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Original Research Paper

Testing by Non-Destructive Control

[1]Relly Victoria Virgil Petrescu, [2]Raffaella Aversa, [3]Bilal Akash, [4]Ronald Bucinell, [5]Samuel P. Kozaitis, [6]Taher M. Abu-Lebdeh, [2]Antonio Apicella and [1]Florian Ion Tiberiu Petrescu

[1]*ARoTMM-IFToMM, Bucharest Polytechnic University, Bucharest, (CE), Romania*
[2]*Advanced Material Lab, Department of Architecture and Industrial Design, Second University of Naples, 81031 Aversa (CE), Italy*
[3]*Dean of School of Graduate Studies and Research, American University of Ras Al Khaimah, UAE*
[4]*Union College, USA*
[5]*Florida Institute of Technology, USA*
[6]*North Carolina A and T State University, USA*

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Corresponding Author:
Florian Ion Tiberiu Petrescu
ARoTMM-IFToMM,
Bucharest Polytechnic University, Bucharest, (CE), Romania
Email: scipub02@gmail.com

Abstract: This paper describes an application of industrial robots that gain ground mainly in the aerospace industry. It is a TTT manipulator whose task is to automatically position the end-effector, in this case a complex sensor system and a eddy-current probe in the position set by the software application for testing by non-destructive ultrasound control of tickets and bars of titanium, both round and square, or any other transparent ultrasound metal (obviously in a certain range of sizes). For surface control, the effector also includes a Eddy current (Eddy current control system). The installation performs ultrasonic control by the echo boost method in total immersion using as a water coupling medium. This method provides the best coupling for automated control systems. This plant was specially produced for ZIROM S.A. A unique producer of titanium ingots in Romania by the reputed German company Karl Deutch (leader in this field), the founder of the company being also one of the inventors of the non-destructive ultrasonic control method, the part of Eddy current being produced by the German company Prüftechnik. This paper aims to explore the state of the art of non-destructive automatic ultrasonic control techniques according to the possible methods to be adopted, by the applications that demand such methods, by reviewing a series of installations more or less similar to those of Zirom s.a. It is thus found that there are a multitude of pine technical solutions that can be done with an ultrasonic automatic control and precision. In this context, the last chapter of the paper that attempts to probe the possible evolution of the future of US control in this field is of great importance because in the current pace of innovations in all fields, but especially in IT and electronics, the future holds many surprises.

Keywords: Industrial Robots, Automation, TTT Manipulator, Eddy-Current, Complex Sensor System, Software Application, Testing by Non-Destructive, Ultrasound Control, Bars of Titanium, Transparent Ultrasound Metal, Range of Sizes, Surface Control, Echo Boost Method, Total Immersion, Water Coupling Medium, Electronics

Introduction

The development and diversification of machines and mechanisms with applications in all fields requires new scientific researches for the systematization and improvement of existing mechanical systems by creating new mechanisms adapted to modern requirements, which involve increasingly complex topological structures.

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The modern industry, the practice of designing and building machinery is increasingly based on the results of scientific and applied research.

Each industrial achievement has backed theoretical and experimental computer-assisted research, which solves increasingly complex problems with advanced computing programs using increasingly specialized software (Aversa *et al*., 2016a; 2016b; 2016c; 2016d; 2017a; 2017b; 2017c; 2017d).

The robotization of technological processes determines and influences the emergence of new industries, applications under special environmental conditions, the approach of new types of technological operations, manipulation of objects in the alien space, teleoperators in the top disciplines like medicine, robots covering a whole field greater service provision in our modern, computerized society.

In this context, the present paper attempts to make a scientific and technical contribution by describing an application of industrial robots that gain ground mainly in the aerospace industry.

It is a TTT manipulator whose task is to automatically position the end-effector, in this case a complex sensor system and a eddy-current probe in the position set by the software application for testing by non-destructive ultrasound control of tickets and bars of titanium, both round and square, or any other transparent ultrasound metal (obviously in a certain range of sizes).

For surface control, the effector also includes a Eddy current (Eddy current control system).

The installation performs ultrasonic control by the echo boost method in total immersion using as a water coupling medium.

This method provides the best coupling for automated control systems.

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This paper aims to explore the state of the art of non-destructive automatic ultrasonic control techniques according to the possible methods to be adopted, by the applications that demand such methods, by reviewing a series of installations more or less similar to those of Zirom s.a.

It is thus found that there are a multitude of pine technical solutions that can be done with an ultrasonic automatic control and precision. In this context, the last chapter of the paper that attempts to probe the possible evolution of the future of US control in this field is of great importance because in the current pace of innovations in all fields, but especially in IT and electronics, the future holds many surprises (Mirsayar *et al*., 2017).

Materials and Methods

About the Method of Non-Destructive Control with Ultrasunete

The method is based on the phenomenon of producing ultrasonic waves in materials, called generic crystals, under the influence of an electric wire, by passing the wave into the material and receiving it by the same crystal or by another (called receptor).

Waves involved in ultrasonic control are:

- Longitudinal waves-where oscillation direction coincides with the transmission direction (Fig. 1)
- Transversal waves-Where the direction of transmission is perpendicular to the oscillation direction (Fig. 2)
- Waves of surface-acts on the surface of the materials (Fig. 3)
- Waves Lamb-are produced only in thin plates (Fig. 4)

The procedures used in US control are:

- By transmission
- Pulse-echo

The most common is the echo pulse presented schematically in the following picture where it can be observed and the working mode of a apparatus for determining defects - producing device receives and processes the received wave and the result of penetration of the material is seen on the oscilloscope of the apparatus for determining defects (Fig. 5).

The principle of control with echo impulse is also clearly presented in the following picture where the two echoes of the bottom and the emission are distinguished, i.e., from the output of the probe from the touch probe and from the reflection of the wave on the bottom of the material (Fig. 6).

There is a smaller echo in the center of the diagram. This is the echo of the internal flaw and it is more of a concern to us. It is noted that there is also a direct link between the distance of the fault echo and the emission time-base from the diagram and the depth at which the defect in the piece material is found.

There is also a function between the defect size and the fault echo on the diagram.

A great importance is also the threshold-amplification, because overcoming it depends on the acceptance or rejection of the piece to be controlled. Just as important is the gate because for example we will have information about the defects of the piece only in the volume inside the gate.

