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Sectoral Operational Programme "Increase of Economic Competitiveness"

"Investments for your future"

Regional Centre for the Determination of the Characteristics and Monitoring of the Technical State of OCTG – Oil Country Tubular Goods

Within the *Mechanical Engineering Department* of the *Petroleum-Gas University of Ploieşti*, a complex acquisitions project, co-financed by the *European Union* throughout the *European Regional Development Fund*, on the basis of the financing contract ***POSCCE-A2-O2.2.1-2009-4***, in the framework of the *Sectoral Operational Programme "Increase of Economic Competitiveness"* (***POSCCE*** *– Programul Operaţional Sectorial "Creşterea Competitivităţii Economice"*), has recently been implemented, in the period September 2010 – September 2012.

The project with the title "***Regional centre for the determination of the characteristics and monitoring of the technical state of OCTG – oil country tubular goods***" – ***CRDPMTP*** ("***C****entru* ***r****egional de* ***d****eterminare a* ***p****erformanţelor şi monitorizare a stării tehnice a* ***m****aterialului* ***t****ubular utilizat în industria* ***p****etrolieră"*) has been managed by a team led by *Prof. Vlad Ulmanu* (director, who had the initiative of the project), seconded by *Prof. Gheorghe Zecheru* (publicity and relationship with the social-economic environment), *Prof. Marius Petrescu* (logistics), *Assoc. Prof. Gheorghe Drăghici* (development of the mechanical testing laboratory), *Assist. Prof. Marius Bădicioiu* (acquisitions) and *Assist. Prof. Mihaela Călţaru* (financial problems). The same team will coordinate the research activities within ***CRDPMTP,*** involving also other members of the *Mechanical Engineering Department.*

The main purpose of the project consisted of the creation of a regional experimental research centre allowing for the complex testing of all OCTG components, casing, tubing, pipes and fittings (bends, elbows, tees, adapters, etc.) for technological, transmission and distribution used in the petroleum field: drill pipes, drill collars pipelines. The structure of the newly developed experimental research centre is given in the diagram from Figure 1. This research centre provides the necessary conditions for the experimentation of new testing methods and the development of procedures for the monitoring, evaluation and certification of OCTG, which can be integrated in field specific standards and implemented in the manufacturing processes.

CRDPMTP will allow complex research activities regarding OCTG to be performed within the *Mechanical Engineering Department* of our University; from these activities, we can underline the following ones:

