| BULETINUL Universităţii Petrol – Gaze din Ploieşti | Vol. LXII No. 2/2010 | 1 – 8 | Seria Tehnică |
|---|---|---|---|

# The Utilization of Modern Welding Technologies in the Field of the Petroleum and Petrochemical Equipment Manufacturing and Maintenance

Mihail Minescu

Universitatea Petrol-Gaze din Ploieşti, Bd. Bucureşti, 39, Ploieşti
e-mail: mminescu@upg-ploiesti.ro

## Abstract

*The mechanical equipments and the installations employed by the petroleum and petrochemical industry are complex and have to operate in conditions of high economical efficiency and total safety. That is why some of the most modern materials and technologies are used for their manufacturing. This paper presents the preoccupations and achievements of the teaching staff of the Electrical and Mechanical Engineering Faculty and within the Petroleum-Gas University of Ploiesti in the area of welding and of welding related procedures. The research work performed has been oriented towards adapting some welding procedures and technologies for the manufacturing and repairing of petroleum, petrochemical and refinery equipments, which must work in very severe operating conditions and must have a particular operational safety. The results of the research activities carried out by the specialists from the dedicated departments have been materialized in an important number of products, equipments and technologies, in speciality papers published in scientific journals from Romania and abroad, proceeding papers presented at national and international conferences, patents, specialised university courses, Ph.D. theses etc.*

**Key words:** *welding, hardfacing, oilfield equipment, pipeline, build-up welding*

## Introduction

The mechanical equipments and the installations used by the petroleum and petrochemical industry are complex and must operate in conditions of high economical efficiency and full safety. That is why some of the most modern materials and technologies are used for their manufacturing.

Either the installations and equipments from the field of oil and gas wells drilling and of their exploitation or the transport, storage and processing of crude oil, gas and petroleum products are concerned, the working and exploitation conditions for the equipments are extremely severe. The different elements of the installations and equipment are subjected to important mechanical loads, intensive wear phenomena, in high temperatures conditions and within very aggressive environments. The environmental and loading conditions permanently arises problems regarding the constructive shapes, materials and manufacturing technologies for the equipment. In order to respond in economical conditions to the above mentioned strength requirements, specific constructive and technological solutions are frequently adopted, such as the manufacture in combined construction in which the component parts are assembled using

welding, hardfacing with hard alloys of the surfaces exposed to wear, build-up welding with corrosion resistant alloys of the surfaces exposed to aggressive environments etc.

Within this context, remarkable preoccupations in the field of welding and related procedures have existed and exist inside the specialised Departments belonging to the Electrical and Mechanical Engineering Faculty. The research regarding the applications of the welding technologies and of the related procedures to the increase of the oilfield and petrochemical equipment performances has been a permanent preoccupation. This paper presents the foremost results of the theoretical and applicative research work of the teaching staff in the field of welding, and also the manner in which they are retrieved in the training process of the students, including M.Sc. and Ph.D. students.

## Equipments Having Welded Components or Components Manufactured by Using Related Procedures

The petrochemical and refinery apparatus has continuously developed and improved, due to the technical progress both in the field of the elaboration and processing of metallic materials (especially steels) and in the field of making permanent connections (in particular in the domain of welding and mainly steels welding).

In the framework of crude oil refining and petrochemical installations, an important range of devices are encountered, that is:

- heat exchange devices;
- reactors;
- heating devices with thermal source (boilers, furnaces);
- blending and mixing devices;
- devices for product separation and cleaning;
- storage tanks;
- technological pipelines.

The devices listed above, but especially the ones with thick walls, are made from metallic semi-manufactured products obtained by means of plastic deformation from large dimensions ingots, which contain many defects and determine low levels of the mechanical characteristics of the semi-finished products obtained. Furthermore, the welded connections of the components of these devices implies the use of special welding procedures and the construction of welded joints with a great number of layers and rows, having structures in the seam and in the heat affected zone which necessitates the application of post weld heat treatments to ensure in order to guarantee the physical and mechanical characteristics imposed by the safe operation of the devices.

The technological operations most frequently used in the manufacturing processes of the devices are the mechanical workings, the assembly works and the welding works. The share of the assembly and welding activities represents more than 60% from the activities performed in order to obtain such a device.

In the field of oil and gas transportation, pipelines manufactured from steel pipes, jointed by welding, are currently used. The enhancement of the pressure conditions of the transported fluids have imposed the use of pipes with larger wall thickness, made of steels with superior mechanical characteristics. This situation leads to the necessity to solve more complex technological problems when welding the pipes.