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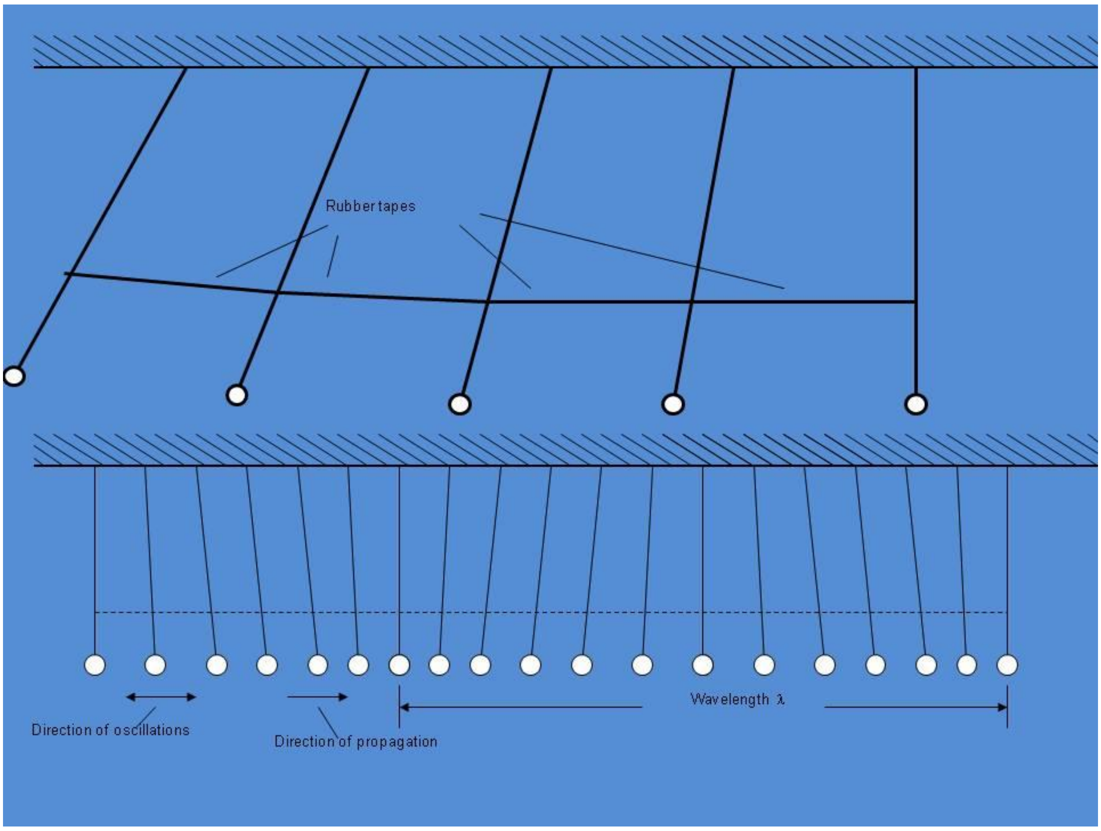

Fig. 1. Longitudinal waves-where oscillation direction coincides with the transmission direction

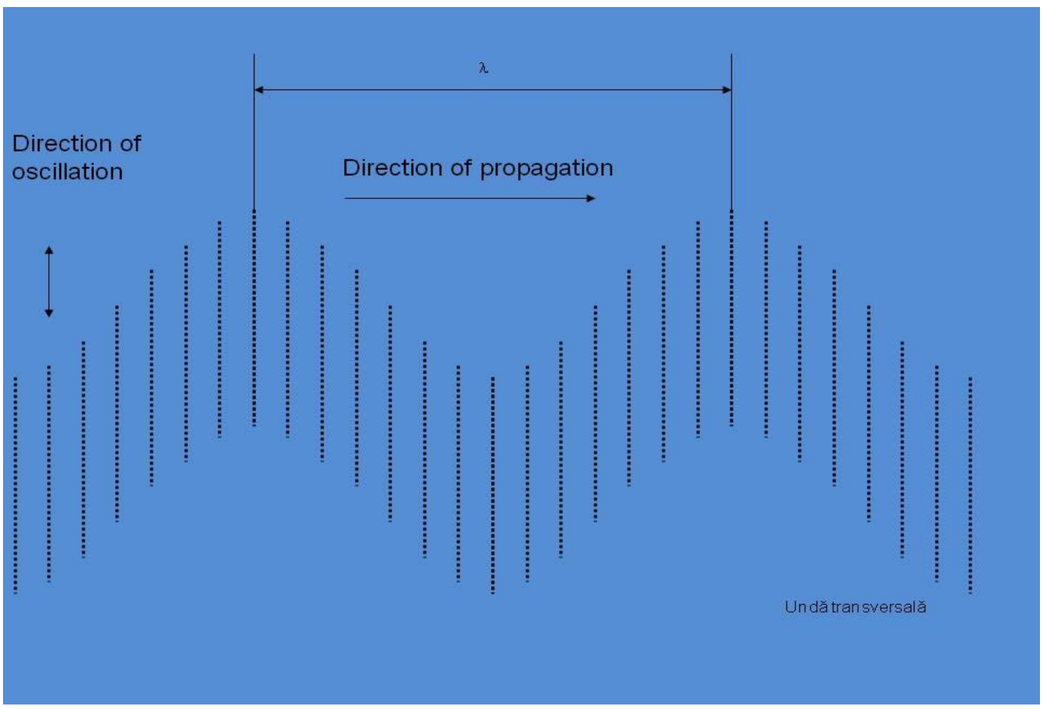

Fig. 2. Transversal waves-Where the direction of transmission is perpendicular to the oscillation direction

