

ON SOME ASPECTS OF THE EVOLUTION OF NONCONVENTIONAL TECHNOLOGIES IN THE LAST DECADE

Dumitru Mnerie[1], Aurel Mihail Titu[2] and Gabriela Victoria Mnerie [3,4]
[1] Politehnica University Timisoara and IOAN SLAVICI University Timisoara, Romania, dumitru_mnerie@yahoo.com
[2] "Lucian Blaga" University of Sibiu, Romania, mihail.titu@ulbsibiu.ro
[3] National R&D Institute for Welding and Material Testing - ISIM Timisoara, Romania, gmnerie@isim.ro
[4] Ioan Slavici University, Timisoara, Romania, gabriela.mnerie@islavici.ro

ABSTRACT: The historical beginning of nonconventional technologies in Romania can be appreciated as the year 1954, when the Institute of Electrotechnical Research, created under the auspices of the Ministry of Electric Energy, was established in Timisoara. That's when the foundations were laid for the creation of the first Electrotechnologies laboratory in Romania at the Department of mechanical technologies (TM), UP Timisoara. After 20 years, the Center for Research in Nonconventional Technologies was established at the "Traian Vuia" Polytechnic Institute in Timisoara. In this paper, some references are made on the evolution of nonconventional technologies in Romania, with an emphasis on some developments from the last 10 years. Some novelties regarding modern applied technologies, based on energy concentration, such as 3D printing using metal powders, ultrasonic welding, are addressed in more detail. Some registered and certified invention patents in the field of nonconventional technologies are also recorded.

KEYWORDS: nonconventional technologies, energy concentrations, 3D printing, ultrasonic welding

1. INTRODUCTION

The Polytechnic School of Timisoara, since its foundation (1920), has proven to be responsive to the needs of local, regional and national industry, permanently focusing on international avant-garde scientific research [1]. By consistently following and respecting this strategic program, it has become over time the pole of Romanian research in the field of nonconventional technologies (NT). The beginnings of Romanian research in this direction in Romania were marked by *Professor Emeritus Aurel Carol NANU* (23.05.1921-04.10.2017), recognized as a pioneer of NT in Romania. In 1954 he was appointed as *Technical Adviser within the Ministry of Electricity* and head of the *Institute of Electrotechnical Research* established in Timisoara in 1954. Professor Aurel Carol NANU coordinated and organized the *First laboratory in Electrotechnologies* in Romania at TM Chair, (UP Timisoara, 1957/58), a *Center for Research on Nonconventional Technologies* (1974), and since 1985, the *Nonconventional Technologies Research Commission*, that has been organized within the Romanian Academy (RSR), Timisoara Branch. In 1974, the Ministry of Education in Romania, with Order no. 7422 A/03.08.1974, set up at the Polytechnic Institute "Traian Vuia" Timisoara, the Faculty of Mechanics, the Department of Mechanical Technology, the *Center for Research in Nonconventional Technologies*, director Prof. Aurel Nanu. This center polarized many scientific and doctoral researchers in the field, having a meritorious scientific activity. *The Ministry of Industry - Central Research Institute* decided in 1975, the establishment of the *Central Research Institute in Machine Construction Technology* (ICTCM) in Bucharest. In 1984, the Romanian Academy established within the Timisoara Branch, the *Research Commission in nonconventional technologies*, appointing the professor Nanu as chairman of the commission. Starting with 1990 the activity of research institutions in Romania, due to lack of funds, has begun to diminish, and this has also affected the organizational work of the ICTCM in the field of NT. When the organization and holding of the XVII-th National *Conference of Nonconventional Technologies in Timisoara* (1993), it was decided to set up the Romanian Association for Nonconventional Technologies (ARTN), based in Timisoara, the Faculty of Mechanics, the Department of Mechanical Technology, with professor A.C. Nanu [1], [2]. ARTN expanded its scope to the main university centers throughout the country, reaching 10 branches in a few years. Within this structure, the activity focused on fundamental and applied research aimed at replacing the mechanical tool, rigid and with limited resistance to action, with an energy tool, capable of removing machining deposits more efficiently. Initially, this energy-erosive process was called „micro-cutting", later materialized by multiplying the erosion variants, in relation to the imposed technological conditions. The novelty of introducing new micro-cutting possibilities, based on