Additionally, the deterioration of the pipelines operating in different working environments and in different loading conditions, presupposes the adoption of uncommon technological solutions

for repairing using welding, particularly when the works must be performed with the pipeline remaining in-service.

The need for the advanced exploitation of the oil and gas resources makes, in the foreseeable future, the volume of drilling works to be continuously growing. Such fact will also lead to an increase of the demand for petroleum equipment (oilfield tubulars, equipment for oil and gas exploitation, sealing system of the valves the petroleum industry a.o.).

It is a known fact that, during the operational process, the components belonging to oilfield equipment (tubulars, drilling bits, equipment for oil and gas exploitation a.o.) are subjected to wear processes. The effects of this complex process are: additional energy consumption, material loss and alteration of the initial state of the contact surfaces.

In order to increase the durability by improving the resistance to wear, in our country but especially at a global scale it is requested that the petroleum equipment (tubulars, drill bits, equipment for petroleum exploitation, sealing systems of the petroleum industry valves a.o.) should be hardfaced with hard materials.

## Achievements of the Specialists from the Petroleum-Gas University of Ploiesti in the Field of Welding and of Welding Related Procedures, with Applications to the Manufacturing and Exploitation of Petroleum Equipment

In the domain of manufacturing and repairing of oilfield tubulars used for the drilling-exploitation activities, the specialists of the Manufacturing Technologies and Industrial Management Department (formerly Petroleum Equipment Manufacturing Technology) have performed important research activities, which have materialized in a significant number of technologies and products that will be itemised in the followings.

- *The manufacturing technology of the drill pipes ∅ 35.5 mm, for prospecting rigs, with tool joints being butt pressure welding, with contact resistance heating*. By means of this technology, important batches of drill pipes have been fabricated within the Micro-production Workshop of the University, according to the orders of the geological prospecting enterprises from our country (Baia Mare, Bucharest, Ploiesti, Tg. Jiu, Câmpulung-Moldovenesc).
- *Technology and installation for heat treatment by HFC quenching, for drill pipes with ∅ 50 mm, with welded tool joints*. In cooperation with the Hot Sectors Research Institute from Bucharest, the **Installation for heat treatment using induction heating with medium frequency electrical current** has been designed and constructed within the Micro-production Workshop of the University**.**
- *The welding technology for the end parts of the pistons for the bore-hole pumps (**Patent No. 95083 - Piston for bore-hole pumps** - OSIM Bucharest).*
- *Internal hardening technology of the cylinders of the bore-hole pumps by means of HFC quenching (it concerns the bore-hole pumps with a unique cylinder having a length of about 5000 mm).*
- **Aggregated machine for the manufacturing of Johnson type spiral filters**, made of shaped wire from stainless steel or carbon steel (see fig. 1). The installation has been patented by OSIM Bucharest, which has issued the **Patent No. 100146/28.08.1989**, with the title **"Machine for filters manufacturing".** According to the project developed within the University, installations for the manufacturing of the Johnson type helicoidal filters have

been constructed, based on cooperation contracts, in more commercial societies from Romania, that is: Stimpex Bucharest, IFLGS Bucharest, Tubulars Base Tg. Jiu.

Using the installations for spiral filters manufacturing, designed and constructed within the Manufacturing Technologies and Industrial Management Department and the Micro-production Workshop, on the basis of some research & development contracts with companies from the petroleum domain and not only, spiral filters with different diameters, made from carbon steel or stainless steel (see fig. 2) and having the applications listed below, were manufactured:

- *filtering elements equipping the oil and gas wells;*
- *filtering elements for drinking and industrial water wells;*
- *filtering elements with ions changing mass from a petrochemical installation;*
- *sea water filtering installation in order to use it as technological water for offshore petroleum platforms, etc.*