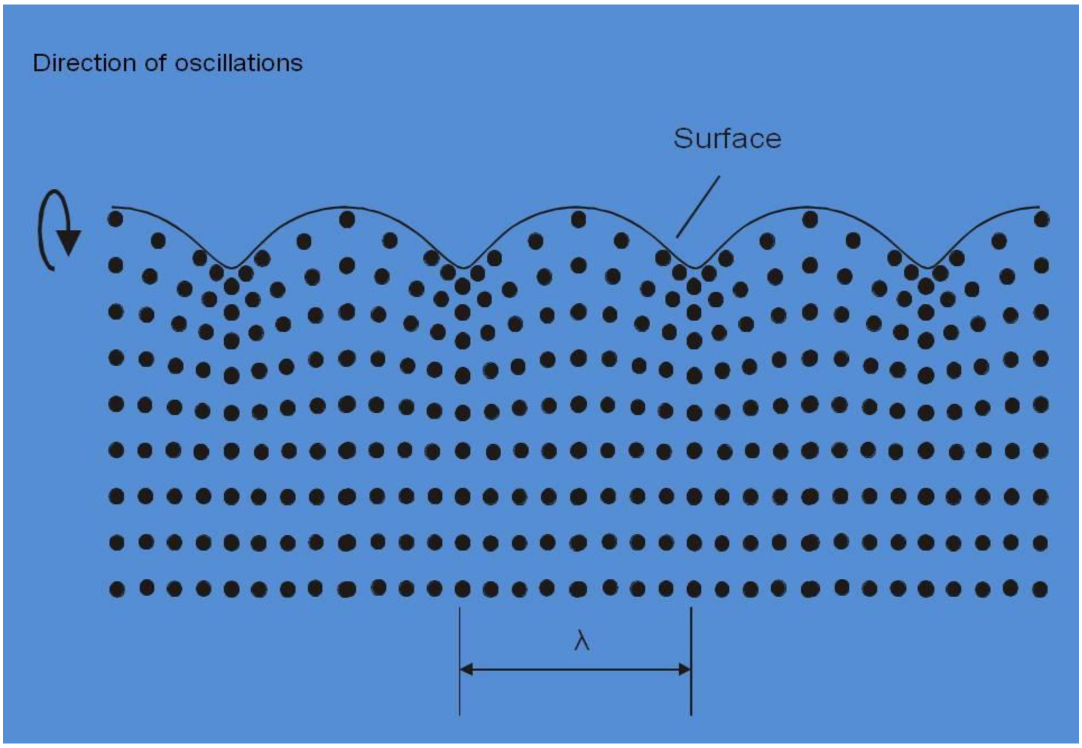

Fig. 3. Waves of surface - acts on the surface of the materials

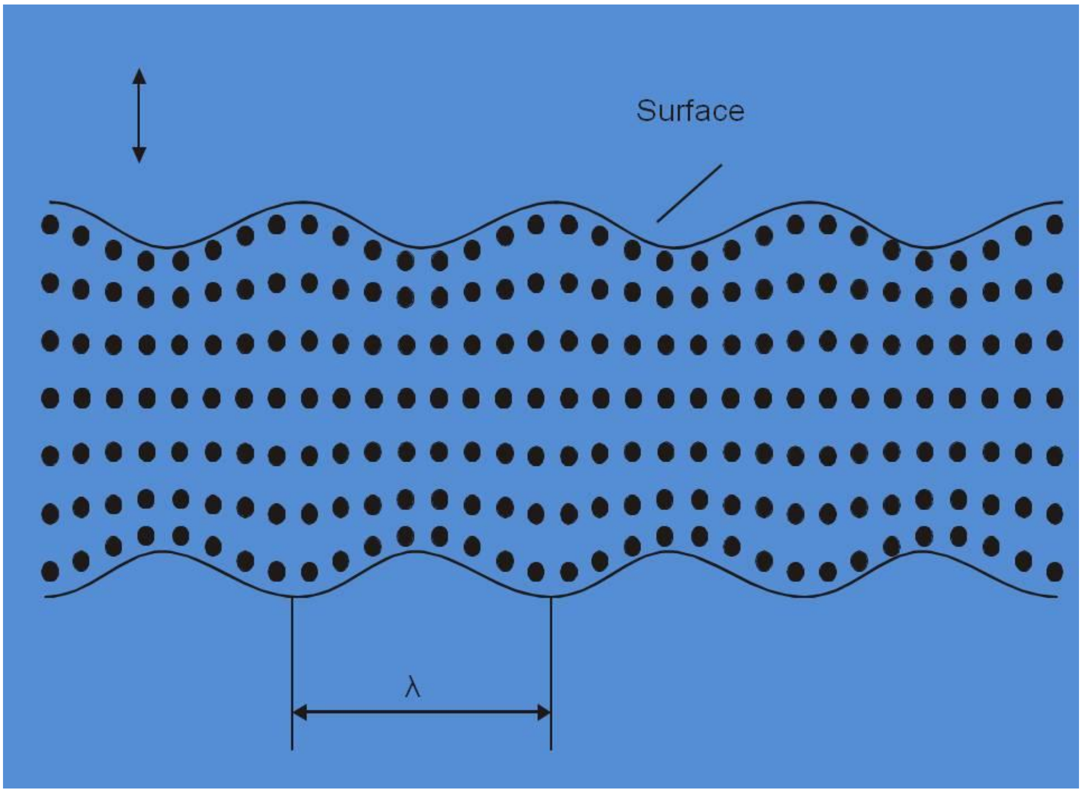

Fig. 4. Waves Lamb - are produced only in thin plates

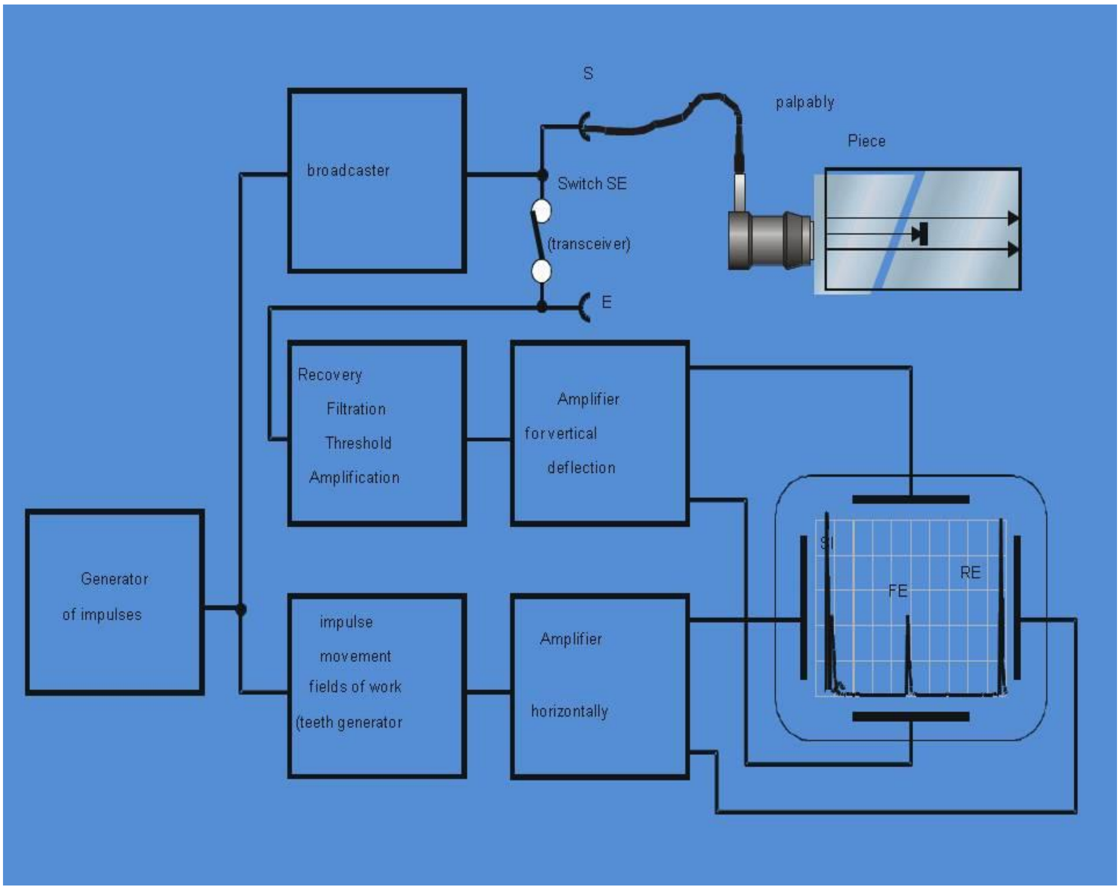

Fig. 5. An echo pulse

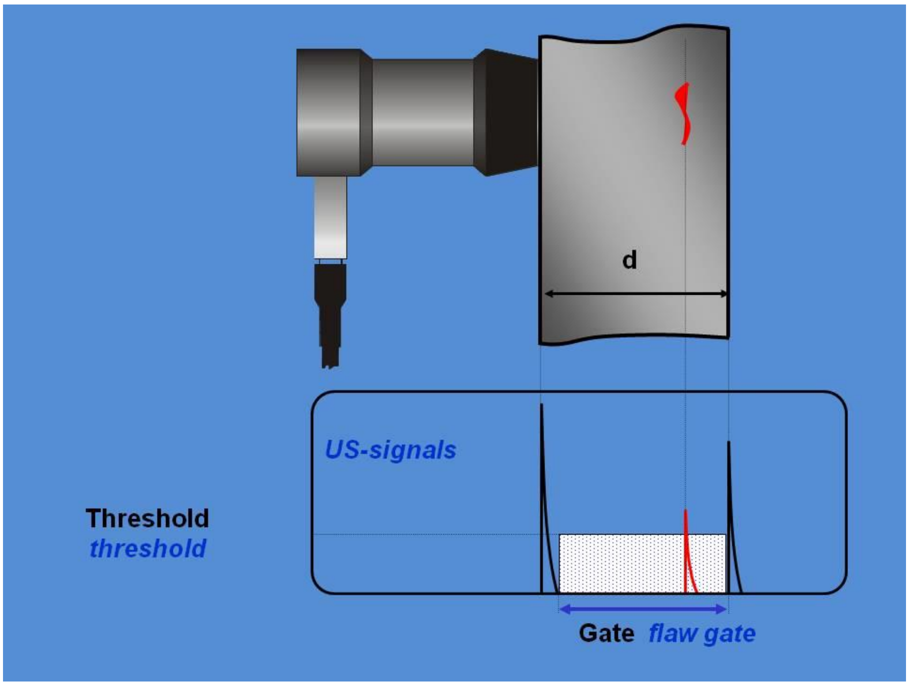

Fig. 6. The control with echo impulse

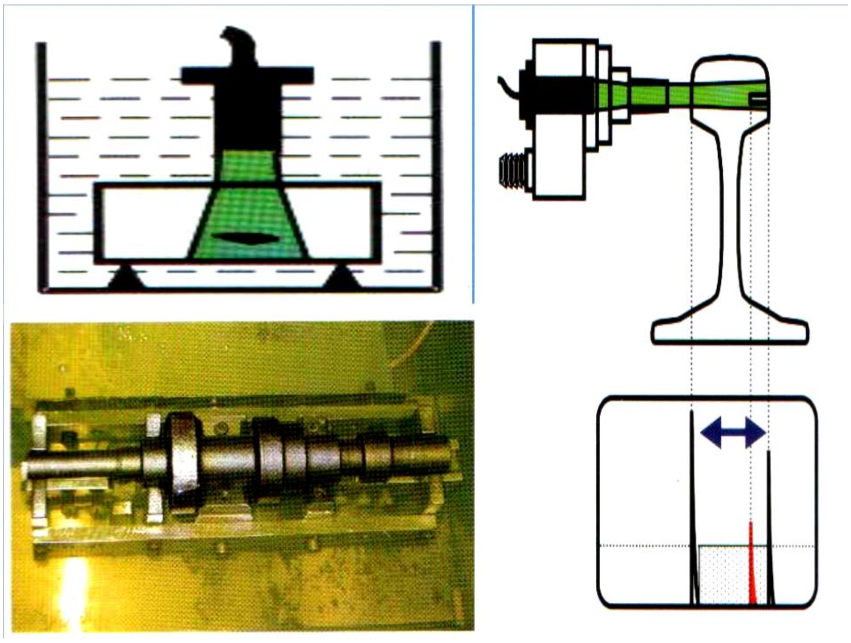

Fig. 7. Non destructive control with ultrasounds in immersion

About the Method of Non Destructive Control with Ultrasounds in Immersion

Air is the bad conductor of ultrasound. Therefore, the best ultrasonic coupling medium with the control piece is water. Normally, the control can only be done with a track piece. Figure 7 shows two applications of the immersion method for various axes as well as the control of the railway tracks. Both installations were produced by Karl Deutch.