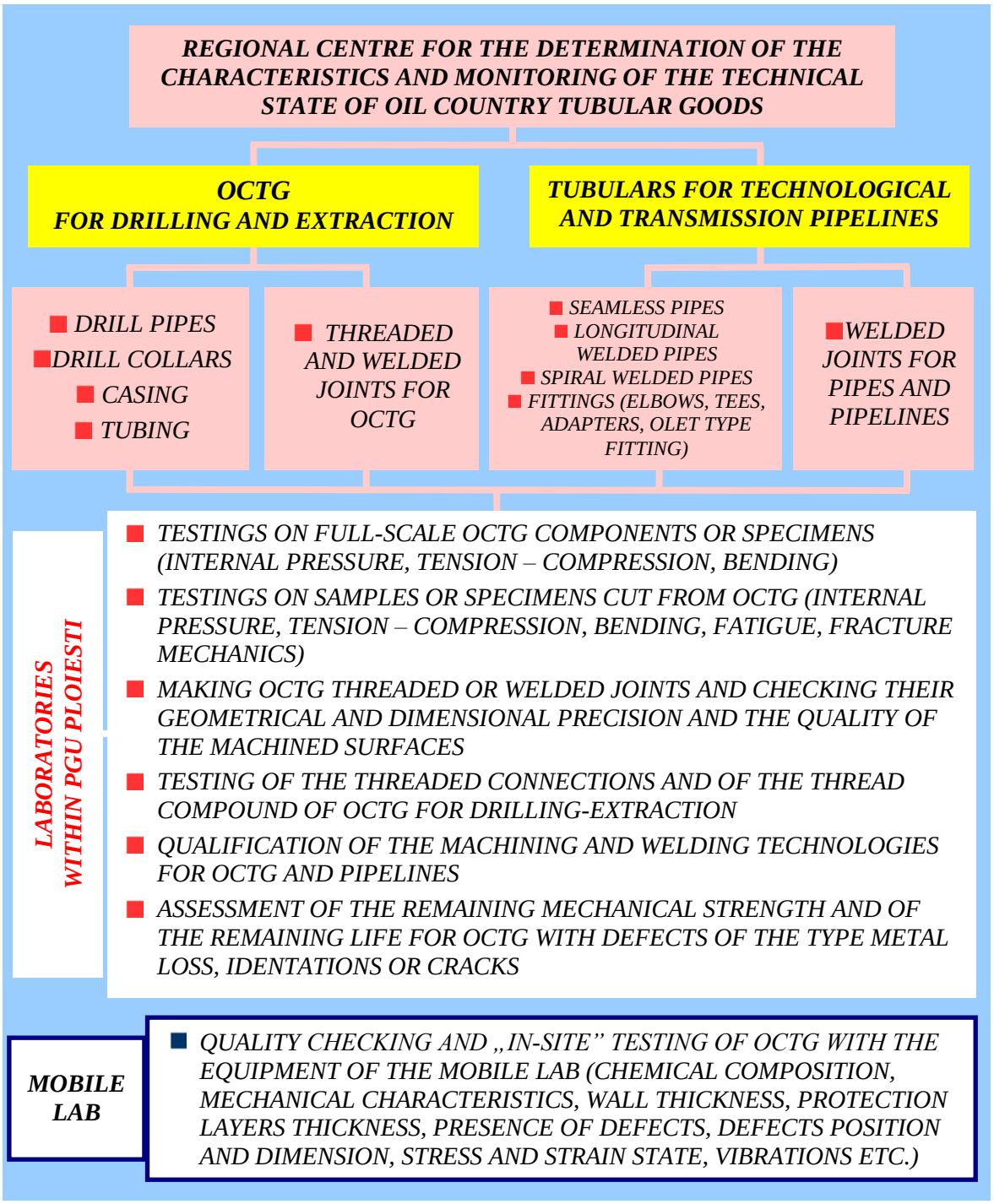


Fig. 1. Structure of the new regional centre - CRDPMTP

- complex research activities and assessments regarding the technical characteristics and performances of OCTG for drilling and extraction;
- improvement of the functional characteristics of the threaded connections used in the petroleum industry;
- evaluation of the technical state, residual mechanical strength and remaining operating life of transmission pipelines (with various types of defects);
- assessment, using analytical and numerical methods, of the state of stress and strain

generated in OCTG under complex loading conditions, including: threaded connections, welded joints, components used for pipelines repair;

- structural integrity evaluation and technical risk assessment for OCTG, based on the experimental determination of the mechanical characteristics;
- researches regarding new technologies for OCTG manufacturing, including the efficiency of the mechanical processing for OCTG;
- researches regarding the reliability and efficiency of OCTG connections;
- researches regarding the environmental impact of the materials and technologies used for OCTG manufacturing.

The research centre for OCTG is organized in the following laboratories, hosted in eight rooms which have been modernised to that purpose within the project:

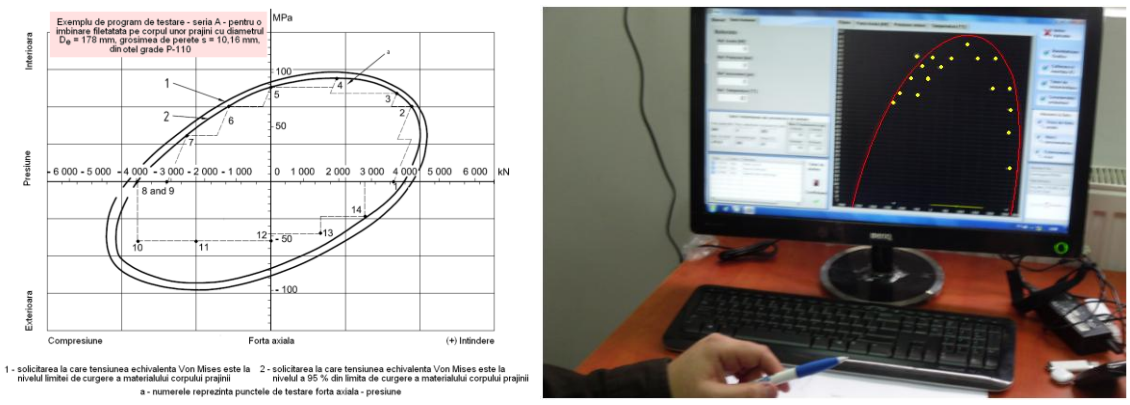
1. ***Laboratory for complex mechanical testing of OCTG*** (the main laboratory of the Centre), equipped with an installation for complex testing of OCTG under combined loads, the unique one in Romania capable of performing the complex testing procedures recommended by ***ISO 13679***, a make up / break out testing machine etc. These equipments are briefly described below (it has to be mentioned that the first three items, the most impressive installations from *CRDPMTP*, have been designed and manufactured in our country with the help of specialists from our University):