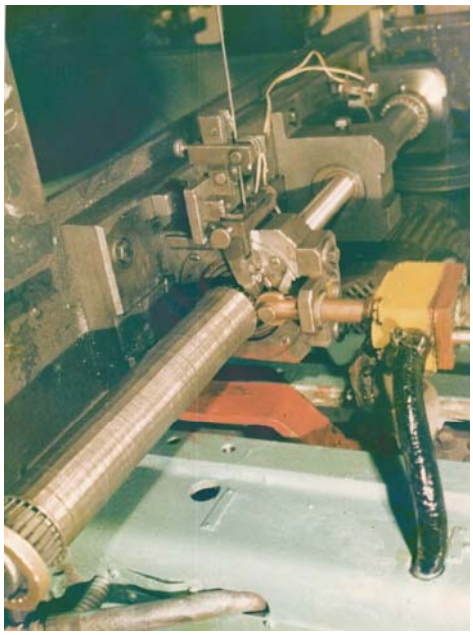

**Fig.1.** Aggregated machine for the manufacturing of Johnson type spiral filters

**Fig 2.** Types of helicoidal filters

- **Friction welding installation**, designed and constructed at the Petroleum-Gas University of Ploiesti, within the Micro-production Workshop. Using this installation, research works have been carried out and welding technologies have been developed for the following products:
  - *high pressure pipelines for oilfield installations having friction welded nipples*, for the enterprise Upetrom - 1st of May from Ploieşti;
  - *the technology for the manufacturing of cutting tools having the active part friction welded to the body of the tool*, for the enterprise UPET from Targovişte;
  - *the manufacturing technology of the tubular sucker rods with friction welded ends*, for the enterprise Sterom from Câmpina;
  - *the manufacturing technology of the drill pipes ∅ 35 mm for prospecting rigs, with EW 35 tool joints, friction welded and heat treated by means of HFC quenching,* for the Geological Prospecting Enterprise from Baia Mare;
  - *the study of the possibility to construct the reaction pipe apparatus using friction welding*, for Upetrom - 1st of May from Ploieşti.
- **External reconditioning installation of the worn-out tool joints from the drill pipes, using build-up welding** (see fig. 3). An installation for the refurbishing of worn-out tool

joints using build-up welding by means of MIG technique has been designed. The installation and the technology have been patented at OSIM Bucharest (**Patent No. 117518/16.01.1991).**

Using this installation research works oriented towards several directions have been carried out, that is:

- *the design of the reconditioning technologies for the tool joints of worn-out steel drill pipes in the view of re-establishing their wall thickness and extending their exploitation duration*. These works have been requested by the tubulars bases from our country (Moineşti, Tg. Jiu, Boldeşti-Scăieni, Viforâta etc.);
- *researches aimed at the manufacture of drill collars, worldwide competitive, by hardening the external surface applying hardfacing with hard materials*; the research work has been performed within a research project from the framework of the RELANSIN program, to be applied at S.C. UPETROLAM S.A. Bucharest.

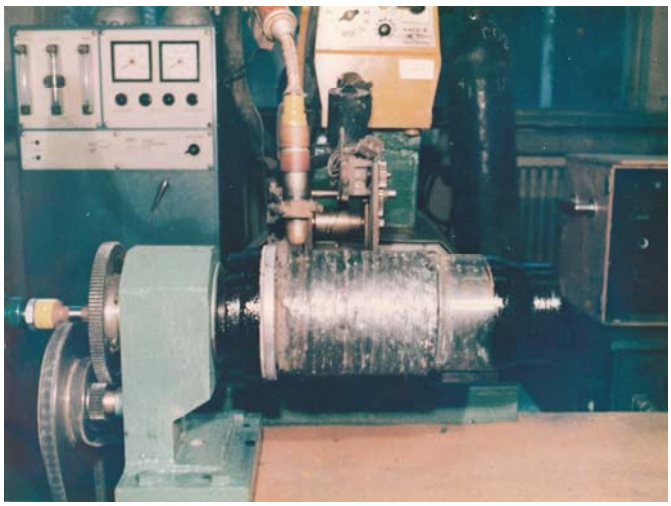

**Fig. 3.** External refurbishing installation of the worn-out tool joints from the drill pipes, using hardfacing by welding

The research work regarding the hardfacing with hard alloys of the external surface of the drill collars, performed in laboratory conditions, has been extended up to the level of implementing this technology in factory conditions.

On the same line, of increasing the operational durability of petroleum equipment by means of surface hardening, the following technologies have also been studied and designed:

- *the reconditioning technology for the worn-out pistons of the borehole pumps for oil and gas by means of the thermal spraying procedure*, in cooperation with commercial societies working in the domain of oil and gas exploitation;
- *the hardening technology for the sealing surfaces of industrial valves employed in the petroleum industry by thermal spraying using the HVOF (High Velocity Oxygen Fuel) technique* by means of a modern installation served by a specialized robot. The installation is within the endowment of the Manufacturing Technologies and Industrial Management Department. The research work is performed within a research contract in the framework of the National Research, Development and Innovation Plan II, program 4 – Partnerships in Prioritary Domains with the theme: *Un-conventional high precision technologies for the increase of the durability of the valves, with applications in the petroleum industry*;
- *hardening technologies of the internal surfaces of the valves mounted on the transport pipelines and inside the separation and treating installations for crude oil and gas from the oil fields by means of hardfacing using various welding procedures*; in collaboration with the commercial society UZTEL S.A. from Ploiesti. The special problem which has been

solved in the frame of these applications was the one of adapting through changes, sometimes consistent, some components of the existing equipments to the shape and dimensions of the internal surfaces to be hardfaced, in the conditions in which the quality requirements for the deposited layers are fulfilled.