In principle, ultrasound is reflected by any surface and any internal defect. In most cases the same transducer emits and receives ultrasounds. Ultrasonic pulses are converted into electrical signals displayed on the screen. The amplitude of the reflected signal is somewhat proportional to the magnitude of the fault. Sonic track time gives us information on the location of the fault. The front and bottom surfaces give great echoes. The control area is framed into an electronic gate within which only failures will be evaluated. A threshold is set which determines whether the defect found is critical. The size of this threshold is usually determined using either the echo amplitude of a known reflector, such as the bottom echo, or the echo resulting from an artificial defect (Cao *et al*., 2013; Dong *et al*., 2013; De Melo *et al*., 2012; Garcia *et al*., 2007; Garcia-Murillo *et al*., 2013; He *et al*., 2013; Lee, 2013; Lin *et al*., 2013; Liu *et al*., 2013; Padula and Perdereau, 2013; Perumaal and Jawahar, 2013; Petrescu and Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e, 2016a; 2016b; 2016c; 2016d; 2016e; 2013; 2012a; 2012b; 2011; Petrescu *et al*., 2009; 2016a; 2016b; 2016c; 2016d; 2016e; Petrescu and Calautit, 2016a; 2016b; Reddy *et al*., 2012; Taboković *et al*., 2013; Tang *et al*., 2013; Tong *et al*., 2013; Wang *et al*., 2013; Wen *et al*., 2012; Antonescu and Petrescu, 1985; 1989; Antonescu *et al*., 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001; Mirsayar *et al*., 2017).

Total Immersion Control

Air is the bad conductor of ultrasound. Therefore, the best ultrasonic coupling medium with the part to be controlled is water. Normally control can only be done with track piece (Fig. 7).

Partial Immersion Control

Automatic ultrasonic control can often be performed in the case of a partial immersion of the parts to be controlled. Only a small portion of the piece is immersed. The round pieces are spinning until the entire surface of the piece is explored (Fig. 8).

HRP Control System

Partial immersion control and high speed control. Rods or bars have axial movement through the immersion chamber (Fig. 9).

Interstitial Coupling with Water

Another method of ultrasonic coupling with controlled parts uses supports for transducer guides. The ultrasound spreads to the control piece through a full of water (Fig. 10).

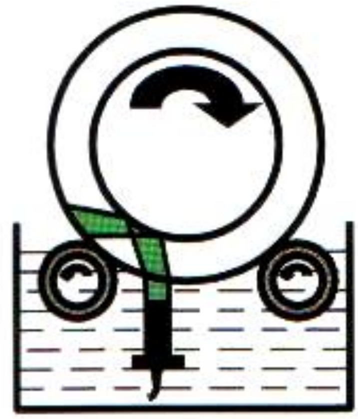

Fig. 8. Partial immersion control

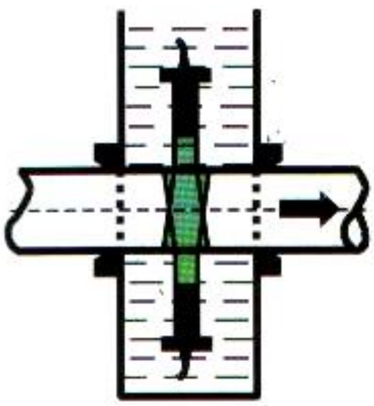

Fig. 9. HRP control system

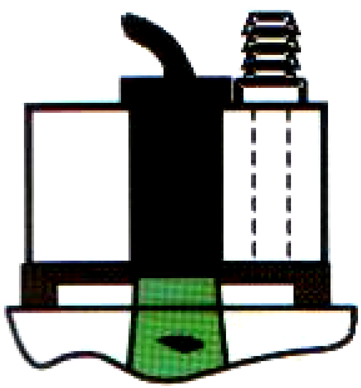

Fig. 10. Interstitial coupling with water

Directional Water Jet Coupling

For this type of coupling the volume of mechanical components is higher. The transducer support provided with the water jet guidance system is guided to the surface of the work piece by means of soles or rollers. This method reduces wear and shortens calibration times (Fig. 11).

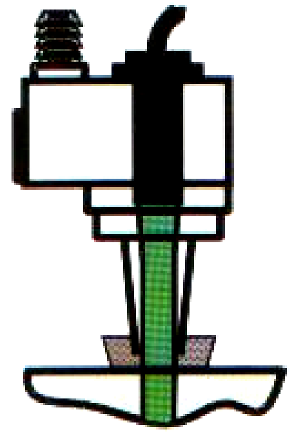

Fig. 11. Directional water jet coupling

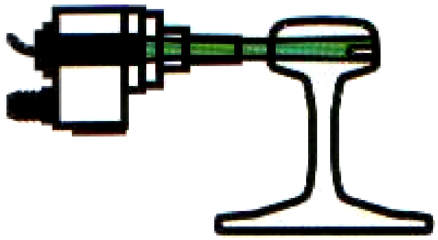

Fig. 12. Water jet coupling, free

Fig. 13. STPS-bar control system

Water Jet Coupling, Free

For complicated profiles, such as rail rails, very good calibration times are obtained using slightly more complicated transducer struts. A free, water jet, a few centrifuges, between the rubber tube and the control piece, ensures the transmission of ultrasounds (Fig. 12).

STPS - Bar Control System

Characteristic for this system is the high speed of control correlated with a special mechanical robustness. Nine transducers provide a wide control coverage. Defects are detected in the central area and immediately below the surface. Round or hexagonal profiles can be controlled with the same settings. You can also control square or flat profiles (Fig. 13).

KNPS-Control System for Billets

Large deviations from the repeatability of the parts to be controlled require a great flexibility in the positioning of the US transducers. The supports of these transducers are guided, on the surfaces of the parts, with soles or rollers. As with the STPS system, water jet coupling is used (Fig. 14).

RPS/RPT-Pipe Control

Pipe control requires many directions of incidence. Pipes typically rotate. Longitudinal defects are detected by transmitting ultrasounds in circumferential directions. The transverse defects are detected by the proper inclination of the transducers relative to the pipe axis. The large number of transducer mounts required the design of a compact control system. Controls for the control of pipes or cylinders differ very little (Fig. 15).

HRP Pipe and Bar Control System

A high control speed can be achieved if the parts to be controlled do not rotate. Neither the control tanks rotate. The immersion control boxes contain the transducer bearing boxes. The entire control area is covered by transducers with curved surfaces (Fig. 16).

SCHN Rail Control System

Almost all rail profile is covered with US freely positionable transducers. Water jet coupling leads to short adjustment times and low mechanical wear (Fig. 17).

Welding Control System

Welded pipes can also be controlled automatically. Small diameter pipes are ERW type. Large diameter pipes of the SAW type can be welded longitudinally or spirally. Use solenoid and/or water jet coupling (Fig. 18).

