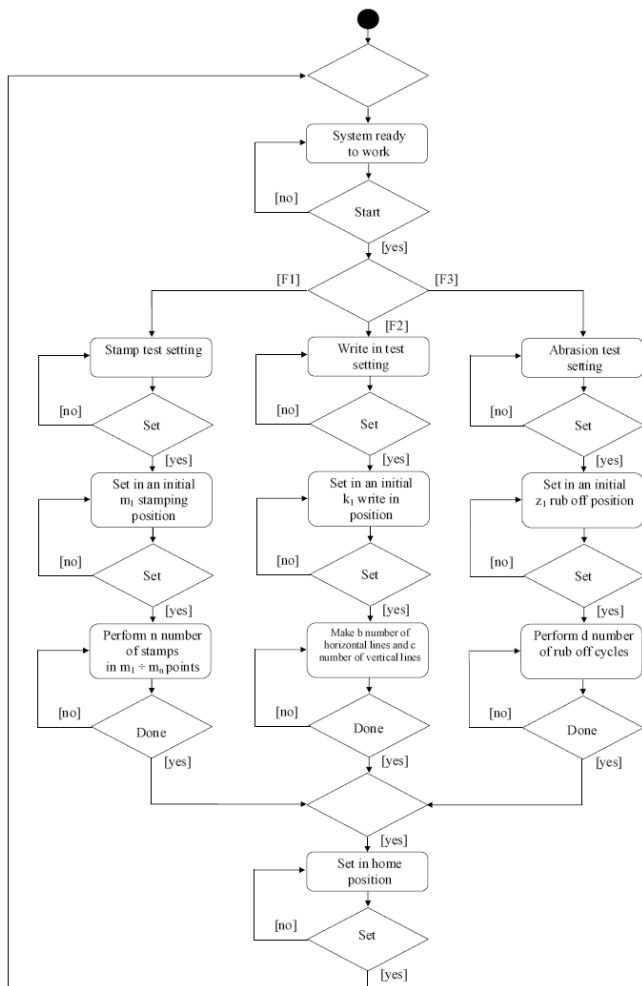


Fig. 6. UML activity diagram for the multifunctional tester control system

Rys. 6. Diagram aktywności UML systemu sterowania testerem wielofunkcyjnym

The first procedure to be conducted by the operator, in the case of a write-in test, just like in the aforementioned case of a stamp test, concerns the configuration of mechanical elements that is the changeable head, the stand and the documents that will be used. Then, the test area is defined and characteristic points P1 and P2 on the diagonal of the test area are programmed. Once test parameters are determined, the setting procedure is finished and the write-in test procedure for the test area selected is initiated. The working head moves into k_1 position from which the write-in test starts. The b number of horizontal and c number of vertical lines are drawn automatically according to the assumed algorithm for the test area selected. Once the set numbers of lines are drawn, the write-in test is completed and the working head returns to its

initial k_1 position. The system changes over to standby and the user is again notified (information displayed on the operator screen).

In the case of an abrasion test, the operator starts again with the configuration of mechanical elements to be used. Then, the test section is defined and characteristic points P1 and P2 of the section are programmed together with the d number of rub off cycles. The test setting is finished when all abrasion test parameters are characterised. After that the abrasion test begins. The working head is set in an initial z_1 position and then the d number of rub off cycles is performed along the programmed test section. The abrasion test is completed when all the rub off cycles are performed and the working head returns to its initial position. The system changes over to standby, which is confirmed on the user screen.

5. Control system parameters

The developed control system is characterised by the following working parameters: stepper motor speed range on the onset: 2.60 – 416.00 mm/s; stepper motor acceleration range on the onset: 0.068 – 40.000 m/s²; value of an angle of a single step of the stepper motor: 1.8° ± 5 %; nominal stepper motor holding torque: up to 9.3 Nm. Nominal parameters of the DC motor used, on the other hand, are as follows: rotation speed of 40 rpm, load torque on the motor shaft up to 5 Nm.

The movement of the working head is measured with the use of a measuring transducer of a stepper motor and presented in form of a voltage signal ranging between 0 – 10 V in the analogue output of the stepper motor.