   - *Installation for complex testing of OCTG under combined loadings* (traction/compression, bending, and internal/external pressure – see fig. 2), with the axial loading capacity of 4 MN, the internal/external pressure loading capacity up to 225 MPa and the maximum bending force of 1.5 MN. This installation can perform static tests under traction/ compression, internal pressure and bending loads, applied independently or in combination, simultaneously or successively, on full scale OCTG specimens or full scale threaded connections for OCTG, with the outside diameter (OD) values between 50 ... 500 mm (2 ... 20 in) and the length of 400 ... 5000 mm. External pressure loadings can also be applied with the help of an additional pressure chamber described below (fig. 4,b). Our installation can perform experimental test programs in which the specimens with threaded connections are subjected to complex loadings, consisting of the successive application of standard combinations of mechanical loads, as per ***ISO 13679*** (see fig. 3,a); a threaded connections passing all testing series validates its appropriate behaviour during exploitation and represents the basis for the qualification of the existing or new types of threads. The installation is completed with a *command and data acquisition laboratory*, provided with specialised equipment and dedicated software (fig. 3), including video equipment for recording and visualizing the tests through which all the components of the installations for complex mechanical testing and for collapse testing are operated and supervised, and which ensures the acquisition, storage, management, processing and interpretation of all data obtained during OCTG testing;

   - *Installations for external pressure (collapse) testing of OCTG* (for drilling – extraction and pipelines – see fig. 4), provided with three pressure chambers (5 in; 8 in and 10 in), capable of testing tubulars with the outside diameter between $2^{3}/_{8}$ ...10 in, and threaded connections up to $9^{5}/_{8}$ in, at a nominal pressure up to 150 MPa (maximum: 225 MPa). The external pressure can be applied either as a separate, unique load (using the 10 in pressure chamber – fig. 4,a) or in combination with traction/compression and/or bending loads, applied by the installation for complex testing of OCTG (using the 5 in or 8 in pressure chamber – fig. 4,b – mounted on the complex testing installation – fig. 2);

   - *Make up / break out testing machine* (fig. 5), with controlled torque (maximum torsion moment 68 kNm), for OCTG with outside diameters up to 23⅜ in and the length up to 2000 m, equipped with automating recording of the torsion moment. This machine

Fig. 2. Installation for testing OCTG under combined loadings



a **b**

Fig. 3. Equipment and software for data acquisition during OCTG complex mechanical testing:
a – scheme of a complex test series for OCTG threaded connection, according to *ISO 13679*;
b – PC while running the software for data acquisition and tests supervision.

a **b**

Fig. 4. Installations for external pressure (collapse) testing of OCTG:
a – 10 in pressure chamber (for separate collapse testing);
b – pressure chamber for testing in combination with other loadings.

Fig. 5. Make up / break out testing machine

performs the continuous making up of the threaded connection until a given torsion moment is reached and the continuous breaking out of the threaded connection at a value of the moment allowing for an easy breaking out by hand of the connection;

- *Installation for mechanical testing of polyethylene pipes, BLUE LINE* model, capable of performing static tests under constant internal pressure and temperature, using water as both pressurizing (interior) and thermostatic (exterior) environment, on full scale PEHD pipe specimens with the outside diameter 16...630 mm, with the maximum working pressure of 20 MPa (fig. 6);
- *Microscope for threads* which can control the profile of the threads / threaded connections used for OCTG (fig. 7), having a maximum loading capacity of the table of 130 kg and being able to measure specimens with the diameter up to 250 mm (magnification 10x) or 100 mm (magnification 100x).