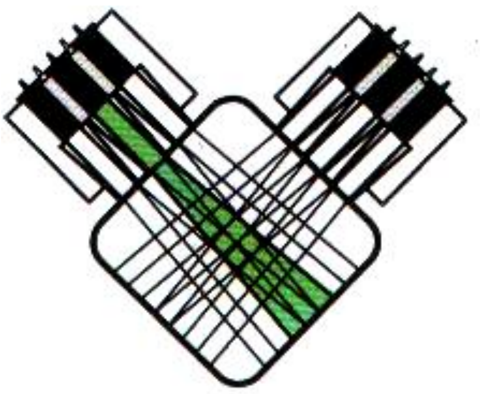

Fig. 14. KNPS-control system for billets

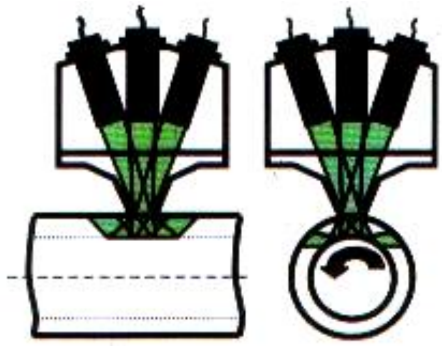

Fig. 15. RPS/RPT-pipe control

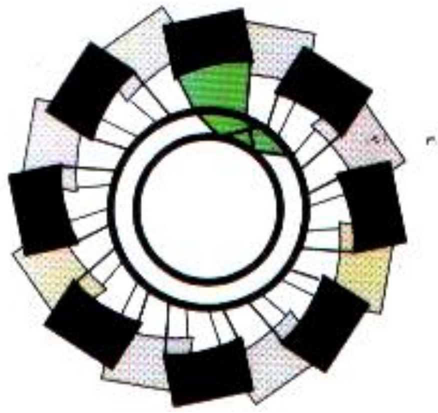

Fig. 16. HRP pipe and bar control system

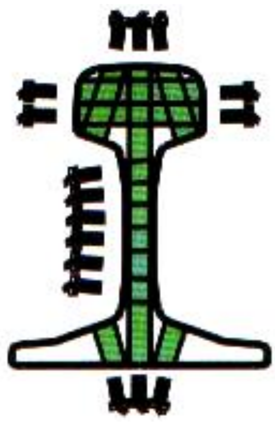

Fig. 17. SCHN rail control system

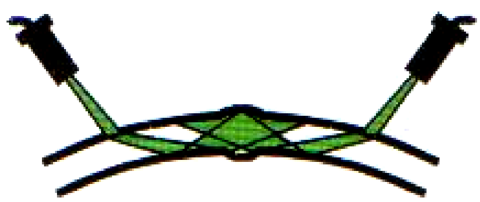

Fig. 18. Welding control system

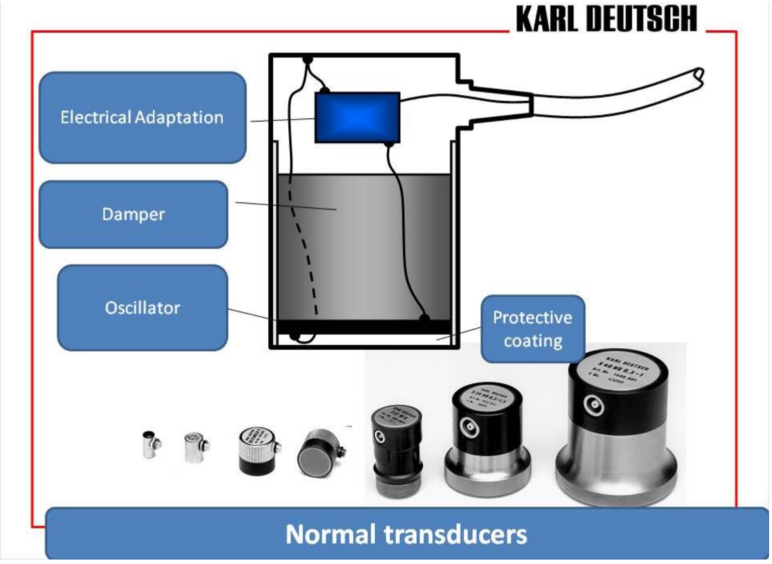

Fig. 19. A normal transducer composing

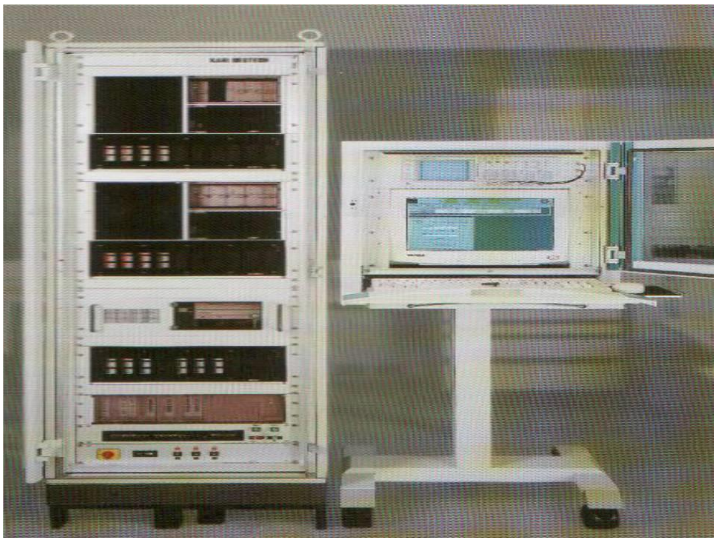

Fig. 20. ECHOGRAPH-ultrasonic electronics

Composing a Normal Transducer of Longitudinal Waves

In principle, a fingerprint transducer (Fig. 19) consists of an oscillator (a crystal of a special material that has the property as the variation of the electric current that crosses it changes its size by emitting ultrasonic waves and vice versa under the effect of the sonic pressure modifying its size emitting a current electric - piezoelectric effect).

In Fig. 20 one can see an ECHOGRAPH - ultrasonic electronics.

Modern digital electronics can command a multi-channel control system.

The current version of the electronic digital system ECHOGRAPH offers a wide variety of freely programmable parameters.

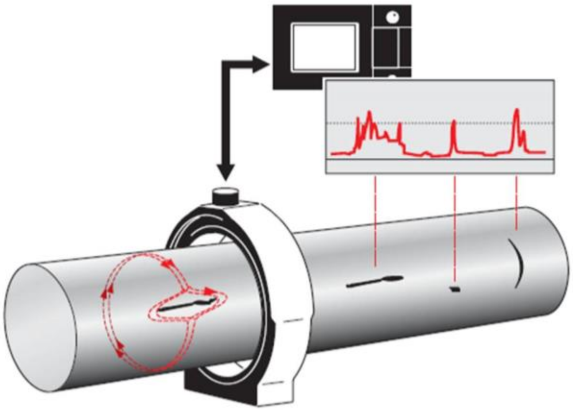

Fig. 21. The control coil

It is important for the beneficiaries to use up to four control gates.