the erosive principle, determined in fact by energy concentrations, led to the emergence of dimensional machining technologies through electrical and/or electrochemical erosion, plasma-based machining, laser, ultrasonic waves, etc., all generically called: NONCONVENTIONAL TECHNOLOGIES (NT) [1].
This research aims to identify the existence of some characteristics of the forms of progress of research in the field of nonconventional technologies carried out in the over 70 years since its emergence, as well as to forecast the context in which this direction will continue to evolve. *Can we still talk and research nonconventional technologies? Will they continue to be of interest?*

2. CONSIDERATIONS ON THE RESEARCH BASIS AND METHOD

For the research, the first step was to analyze the bibliography developed over time, especially through the involvement of ARTN members, an open community, formed in the vast majority by researchers in the field of nonconventional technologies.
To streamline the promotion of research results in the field of NT in Romania, in 1997, at the initiative of ARTN and under the aegis of the Romanian Academy, the Timisoara branch, the „*Nonconventional Technologies review*" was established [1].
As research in the field of nonconventional technologies advanced, it was considered necessary to ensure a documentation base on the principles, methods and new application procedures, in 2003, ARTN launched the first volume of the *Treaty of Nonconventional Technologies*, with the general coordinator being *prof.univ.dr.doc.șt.DHC Eng. Aurel NANU*. In the introductory part of the *Treaty*, the coordinator, after an extensive international history of NT, presents a review of the scientific research activity carried out in the first 50 years since its launch. Thus, the first doctoral theses defended in this field, in the years 1969-1970, are made known. (Table 1) [1].

Table 1. – The first doctoral theses in the field of TN defended in the years 1969-70 [1]

Thesis title	Author	Scientific supervisor
Fundamental phenomena in electric spark machining with oscillating electrode	Alexandru NICHICI	Prof.dr.doc.șt.ing.Aurel NANU (Timisoara)
Contributions to the study of controlled pulse machining of indigenous materials	Gheorghe OBACIU	Prof.dr.ing. Ion Stănescu (Brasov)
Study on the machinability of nodular cast irons by electroerosion processes	Gheorghe SAVII	Prof.dr.doc.șt.ing.Aurel NANU (Timișoara)
Contributions to the study of electrochemical machines and self-adjusting feed machines	Mircea IVAN	Prof.dr.ing. Ion STĂNESCU (Brașov)
Contributions to defectoscopy with penetrating electromagnetic radiation	Marin NĂSTASE	Prof.dr.doc.șt.ing.Aurel NANU (Timișoara)
Research on spot pressure welding of thin aluminum sheets and some aluminum alloys with energy stored in an electrostatic field	Vladimir POPOVICI	Prof.dr.ing. Mihai BRAȘOVAN (Timișoara)
Compactification of metal powders under the influence of vibrating energy	Gheorghe MATEI	Prof.dr.ing.Alexandru DOMȘA (Cluj-Napoca)
Contributions to the study of fundamental phenomena in complex erosion processing	Vasile POPOVICI	Prof.dr.doc.șt.ing.Aurel NANU (Timișoara)
Research on plasma welding loading of corrosion and wear-resistant alloys	Vasile BERINDE	Prof.dr.doc.ing. Corneliu Mikloși/ prof.dr.doc.ing. Vladimir POPOVICI (Timisoara)

In the following years, almost 500 theses on NT topics were defended, of which 82 were coordinated by *Professor Aurel NANU*. News in the NT field was also made known when the *Conferences on nonconventional technologies* (which reached their XXIII edition in 2024), where over 1700 other scientific papers were brought to public attention. Among these are also synthesis papers that dealt in one way or another with the present and/or prospects of NT. It is appreciated that, with the generalized progress of technologies, one can no longer speak of a clear delimitation between the fields of NT, only differences between the opinions of specialists in the field being reported. For example, the use of EDM technology leads to large annual savings for the processing of various parts, the amortization of additional investments becoming increasingly shorter in time. And the EDM market reflects spectacular growth from year to year [3], [4], [5], [6].
Following the specific papers in the field of NT that are found in the Web of Science database, a number of 1155 papers published between 2015 and 2019 were identified, distributed partially or fully, across

different NT categories. Significantly, the number of citations in these works is constantly increasing, coming from research groups from all over the world. If at first the predilection for NT was that of European and American researchers and companies, now the interest is globalized [4].

