Secure Systems Design and Technology Development. Veliko Tarnovo, Bulgaria
Proceedings of the International Scientific Conference, 2026. Volume II, 413-417

Laser Marking on Samples With Chromium-Nickel Coating

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***Abstract* — In the 21st century, laser marking is increasingly used. Very good results are achieved when working on resistant materials such as plexiglass or chromium-nickel samples, where good color marking is also achieved.**

Products that are made of or coated with chromium-nickel are used in the manufacture of a number of parts and products. This is especially true for products that are produced in the enterprises of the military-industrial complex. Marking such products in the current complex international situation and the conduct of military operations in Ukraine, Israel, Yemen and other countries will make tracking military production a much easier task. The experiments were conducted on thin samples of chromium-nickel and the change in marking quality with changes in the speed and power of the laser and the roughness of the material were studied. The results obtained were analyzed and this will provide an opportunity both for using the results obtained and for continuing research. These studies were conducted at the Laser Center of Rezekne Academy of Technology during an Erasmus internship.

Keywords* — *chromium-nickel, laser, marking, power, roughness, speed.

I. Introduction

Joint research in the field of laser technologies between the Rezekne Academy of Technology, as the lead partner, and the National Military University "Vasil Levski" began in 2018. The partnership between the educational institutions is even older, as the first framework agreements for cooperation and agreements under the Erasmus program were signed more than 10 years ago. There is a regular exchange of students and lecturers between the two educational institutions, and joint research projects are developed and research is conducted, mainly in the field of laser technologies.

Teachers, cadets and students from the military educational institution from Bulgaria have also visited the Latvian university many times. During practical training, cadets and students from the National Military University under the leadership of Prof. Lazov have conducted research and data processing from experimental and theoretical studies of various materials in the laser center in Rezekne.

Laser marking on chromium-nickel is a process in which a laser beam is used to create permanent markings on the surface of the material. This method is popular due to its high precision and the ability to create detailed and complex designs [1], [2], [3].

The laser marking process occurs when the laser generates a concentrated beam of light, which is directed at the surface of the chrome-nickel. The material absorbs the energy from the laser, which leads to local heating and a change in the surface structure. Depending on the laser settings, a different effect can be achieved - from a color change to deep engraving [4], [5].

Laser marking on chrome-nickel has a number of time-proven advantages:

1. High contrast is achieved, in which the markings are clearly visible and legible, even at small sizes.

2. It has very high durability, because laser markings are resistant to wear, corrosion and high temperatures.

3. It has high marking precision, with the ability to create complex and detailed designs with high resolution.

4. The process does not violate the integrity of the material and does not lead to mechanical damage [6], [7].

This method is widely used in various industries, including automotive, medical and electronic, for marking parts, tools and components, as well as in military production [8]

Online ISSN 3044-7771
https://doi.org/10.68302/std2026.vol2.193

II. Materials and Methods

Laser Procedure Setup and Parameters Stainless steel contains chromium in its composition, which provides chemical stability and high heat resistance of the alloy and makes it suitable for use in the laser process [9], [10], [22]. In this study, 2 mm thick chromium-nickel steel plates with an initial roughness level Rz = 8.42 µm, reflectivity R (λ=1.06 µm) = 0. 75, thermal diffusivity a = 3x10-6 m2/s, thermal conductivity k = 37 W/mK, melting point = 1800 °C and boiling point = 3145 °C were used. At the initial stage, the surfaces were cleaned with acetone to avoid any dirt or stains. As a source of laser radiation with a wavelength of $1055<\lambda<1075$ nm, generating pulses with a duration of 4 seconds, a nanosecond pulsed ytterbium fiber laser supplied by IPG Photonics Corporation $<\tau<200$ ns at a repetition rate of $1.6<f<1000$ kHz was selected. The configuration of the laser processing system developed for the purposes of scribing and marking is presented in Fig. 1 and consists of 1) IPG Photonics nanosecond fiber laser, 2) optical fiber transfer, 3) SCANLAB scanning system, 4) 100 mm objective, 5) Neff-Wiesel linear drive for vertical movement, 6) XY coordinate stage, 7) Kollmorgen ACD servo drives.

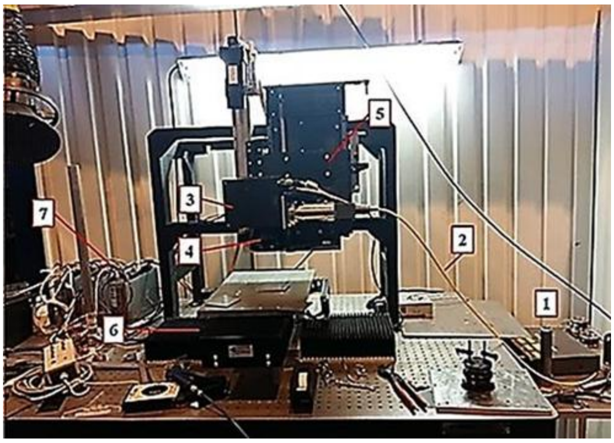

Fig. 1. The configuration of the laser processing system [4].