Each control gate can evaluate the echoes after three different thresholds.

The weakest signals may be amplified by more than 100 dB.

High repetition frequency and frequency bandwidth are two common things for this system. In addition, he uses a noise suppression algorithm (Cao *et al*., 2013; Dong *et al*., 2013; De Melo *et al*., 2012; Garcia *et al*., 2007; Garcia-Murillo *et al*., 2013; He *et al*., 2013; Lee, 2013; Lin *et al*., 2013; Liu *et al*., 2013; Padula and Perdereau, 2013; Perumaal and Jawahar, 2013; Petrescu and Petrescu, 1995a; 1995b; 1997a; 1997b; 1997c; 2000a; 2000b; 2002a; 2002b; 2003; 2005a; 2005b; 2005c; 2005d; 2005e, 2016a; 2016b; 2016c; 2013; 2012a; 2012b; 2011; Petrescu *et al*., 2016; 2009; Reddy *et al*., 2012; Tabaković *et al*., 2013; Tang *et al*., 2013; Tong *et al*., 2013; Wang *et al*., 2013; Wen *et al*., 2012; Antonescu and Petrescu, 1985; 1989; Antonescu *et al*., 1985a; 1985b; 1986; 1987; 1988; 1994; 1997; 2000a; 2000b; 2001; Mirsayar *et al*., 2017).

The Non-Destructive Control Method with Swirling Currents

Electromagnetic Method

The control coil (primary winding; Fig. 21) generates an alternating magnetic field that induces an electric current, the so-called "eddy current," in the control-piece.

The presence of a defect on the surface of the piece produces a 'disturbance' in the electric circuit detected by the coil and transmitted to the oscilloscope where it can be evaluated according to the threshold.

Pipe, bar and wire producers, in order to meet the continuous demands of the beneficiaries to increase the quality of their products, require and use quality assurance systems that can meet these requirements. In order to stay at the top of these conditions, metallurgy manufacturers use fully automated non-destructive control methods, which, based on reliable resolutions, certify the quality of the controlled products.

The overriding concern of manufacturers is to optimize the production process to reduce stops and scrapes during manufacture.

Eddy current control is one of the most important control methods for the semi-finished industry.

Regardless of the control speed, cool or hot materials can be fully integrated into the control line. Immediate reporting on product quality, ensures immediate recognition of worsening production and remedial action.

Eddy current control installs quickly, is easy to serve and provides information that you can rely on at any time.

Circumferential control and segmented coil welding and magnetization unit.

Results

It displays the defect during calibration with a square standard (Fig. 22).

At the end of the test, the installation computer issues a noticeable B (B-scan) control bulletin for round and square bars in which the defect acceptance thresholds (line to the limit of the two colors) are visible, as well as their position along the length and in depth reported by each touch probe (Fig. 23).

A robotic system usually consists of a mechanical manipulator, a final effector, a microprocessor based on a controller, a computer and other devices.

Six-axis robots have traditionally been used on production lines to move the end effector between two points where the path was not very important. Generally, the end effector was moved manually until the robot taught it. Then repeat the movement in that position and orientation whenever the application requested it. More recently, the technical capabilities of the present (couples, motors, software) have made the robots more flexible and smarter and can perform more complex tasks.

The use of Ultrasonic Testing (UT) robots offers great flexibility for US inspections, with fast control and efficiency, especially for controlling large geometry complexity pieces. However, it was necessary to develop appropriate software to integrate the robots with the latest generation control tools. Trajectory planning (trajectory or path generation) for NDT control, is a very specific task. Commercial software for off-line robot programming stems from the need to flexibly handle manipulators to perform various traditional machining operations (turning, welding, drilling, etc.). As a result, many commercial software applications for off-line programming of robots are expensive tools that incorporate a lot of CAD/CAM functions with unnecessary purposes and features. Despite the abundance of features, a software trace-generating program of commercial software should usually be subject to change before all the necessary NDT inspection requirements are met. A number of problems are often present in the original trajectory being generated by software functions specifically generated for processing and production operations, rather than for ND tasks.

There are significant complications when it takes two or more robotic arms to be synchronized in order to perform a certain NDT inspection. Ultrasonic Transmission Technology (UTT), for example, uses two transducers: One transmitter and one receiver; The receiver being placed on the opposite side of the component and faced by the transmission probe. Currently, many commercial software (such as Del Cam and Master Cam) do not support robots working in tandem. Fast Surf allows partial synchronization of robotic movements (for example, at the beginning or end of complex trajectory points) using I digital/O signals, but synchronization is not complete over the full path required for the UTT technique. Ultrasounds have the advantage of good penetration of materials and the fact that they are not a polluting method. Robots have the advantage of very good flexibility, so they can use both the advantage of robots and ultrasound control for applications of this type in aviation and beyond (Fig. 24).