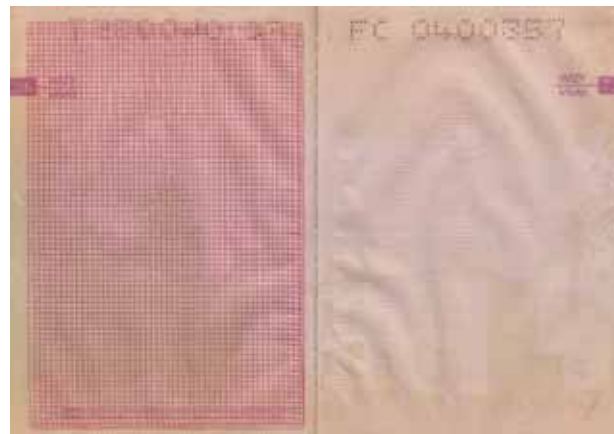


Fig. 7. Example of verification test results for an electronically protected document obtained from a normative write-in test

Rys. 7. Przykład wyników badań weryfikacyjnych dokumentu z zabezpieczeniem elektronicznym, uzyskanych po realizacji normatywnego testu zapisu

Solution developed allows for the realisation of tests with following parameters: for stamp tests the stamp area should be within the range of 29 × 29 mm up to 180 × 100 mm, and it can be defined for any point of the test table. Additionally, energy of stamping can also be

programmed for the stamp tests. In the case of write-in tests, the size of the test area should be from 1.5×1.5 mm to 210×130 mm. Similarly to the stamp test, the test area can be freely defined. As for the abrasion test, the length range of rub off lines is between 20 to 200 mm. The length of the line can be set for any point at the test table. In the case of this particular test, it is also possible to set the number of rub off cycles from 1 to 1000.

Emergency states are signalled when stepper motor drives are faulty or there is no power supplied to them. Moreover, the system developed can communicate via Ethernet network (data transmission speed: 10 or 100 Mbit/s).

6. Summary

The control system of the multifunctional device is the most complex solution out of the control systems of test apparatus for electronically protected documents designed, which is visible particularly in its ability to realise three different types of tests (stamping, write in, abrasion) of normative or programmable character. Normative tests realised comply with ICAO recommendations, whereas programmable tests elaborate on requirements stated in these recommendations. The tests can also be performed on differently sized documents, and the value and intensity of load to be imposed can be individually programmed for them.

The system agrees with formal and functional requirements concerning the following: conformity of tests with suitable norms, efficiency of the solution, possibility to be included into a series of testers and to be extended.

The solution presented can be used in tests of entire electronically protected documents or individual layers of materials they are made of, i.e.: RFID labels or paper, which are tested at the stage of product design or prototyping.

Low impact load or abrasive load systems of different load frequencies constitute another field of application of the developed solution.

The system presented can work individually or it can be connected, via the Ethernet network, to a superior control system of a network of test devices, which enables parallel realisation of investigations concerning the same group of products.

Behavioural analysis presented in the paper can be used for the development of a simulation module and an automatic record converter for the activity diagram allowing for data to be converted into the programming language of the PLC controller.

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System sterowania wielofunkcyjnego urządzenia do testowania dokumentów z zabezpieczeniem elektronicznym

Streszczenie: Wprowadzanie do dokumentów papierowych zabezpieczeń elektronicznych stwarza konieczność ich wielokryterialnego testowania, a tym samym opracowywania specjalistycznych testerów. Przykładem takiego urządzenia jest tester wielofunkcyjny. W artykule przedstawiono system sterowania tym urządzeniem, realizującym testy: stemplowania, zapisu oraz ścierania w dokumencie z zabezpieczeniem elektronicznym. Opisano strukturę sprzętową systemu sterowania oraz strukturę realizowanych testów. Przedstawiono analizę behawioralną z zastosowaniem diagramów aktywności języka UML. Zaprezentowano parametry techniczne opracowanego systemu sterowania oraz możliwości jego zastosowania, w typoszeregu urządzeń testujących.

Słowa kluczowe: testowanie produktów, układy RFID, zabezpieczenia dokumentów, obciążenie udarowe, obciążenie ścierne, diagram aktywności UML

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