Professor Aurel NANU estimated that in 2003 the share of NT in technologies applied worldwide was 15-20%, and in Romania only 2-3% [1].

For a more eloquent analysis of the perspective of the positive evolution of research in the field of NT, we proceeded to the analysis of the patenting situation of technical solutions based on NT.

Several important accessible databases were consulted, such as: OSIM (Romania) [7], Espacenet (EPO) [8], and Google Patents [9]. The research was also based on the analyses and discussions held with the researchers-inventors from ISIM Timisoara, benefiting from the support of the *Welding Technology Transfer Center CENTA* -ISIM [10].

The analysis of the general situation of patents in the entire NT field proved to be extremely complex, varying in relation to the type of technology, the degree of novelty and practical applicability.

Annually, inventions were patented both based on the principles of dimensional processing through electrical, electrochemical, complex erosion, aggregation/powder deposition/3D printing, nanotechnologies, and especially based on the principles of laser and ultrasound.

Some of the most recent inventions from each category were selected and analyzed:

- **Electrical Discharge Machining** (EDM):

Device for machining holes with arc-shaped axis by electroerosion - RO 128374 (Slătineanu L., Uliuliuc D., Coteață M., Grigoraș, I.).

Electrode and process for electro erosion machining - D-72064

Adaptive control circuits for electrical discharge machines - D-72069.

- **Ultrasound**:

Ultrasonic device for evaluating the flow of a melt of polymer and composite polymer materials - RO 130336 (B1) - Sîrbu N. A., Șerban V-A.

Process for ultrasonic welding of parts with spatial configuration of welding zones - RO133155 (B1) / 2022-07-29, (ISIM Timisoara - Sîrbu N-A.).

Ultrasonic processing device - RO 125894. (Slătineanu L., Dodun-Des-Perrieres, O., Coteață M., Uliuliuc D.)

Ultrasonic turbidimeter - RO 126710 B1. (Sonia Gutt S., Gutt G.)

Ultrafiltration-ultrasonic process for the purification of wastewater from the textile industry - RO 122813.

- **Nanotechnologies**:

Nanoelectrodes for pollution control - RO119032.

- **Laser**:

Synchronization and phase shift control system for a tandem pulsed laser and pulsed wig welding process - RO127790 (B1) - Birdeanu A. V, Verbitchi V.

Laser cutting apparatus and method - US20160281589A1.

Method and device for laser welding with real-time depth control - EP2327445B1.

Laser engraving system with variable pulse duration - US9409196B2.

Ultrashort pulse laser processing system for microfabrication - US10350663B2.

Laser ablation apparatus and method for precise tissue removal - US8858550B2.

Laser cleaning device with adaptive focus - EP3290327B1.

System and method for selective laser melting using optimized scan patterns - US10493759B2.

- **Water jet**:

Device for driving a waterjet cutting head – RO 130835 (B1), (Sîrbu N-A; Ionescu D - ISIM Timisoara)

Device for transverse machining by water jet cutting process - RO131032 (B1), (ISIM Timisoara - Sîrbu N-A., Perianu I. A., Ionescu D.)

System and method for measuring the diameter of abrasive water jet for leading the cutting process - RO130944 (B1), (ISIM Timișoara - Perianu I. A., Verbiţchi V., Ionescu D.).

Support device for a tool of a cutting installation with water jet/abrasive water jet - RO132639 (B1) / 2024-07-30, (ISIM Timișoara, Perianu I. A., Ciucă C.)