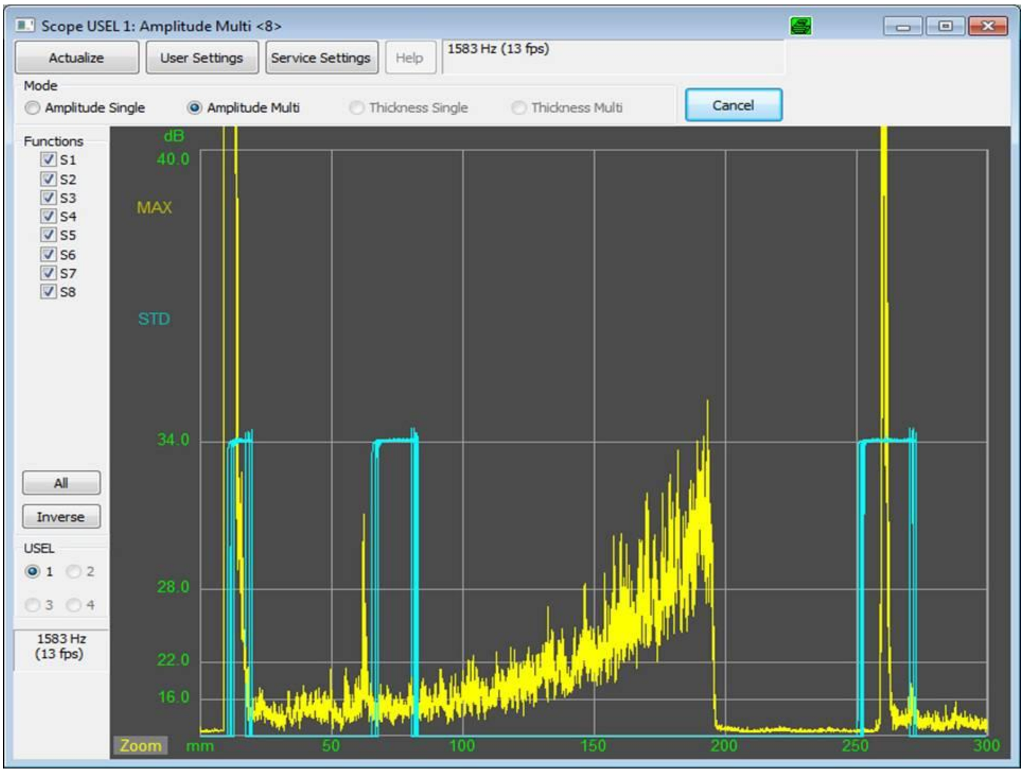

Fig. 22. Scanning a defect during calibration with a square standard

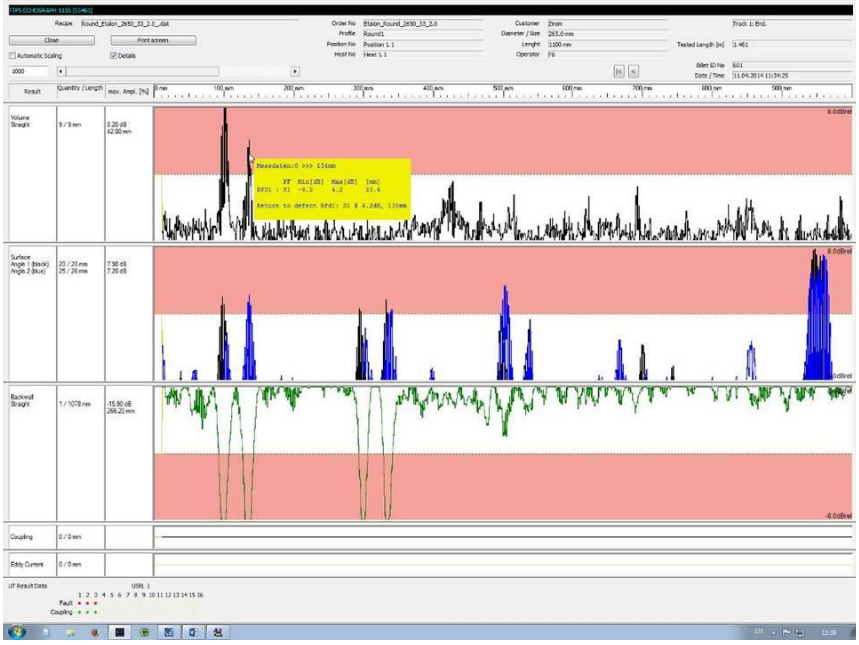

Fig. 23. At the end of the test, the installation computer issues a noticeable B (B-scan) control bulletin

Fig. 24. Robots in ultrasonic testing of aircraft turbine blades

Discussion

The development and diversification of machines and mechanisms with applications in all fields requires new scientific researches for the systematization and improvement of existing mechanical systems by creating new mechanisms adapted to modern requirements, which involve increasingly complex topological structures.

Although not applicable in any situation, there may be advantages in using industrial robots in ultrasound systems, instead of traditional Cartesian scanners based on Robot Gantry type. Robots have excellent stiffness and repeatability-they are also available for short delivery and at an economical cost because they are widely used.

In the past, there have been limitations in the use of industrial robots in the field of ultrasonic testing due to low positioning feedback and the generation of disturbing "noise" by the servo drive systems of the engines. Currently, these limitations have been exceeded with a unique single control system of movement.

Conclusion

This paper describes an application of industrial robots that gain ground mainly in the aerospace industry. It is a TTT manipulator whose task is to automatically position the end-effector, in this case a complex sensor system and a eddy-current probe in the position set by the software application for testing by non-destructive ultrasound control of tickets and bars of titanium, both round and square, or any other transparent ultrasound metal (obviously in a certain range of sizes). For surface control, the effector also includes a Eddy current (Eddy current control system). The installation performs ultrasonic control by the echo boost method in total immersion using as a water coupling medium. This method provides the best coupling for automated control systems. This plant was specially produced for ZIROM S.A. A unique producer of titanium ingots in Romania by the reputed German company Karl Deutch (leader in this field), the founder of the company being also one of the inventors of the non-destructive ultrasonic control method, the part of Eddy current being produced by the German company Prüftechnik. This paper aims to explore the state of the art of non-destructive automatic ultrasonic control techniques according to the possible methods to be adopted, by the applications that demand such methods, by reviewing a series of installations more or less similar to those of Zirom s.a. It is thus found that there are a multitude of pine technical solutions that can be done with an ultrasonic automatic control and precision. In this context, the last chapter of the paper that attempts to probe the possible evolution of the future of US control in this field is of great importance because in the current pace of innovations in all fields, but especially in IT and electronics, the future holds many surprises.

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2-Contract research integration. 19-91-3 from 29.03.1991; Beneficiary: MIS; TOPIC: Research on designing mechanisms with bars, cams and gears, with application in industrial robots.

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4-Labor contract, no. 35/22.01.2013, the UPB, "Stand for reading performance parameters of kinematics and dynamic mechanisms, using inductive and incremental encoders, to a Mitsubishi Mechatronic System" "PN-II-IN-CI-2012-1-0389".

All these matters are copyrighted! Copyrights: 394-qodGnhhtej, from 17-02-2010 13:42:18; 463-vpstuCGsiy, from 20-03-2010 12:45:30; 631-sqfsgqvutm, from 24-05-2010 16:15:22; 933-CrDztEfqow, from 07-01-2011 13:37:52.

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All the authors contributed equally to prepare, develop and carry out this manuscript.

Ethics

This article is original and contains unpublished material. Authors declare that are not ethical issues and no conflict of interest that may arise after the publication of this manuscript.

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