A fiber pulsed ytterbium laser was emitted and fed into a collimating system via an optical fiber to form a parallel beam output. A dual-axis galvanometer scanning system (hurrySCAN II 14 digital scanning head from SCANLAB corp.) was installed to move along the X and Y axes. A focusing lens with a focal length of 100 mm was used to focus the laser radiation onto the surface of a steel plate [11, 12, 24]. Additional horizontal movements and vertical movements can be performed using a multi-axis linear motor coordinate stage, which allows for an extension of the working space to 250×250 mm. The laser radiation parameters and scanning speed can be changed using the developed labVIEW code. Also, all vertical and horizontal movements can be controlled by the same code.

The coatings and markings of the products must withstand different environmental conditions and must not change during the period of use of the product [1], [9], [13]. This is extremely important in the production of military products. In this study, an environmental test was performed in a chamber based on several different operating conditions [14], [18], [23]. The products were tested under extreme conditions, at temperature and humidity values that are rarely encountered in real conditions, but due to the specificity of the products, such environmental parameters were selected as a combination of extremely low or high temperatures (-40, -20, 40, 100 °C) with high humidity (70%, 90%). In this way, the stability of the samples under normal conditions for a long period in different parts of the globe and under extreme operating conditions is guaranteed. At the same time, this way the short duration of the test exposure (24 hours) compared to the actual operating time is compensated. The first test was carried out under environmental conditions with a temperature of -20 °C and a humidity of 70% [4], [15], [17]. The result shows that there is no change in the colors or materials after 36 hours in the environmental test chamber. No damage or defects were found in the surface layers in the optical microscope analyses.

III. Results and discussion

The process of color laser marking on chromium-nickel steel involves the sequential melting and solidification of the material, which leads to oxidation and nitriding of the surface of the material. The final surface and the formation of an oxide film are the result of repeated work with a pulsed laser, which varies depending on the heat of the laser and the value of the overlap of the laser pulses [4], [16], [19], [20]. The resulting surface relief and color are affected by almost all parameters of the laser source. In this study, the dependence of the microhardness of a series of samples on the scanning speed, laser power, pulse duration and laser pulse frequency is investigated. The study of the dependence of the resulting color on the surface relief is not the goal of this study, the goal of the study was to obtain high-quality and durable marking on chrome-nickel steel [4], [21].

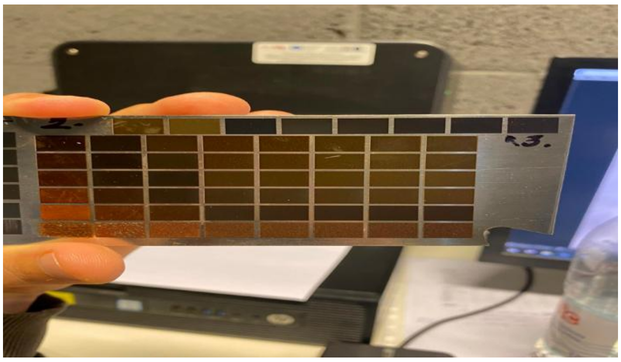

Fig. 2. Matrix of the study of sample 2

Due to the impossibility of presenting the entire study due to its large volume, we will focus on some basic data and graphs that were obtained after measuring the results and analyzing them.

Fig. 2 shows the results obtained for measuring the microhardness of the surface of sample No. 2. Measurements were made at a constant speed of 100 m/s. of the laser beam and at a laser emission frequency of 500 kHz. During the measurement, a 7x7 field matrix was made, with the variable values being the laser power and the marking step. The results of the study are shown in Table 1.

TABLE 1 MEASUREMENT OF MICROHARDNESS OF CHROMIUM-NICKEL STEEL, SAMPLE 2

	Speed: 100m/s ; Frequency: 500 kHz; Pulse duration: 8n/s; Loop1-90° Loop2 0°							
	Step (µm)	**10**	**12**	**14**	**16**	**18**	**20**	**22**
Step	25	0,431	0,492	0,474	0,513	0,563	0,675	0,695
	50	0,339	0,572	0,424	0,53	0,607	0,646	0,676
	75	0,357	0,424	0,518	0,629	0,726	0,79?	0,82?
	100	0,228	0,465	0,537	0,67	0,629	0,692	0,712
	125	0,14	0,424	0,486	0,622	0,622	0,619	0,642

The obtained results are also shown in fig. 3. There the dependence of the untreated surface SQ on the marking steps is shown. It is clearly seen that up to the fifth step the change is close to linear with increase. After that, however, a sharp change in the picture occurs and no dependence can be determined because the change is different for each measurement.