In the field of the manufacturing of petrochemical and refinery apparatus, the research works of the specialists from the Faculty have been oriented towards the following directions:

- *Researches regarding the cracking tendency and the capacity of crack arresting at the R52 and 10Ni14 steels used for the construction of the pressure vessels*, in cooperation with the commercial society UZUC S.A. from Ploiesti;
- *Researches regarding the behaviour during welding of R44 and R52 steels welded with homologated approve technologies,* in collaboration with the commercial society UZUC S.A. from Ploiesti;
- *Researches regarding the behaviour to cracking corrosion under loading in aqueous environment with $H_2S$ of the welded joints of the parts made of the W1.6903 steel, made with type N GRINOX61 electrodes,* in cooperation with the commercial society UZUC S.A. from Ploiesti;
- *Researches regarding the behaviour of the welded joints from R44 5a and R52 6b sheet automatically SAW welded under OP44TT(Oerlicon) and D3 (Ancos) flux with S10Mn1Ni1 and S2Ni2.5 welding wires*, in collaboration with the commercial society UZUC S.A. from Ploiesti;
- *Researches regarding the definition of weldability and fracture mechanics criteria for sheets and forgings from C-Mn low alloyed steels*, in cooperation with the commercial society UZUC S.A. from Ploiesti;
- *Researches regarding the optimization of the steels used for some components of the sections of the drilling masts intended to operate at low temperatures*, in collaboration with Upetrom - 1st of May from Ploiesti;
- *Fracture mechanics researches for the assessment of the welding behaviour and operational safety of pressure equipment made of various types of steel*. These researches have been ordered by the enterprises UZUC Ploieşti, IPCUP Ploieşti, 1st of May – UPETROM Ploieşti, IUC Găieşti a.o.

Preoccupations have also existed in the field of the welding related procedures. Thus, it can be mentioned *the manufacturing of core drills armed with pins made of metal carbides to be used for geological prospecting drilling*. Based on a research contract with IFLGS Bucharest and in collaboration with the Enterprise Diarom Bucharest, cored drills armed with pins made of metal carbides, by brazing using induction heating with medium frequency current have been manufactured within the Micro-production Workshop. At that time, the importation of such drilling tools has been eliminated.

Furthermore, *a brazing technology, using medium frequency current heating, of the cutting part made of sinterised metal carbides to the cutting tools (lathe tools and cutters)* has been developed.

Within the action of introducing new materials and assembling technologies, we can also evidence the preoccupations of the specialists from UPG for the use of copper made pipes and fittings within the natural gas internal installations. It has to be mentioned that presently only steel made pipes and fittings are used for the construction of these installations. The possibility of replacing the classical joints between the copper pipes and fittings, made by brazing or welding, with press fit joints, using a special additional sealing element, has been studied. An important component of the researches in this direction is the development of the methodology and equipment for studying the behaviour in time of such types of joints. Stands for testing the joints for fatigue under different types of loads (rotational bending, static bending, torsion) have been designed and constructed in order to assess if the tested joints loose their tightness with the

time. The results of the research work performed have allowed for the homologation of the press fit jointing procedure for the copper pipes and fittings to be used within the natural gas installations. The research work has been financed by means of a project in the framework of the RELANSIN program, in partnership with Distrigaz South Bucharest.

Once the high density polyethylene pipes have been introduced in the construction of the natural gas and water distribution networks in Romania, as it is normal to happen in any university, notions about these materials (properties, utilization, methods for processing, assembling and testing of the joints) have been included within the speciality courses. Presently, the ZONAL CENTER FOR PROFESSIONAL TRAINING – POLYETHYLENE WELDING, where polyethylene welders are trained and specialized, functions within the University and is provided with welding installations for polyethylene pipes and fittings. The destructive testing laboratory within the Faculty, authorised by ISCIR, is also provided with a **Tensile testing machine for plastic materials**, which allows the University, in collaboration with ISCIR Ploiesti, to train and to certify polyethylene welders. Moreover, all the students belonging to the mechanical and elecromechanics specializations are the beneficiaries of the existence of the polyethylene welding centre in order to train themselves in this field.

In the field of steel pipelines for oil and gas transportation, a tight collaboration between the specialists from the University and the commercial societies which build and exploit the pipeline systems from Romania has existed and still exists.

While laying the first trunkline for natural gas transit on the Romanian territory, the section Isaccea - Negru Vodă, technical assistance has been granted for solving some special execution problems which occurred during the construction.