1a. ***Destructive testing laboratory***, equipped to perform the following tests: tensile test, compression test, bending test, fatigue test (alternating and oscillating cycles, low fatigue cycle), fracture mechanics static and dynamic tests (determination of K_{Ic}, K_{Id}, J_{Ic} and da/dN), impact bending test to determine the impact energy and transition temperature. This laboratory is provided with the following *destructive testing equipments*:

- *static and dynamic universal testing machine Walter Bai LF300*, with the loading capacity up to 300 kN (fig. 8,a);
- *Charpy pendulum impact testing machine Walter Bai 450* with the maximum impact energy of 450 J (fig. 8,b) (provided with ultra cryostat for cooling the specimens in order to determine the ductile-brittle transition temperature);
- two *rotary bending fatigue testing machines Walter Bai* with the maximum bending moment of 20 Nm / 60 Nm (provided with furnace for heating the specimens up to 800^{o}C).

1b. ***Intelligent modular equipment for the control of OCTG structural integrity***, equipped to perform the following tests: samples preparation and examination using optical and electronic microscopy of metallic and non-metallic materials structure; quantitative analysis of chemical elements in solid samples of alloys with Fe, Al, Cu, Ti base; micro-hardness testing of the constituents and phases within the materials structure. This equipment is provided with the following modules:

- *Scanning electron microscope* (SEM) – *Hitachi* (fig. 9), with conventional cathode, intended for the microscopic study of the structure and surface of various materials, with the possibility of determining the chemical composition and the phases of their structure;
- *Laboratory spectrometer with optical emission – FOUNDRY MASTER PRO*, for the quantitative analysis of chemical elements in solid samples; it is provided with an optical system based on CCD (Charge Coupled Device) technology, to be able to have an unlimited number of measuring channels and flexibility for adding future calibrations;
- *Micro-hardness tester – DURASCAN 20*, for the determination of Vicker and Knoop micro-hardness of metallic and non-metallic materials;
- *Digital ferrite-meter – MF 300F+AC*, for the non-destructive determination of the ferrite content of welded connections and parts made of various alloys (stainless and heat-resistant steels of the austenitic and austenitic – ferritic type), according to EN ISO 8249 or equivalent;
- *Infrared thermal imaging camera – FLIR E50* (-20°C … 600°C), for the identification of the hot spots of OCTG and of the mechanical systems within the petroleum equipment, by means of distance thermal scanning;
- *Equipments for sampling and preparing metallographic samples*: abrasive cutting machine for metallographic samples – *SERVOCUT-301MM*; automatic grinding and

polishing machine for metallographic samples – *Forcipol 2V*; automatic mounting press for metallographic samples – *Ecopress 100*; grinding machine for steel sampling preparation for spectral analysis – *Spectral 350*; electrolytic polishing and etching machine – *Polisec C25*.

Fig. 6. Installation for mechanical testing of polyethylene pipes

Fig. 7. Miscroscope for threads

2. ***Laboratory for scientific research in the field of intelligent control technologies of oil and gas transmission pipeline systems***, provided with the following equipments:
   - *Stand for researches regarding the intelligent control of OCTG*, consisting of a *portable guided waves electromagnetic / magnetostrictive generator MSSR3030R*, provided with a

portable system for control (defects detection), data acquisition, processing, analysis and storage, including a licensed software for data acquisition, processing, evaluation and storage, dedicated for OCTG inspection and monitoring, magnetostrictive transducers set; it is used for non-destructive control of OCTG under operation in the petroleum and petrochemical industry (OCTG for drilling and extraction with 2 ⅜ ... 20 in OD; steel transmission and distribution pipelines for gas – 1 ... 40 in OD – and liquid petroleum products – 1 ... 20 in);

- *Intelligent equipment for dimensional control of OCTG* (modular PIG equipment), *OMNISCAN MX PA/ECA-OLYMPUS*, provided with a portable control unit and the examination modules: *MX PA16:128*, using the non-destructive control methods *Ultrasonic Phased Array* (UT-PA), *Ultrasonic Conventional* (UT) and *Ultrasonic Time Of Flight Diffraction* (UT-TOFD); *MX ECA32*, using the methods *Eddy Current Conventional* (EC) and *Eddy Current Array* (ECA). This equipment is used for the dimensional control of the cross-section of OCTG for drilling – extraction and for technological and transmission pipelines (1 ...40 in), the identification and localization of dimensional defects, the non-destructive dimensional analysis, manual and automatic, of the imperfections and defects, thickness mapping and the analysis of defects due to the corrosion of OCTG used in the petroleum and petrochemical industry, in operating conditions.