- 3D Printing:

3D printing system and process - B29C64/209

Methods and systems for enabling and scheduling 3D printing-based fabrication - G05B19/4099

Optimizing 3D printing using segmentation or aggregation - B29C64/386

Additive manufacturing system with an addressable laser array and real-time feedback control for each source - B29C64/153.

From the analysis of the descriptions of the listed patents, a diversified approach to NT was found, with frequent solutions based on combinations of established principles. Thus, several types of specific technologies can be applied for 3D printing, each using different combinations (hybrid solutions). For example, in the case of SLA (Stereolithography), the solidification of the liquid photopolymer resin is achieved using a laser. The 3D printing method using SLS (Selective Laser Sintering) is based on the sintering of plastic or metal powders using a laser. In the case of Metal Printing (SLM/EBM), the sintering or selective melting of the metal is applied with a laser or electron beam [10].

3. RESULTS

Analyzing the patented solutions, both a deepening of research in the field and an expansion of the fields of application were noted. Methods and procedures of unidirectional typological inspiration are found, respectively with the combined use of the principles underlying NT.

For example, dimensional processing using the laser beam now includes a wide range of applications, grouped into 3 main directions:

1. Laser cutting: with technological solutions that ensure high precision, with clean edges, with a minimal thermally affected area, of complex geometries, applied to various types of materials, The applied laser cutting varieties can also be divided into 4 categories: with vaporization, melting, with oxygen supply, simultaneous control of the rupture.

2. Laser marking and engraving, ensuring high contrast and high speed of action.

3. Laser welding, providing high-strength welds, with narrow seams, with minimal distortion, especially valuable for joining different materials, including suitable for thin sections [11].

If the history of the beginnings of NT was marked in 1967 by the installation at the Faculty of Mechanics in Timisoara of the first carbon dioxide laser (FC 100 - an experimental model manufactured in 1967 at the Laser Section of the Central Institute of Physics in Bucharest) [1], currently this solution has been adopted and developed quite a lot. Fiber laser generators are currently noteworthy, which use glass fiber doped with rare earth elements as an amplification medium. Under the action of pump light, a high-power density can easily form inside the optical fiber, which causes the laser energy level of the working substance to invert the number of particles. Unlike the CO_2 based generation solution, in this case the beam at the output appears as invisible light. The structure of the optical path is simpler, with lower environmental requirements (high tolerance to dust, vibrations, shocks, temperature and humidity). The fiber laser is faster at cutting thin plates [11].

The laser can also be the basis of rapid prototyping technology.

Industrial practice has also taken over laser heat treatment processes, with selective heating and rapid cooling of areas, inducing precise microstructural changes in the surface layer of the material in a controlled manner.

Laser technology is evolving rapidly, with increasingly extensive applicability, in major manufacturing industries, in the areas of automobiles, electronics, complex machinery, aviation, but also for medicine, agriculture or pharmaceuticals [12].

Also, from the research conducted on new patents in the field of technological exploitation of ultrasound, new directions of action have been identified. The solution of *high-intensity focused ultrasound* (HIFU) has found exceptional applicability in medicine, in the implementation of non-invasive treatments for tumors, uterine fibroids or prostate. The diversification of the expansion of ultrasound-based technologies in industries can be exemplified both by the explosion of technological solutions for welding and surface cleaning, but also in support of non-destructive testing operations. Of maximum interest are the applications in the biotechnology field, for the destruction of cells for the extraction of DNA or proteins (ultrasound cell lysis) or ultrasonic micro fluidization, consisting in the manipulation of fluids in microscopic channels for biomedical applications [13], [14].

The current performances of the application of NT are continuously increased by the adoption of numerical control systems, generally automation and/or robotics [15].