At present, a fruitful cooperation between SNTGN - Transgaz S.A. Medias and the Petroleum-Gas University of Ploiesti is in progress, aimed at solving some technical problems linked to the maintenance of transport pipelines, that is:

- *development of the technologies for the remediation of the defects detected on the tubulars of the transport pipelines;* several repairing technologies for the transport pipelines have been designed, able to be applied based on some selection criteria, as a function of: the defect type, the working conditions, the manner in which the pipeline is placed, if it remain in-service or not, etc.
- *investigation of weld defects and evaluation of the remaining mechanical strength of the welded seam from the pipeline ∅48" under-crossing the Danube at Isaccea;*
- *investigation of the causes provoking the accident on the pipeline DN400 Govora-Drăgăşani;*
- *elaboration of Technical Norms regarding the maintenance of the National System for Natural Gas Transportation;*
- *training in the field of welding of the personnel that is working in the maintenance division of gas transport pipelines.*

The results of the preoccupations and of the research work listed above have materialised in a great number of scientific papers published in prestigious, specialised journals from our country and from abroad, proceeding papers presented at national and international conferences, specific university courses for students participating in the bachelor, M.Sc. and Ph.D. programs.

In addition, a significant number of Ph.D. theses have been elaborated in the field of welding by teaching personnel and specialists from production, under the guidance of prestigious professors from the University, among which:

- Contributions regarding the safety of the welded constructions of the drilling installations;
- Researches regarding mechanisation of the welding operations of petrochemical equipment manufactured from steels cladded with stainless steels;
- Researches regarding the stainless steels of ferritic-austenitic type used for the construction of welded vessels;

- Interactive systems of registrations processing for the automatic control of the welding process;
- Contributions to the development of an automatic management system of an electric arc welding robot.

At present, a number of three Ph.D. theses guided by Ph.D. leading professors from the University, which developed research work in the field of welding, are at the final stage of completion:

- Theoretical and experimental analysis of the hardening technology by means of surfacing with hard alloys/materials of the surfaces of some petroleum equipment subjected to intense wear processes;
- The influence of the welding materials upon the quality of the welded joints made of steels for pressure vessels and pipelines;
- Research regarding the technology of internal hardfacing with hard alloys of the sealing surfaces of valves and other similar elements from the petroleum industry.

The scientific production of the teaching staff belonging to the University comprises, besides the scientific papers and the Ph.D. theses, numerous specialised university courses which contain an important amount of problems connected to the welding of materials and to the welding related procedures. In addition, many graduates have, within their graduation project or dissertation work, topics treating the welding technology for different petroleum and petrochemical equipments.

## Conclusions

The present paper included a concise review of the research activities performed and of the results obtained by the specialists from the Electrical and Mechanical Engineering Faculty in the field of the applications of the welding procedures and technologies to the manufacturing and repairing of petroleum, petrochemical and refinery equipment. These results are also the fruit of a strong involvement of the teaching staff belonging to the Faculty in solving numerous technical problems arisen, on one hand, by the manufacturers of petroleum and petrochemical equipment, and on the other hand, by those who exploit them, i.e. the commercial societies that drill the wells, extract oil and natural gas, process them, and, not at last, the ones that transport oil, gas and petroleum products.

# Utilizarea tehnologiilor moderne de sudare în domeniul fabricării şi mentenanţei echipamentelor petroliere şi petrochimice

## Rezumat

*Echipamentele mecanice şi instalaţiile utilizate în industria petrolieră şi petrochimică sunt complexe şi trebuie să funcţioneze în condiţii de înaltă eficienţă economică şi deplină siguranţă. De aceea, la fabricarea acestora se folosesc materiale şi tehnologii dintre cele mai moderne. În lucrare sunt prezentate preocupările şi realizările cadrelor didactice de la Facultatea de Inginerie Mecanică şi Electrică din cadrul Universităţii Petrol-Gaze din Ploieşti în domeniul sudării şi al procedeelor conexe sudării. Cercetările efectuate au fost orientate pe adaptarea unor procedee şi tehnologii de sudare la fabricarea şi repararea echipamentelor petroliere, petrochimice şi de rafinării, echipamente care trebuie să lucreze în condiţii de exploatare foarte severe şi să prezinte o siguranţă deosebită în funcţionare. Rezultatele cercetărilor efectuate de specialiştii din catedrele de specialitate s-au materializat într-un număr important de produse, echipamente şi tehnologii, articole de specialitate publicate în reviste ştiinţifice din ţara şi străinatate, lucrări prezentate la conferinţe naţionale şi internaţionale, brevete de invenţie,cursuri universitare de specialitate, teze de doctorat ş.a.*