3. ***Mechanical processing laboratory*** (fig. 10), equipped with machine tools and CNCs, and also with apparatus for the precision control of the machined parts, making possible the manufacture of OCTG prototypes for drilling – extraction, with different alternatives of threaded heads, and ensuring the manufacture/cutting of specimens for the mechanical tests performed and the quality qualification of the products manufactured in this lab. The following machine tools have been acquired: CNC vertical machining centre *Agma VMC-137G*; CNC horizontal lathe *Topper TNL-130AL*; CNC horizontal lathe for pipe manufacturing *L&L LS1000x900*; CNC horizontal teach-in lathe *Baron Max KL-2460*; water jet cutting machine *Wuxi YCWJ-380*.
4. ***Mobile laboratory for non-destructive testing of OCTG*** (*Crafter GP 35LR Volkswagen* – fig. 11), equipped, among others, with the followings: *MGC Plus* system for automatic acquisition of data for electro-resistive tensometry tests; *ROCKY TH-160* portable hardness tester; *PMI Master pro* mobile spectrometer; *HBDV-IIIU* rheometer; *OLYMPUS 38DL Plus* digital ultrasonic apparatus for thickness measuring; *OLYMPUS EPOCH 1000I* ultrasonic non-destructive tester. The mobile lab allows for in-field tests, on operating OCTG, for the determination of the chemical composition, the mechanical characteristics (including toughness), the wall thickness, the thickness of corrosion protection layers, the geometrical characteristics of flaws or defects of the type metal loss, denting and crack identified on OCTG, the causes of inadequate behaviour of OCTG and the magnitude of the technical risk attached to the OCTG use.

The research center has also been provided, during the project, with hardware facilities (11 PCs, two laptops, a plotter, an *IMAGO* graphic workstation, 3 portable data acquisition systems, 13 UPSs, three Zyxel type switches) and with the following software licenses:

- finite elements analysis software: ANSYS Academic Research – multiple license with 5 tasks (working simultaneously), including TECS (Technical Enhancements and Customer Support); 8 ANSYS Academic Research HPC add-on lincenses with TECS;
- CAD software: Autodesk Inventor Professional 2012 Commercial New NLM;
- CAM software: ENEDU-O (Edgecam Educational on single user key);
- CNC software: ENEDU-S (Edgecam Solid Machinist for education);
- data acquisition software: CATMAN AP.

a **b**

Fig. 8. Equipments for destructive testing:
a – static and dynamic universal testing machine; **b** – Charpy pendulum impact testing machine.

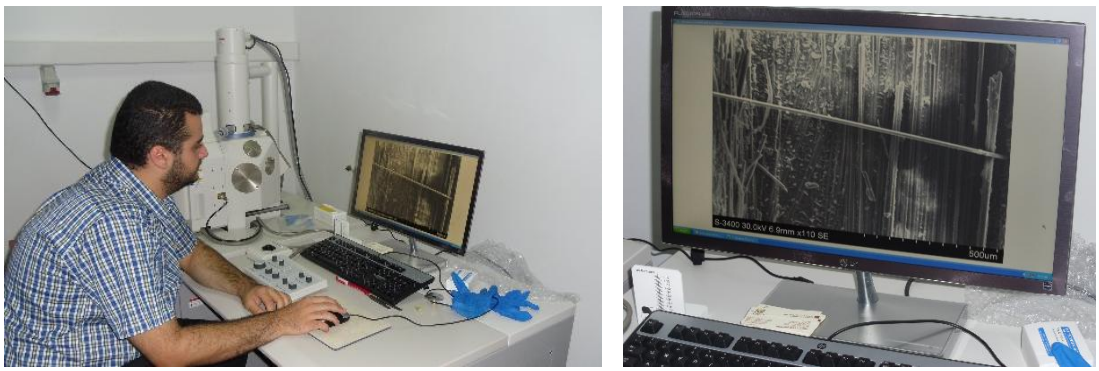


Fig. 9. Scanning Electron Microscope

Fig. 10. Machine tools and CNCs for mechanical processing

Fig. 11. Mobile laboratory for non-destructive testing of OCTG

More than 80 commercial societies, companies and design institutes or research centres from Romania can range within the category of the potential beneficiaries of our research centre. The number of the potential clients increases considerably if we take into account the research teams from other Universities and the students (B. Sc., M. Sc. and Ph. D., from both the Petroleum-Gas University of Ploieşti and Universities in Romania and abroad) that will be able to carry on experimental research programs in the laboratories of the new *Regional centre for the determination of the characteristics and monitoring of the technical state of OCTG*.