Several arguments have been identified that can underpin the thesis regarding the continuity of NT, regardless of the changes in the structure of the factors of technological progress, which have been discussed lately. Thus, as NT were initially defined, they are not reduced to the aspect of modernity or of going beyond the scope of those agreed upon at a given time. Professor Aurel Nanu, more than 30 years ago, explained the conventional aspect by which dimensional processing was carried out, through the physical use of tools, made of materials with superior mechanical properties to the workpieces. *Nonconventional technologies* have replaced the tool with different ways of concentrating on the energies necessary for the desired transformations. In all these 70 years of NT evolution, action has been and is being taken continuously towards the modernization of conventional technologies, to improve the tools, both in terms of shape and the structure of the materials from which they are made.

In parallel, NT is developing, even though there is a higher pace of innovation, working to find new transformation solutions using methods and processes for concentrating energy, obtaining multiplied powers and working speeds, with minimal losses, with high precision and increased quality of processing results.

It has also become aware that dimensional processing does not refer exclusively to parts, parts from different technical systems, but they can also be applied to other environments, even those of a biological nature. Specialists have also accepted the fact that dimensional changes are not limited to those visible on external surfaces, but can be inside bodies, with even inter- or intra-granular, respectively molecular, reference, achieved especially in the application of nanotechnologies.

Another argument for the prospect of developing the scope of NT is given by the interest in miniaturization and reducing energy waste.

4. CONCLUSIONS

Regarding nonconventional technologies, it cannot be said that they represented only a historical stage. Even if in specialized literature and/or on scientific meetings with engineering themes, the name *nonconventional technologies* are not used very frequently for the use in dimensional processing based on energy concentration, this principle is found in a lot of scientific research and technological innovation.

There are multiple examples of novelties regarding modern applied technologies, based on energy concentration, which are in continuous development. Thus, the perspective of the continuity of the existence and use of this category of technologies is ensured, especially from the perspective of the implementation of artificial intelligence in industrial manufacturing processes.

It can be concluded that the future of concentrated energy technologies also belongs to future generations.

5. REFERENCES

1. Nanu, A., *Treaty on nonconventional technologies / Tratat de tehnologii neconventionale, Vol. I*, Editura Augusta, Timisoara, 2003.
2. Nanu, A., Nanu, Dan, *Treaty on nonconventional technologies/Tratat de tehnologii neconventionale, Vol. II Prelucrarea prin eroziune electrica*, Editura Universitatii "Lucian Blaga" din Sibiu, 2004.
3. Nicolae I-R., Mnerie D., Gabriela-Victoria Mnerie G-V., Țîțu A-M., *News and perspectives on the use of the process of processing by electrical erosion in modern organizations, N*onconventional technologies review, Romania, Politehnica publishing house, vol. 24, no.3, (2020).
4. Pirnau, C. Marinescu, M.R. Ghiculescu, L.D. and Pirnau, M., *The nonconventional technologies reflected in Web of Science*, Nonconventional Technologies Review, Romania, Politehnica Publishing House, Vol. 24, No.1, (2020)
5. Jameson, E., C., *Electrical Discharge Machining*, 2001
6. Zion-Market-Research.html.
7. https://www.osim.ro/# OSIM (Romania)
8. https://ro.espacenet.com/
9. https://patents.google.com
10. www.isim.ro.
11. Dean McClements, *EBM vs. SLM: Differences and Comparison*, https://www.xometry.com/resources/3d-printing/ebm-vs-slm-3d-printing/, (2022).
12. Krishna, K.S. Mattia, B. Jun, Q. Dominiek, R. Bert, L. and Xichun, L., *Overview of Hybrid Machining Processes*, Hybrid Machining, Chapter 2, pp. 21-41, DOI: https://doi.org/10.1016/B978-0-12-8130599.00002-6, Elsevier Ltd. (2018).
13. Ghiculescu, L.D., *Nonconventional machining*, Printech, Bucharest, (2014).
14. Skoczypiec, S., *Research on ultrasonically assisted electrochemical machining process*, Int. J. Adv. Manuf. Technol. 52 (5_8), pp. 565-574, (2011).
15. Thoe, T.B. Aspinwall, D.K. and Killey, N., *Combined ultrasonic and electrical discharge machining of ceramic coated nickel alloy*, Journal of Materials Processing Technology, 9293 323-328, (1999).