For detailed information regarding the capabilities and competences of the experimental research centre and the possibilities to use it, based on collaboration protocols or contracts, please contact the management team using the following *contact information*:

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Centru **r**egional de **d**eterminare a **p**erformanţelor şi monitorizare a stării tehnice a **m**aterialului **t**ubular utilizat în industria **p**etrolieră – CRDPMTP

Rezumat

În cadrul Departamentului de Inginerie Mecanică al UPG Ploieşti, s-a încheiat recent, în cadrul POSCCE, un program complex de achiziţii, cofinanţat de Uniunea Europeană prin Fondul European de Dezvoltare Regională, cu titlul de mai sus. Obiectivul principal al proiectului a constat în crearea unui centru de cercetări experimentale care să permită ***testarea complexă a comportării componentelor de material tubular petrolier*** *(prăjini de foraj, prăjini grele, burlane de tubaj, ţevi de extracţie, ţevi şi fitinguri – coturi, curbe, teuri etc. – pentru conductele tehnologice, de transport şi de distribuţie) la acţiunea solicitarilor simple sau combinate din exploatare, evaluarea caracteristicilor de utilizare a acestora, monitorizarea comportării lor în exploatare, certificarea calităţii şi emiterea unor soluţii constructive şi tehnologice pentru diverse tipuri de material tubular.*

CRDPMTP, organizat în mai multe laboratoare (a se vedea schema din fig. 1), este dotat cu echipamente moderne destinate activităţilor complexe de cercetare, dintre care menţionăm următoarele:

- *instalație de încercare complexă a materialului tubular petrolier şi a îmbinărilor filetate ale acestuia (fig. 2 şi 3), ce permite solicitarea simultană sau succesivă a probelor sau componentelor (tronsoanelor) de material tubular cu diametrul exterior de 50 ... 500 mm (2 ... 20 in) la: tracțiune/compresiune (forța maximă – 4000 kN), încovoiere (forța maximă de încovoiere – 1500 kN), presiune interioară/exterioară (până la 2250 bar);*
- *stand destinat încercărilor la presiune exterioară a materialului tubular (fig. 4), dotat cu 3 camere de presiune (5 in; 8 in şi 10 in) care permit încercarea materialului tubular la presiune exterioară, aplicată independent (fig. 4,a) sau combinat (fig. 4,b) cu solicitările la tracțiune şi/sau compresiune dezvoltate de instalația de încercare complexă;*
- *maşină de înşurubat – deşurubat îmbinările filetate ale materialului tubular pentru foraj – extracție (fig. 5) cu diametrul exterior 60 ... 585 mm (2⅜ ... 23⅜ in), cu moment de torsiune controlat (valoare maximă: 6 8000 Nm);*
- *instalație pentru încercări mecanice ale țevilor de polietilenă (fig. 6), ce realizează încercări statice la presiune interioară şi temperatură constante, pe epruvete tip tronson de țeavă din PEHD;*
- *microscopul pentru filete (fig. 7), utilizat pentru controlul profilelor filetelor folosite la materialul tubular petrolier;*
- *echipamente pentru control distructiv, între care o maşină universală pentru teste statice şi dinamice capacitate 300 kN (fig. 8,a) şi un ciocan pendul Charpy (fig. 8,b);*
- *echipament inteligent modular pentru controlul integrității structurale a tubulaturii din industria petrolieră, dotat – între altele – cu un microscop electronic de baleiaj (SEM – fig. 9);*
- *maşini – unelte cu comandă numerică de tip CNC pentru prelucrări prin aşchiere (fig. 10), dotate şi cu aparatură de verificare a preciziei pieselor prelucrate;*
- *laborator mobil (auto) pentru evaluarea stării tehnice a materialului tubular petrolier (fig. 11), ce permite efectuarea de determinări pe teren, pe materialul tubular aflat în exploatare, privind compoziția chimică, caracteristicile mecanice, grosimea de perete etc.*