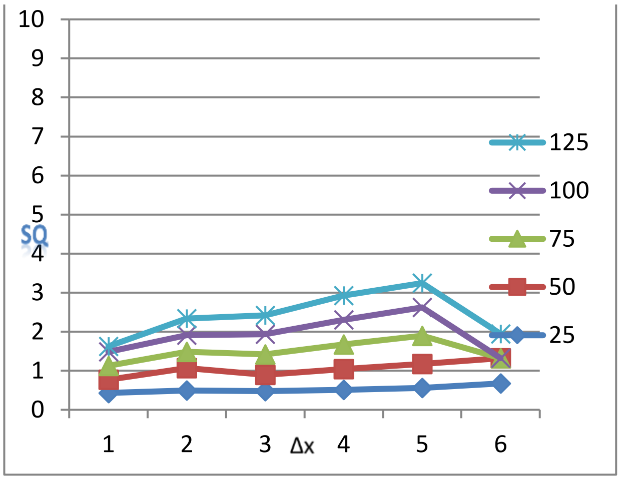

Fig. 3. Dependence of Microhardness on the power and step of the laser beam for sample 2

Measurements were made on 6 samples, with the results up to 4-5 steps having a similar growth rate, and after the fifth step, divergence of the indicators was observed and no definite regularity of the change could be detected, because the changes did not converge in the results obtained. This indicates that to obtain good indicators of laser marking of chromium-nickel steel, the laser equipment must work with small steps up to 50 µm. Similar results were obtained for the other samples studied, which confirms the accuracy of the study and the results obtained.

From Fig. 4 it is clearly seen that the results for other samples have a similar nature.

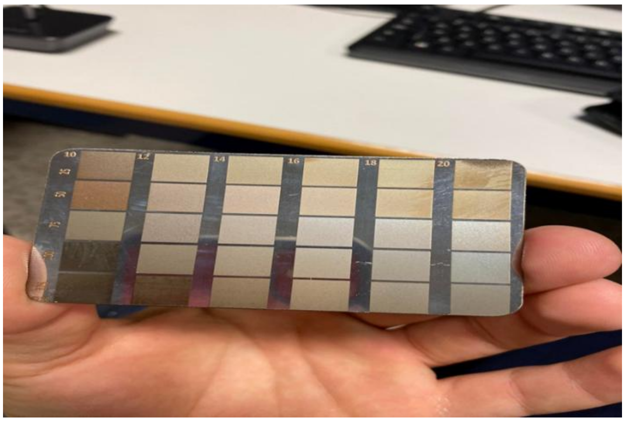

Fig.4. Sample 3

Figure 5 shows the graphical dependences of SQ on the change in x and the step of the laser beam, the graph being built on the basis of the results obtained for marking chromium-nickel steel on sample 3, where very good dependences were obtained. Due to the volume of the report, the results obtained for the remaining samples are not presented, but the authors can further analyze the results and present them in subsequent reports.

Parallel to these studies, studies were also conducted on the achieved quality of the marking and the microroughness of the resulting treated surface. Plates of the same samples of chromium-nickel steel and the same laser were used, with the variable values here being the speed, power and step of the laser beam. The matrix that was developed and the resulting image quality are shown in Fig. 5.

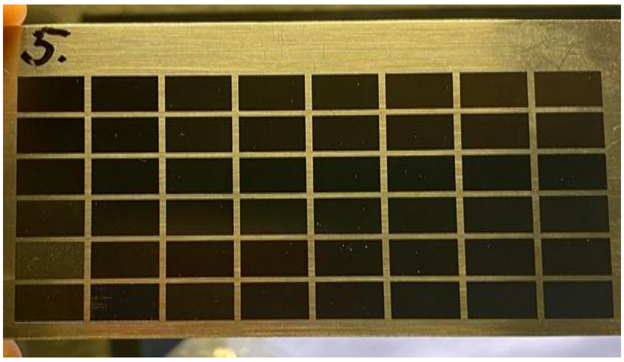

Fig. 5. Plate with matrix from the tests of the quality of roughness of the marking

The data from the measurements made on plate No. 7 are shown in table 2.

TABLE 2 MEASUREMENT OF THE QUALITY OF ROUGHNESS OF THE MARKING ON CHROMIUM-NICKEL STEEL, SAMPLE 7

	Power, W	**6**	**12**	**18**	**36**	**42**	**48**	**54**	**60**
Step	554	445,2	461,6	454,8	453,5	472,3	467,8	479,8	474,1

	454	444	440,6	457	466,7	480,8	481,8	488,1	497,1
	354	441,1	469,3	469,3	473,2	481,6	487,7	483,5	497,8
	254	429	447,3	474,1	478,3	472,9	480,8	478,1	479,2
	154	463,6	467,2	452,4	481,3	469,6	487,6	483,5	493,3
	54	437,4	457,5	497,9	426	427,2	470,4	433,9	458,9

Accordingly, the obtained results were processed and graphs of the dependences of the measurements made on 12 plates with chromium-nickel coating were constructed. Fig. 6 shows the obtained graph of sample 7.

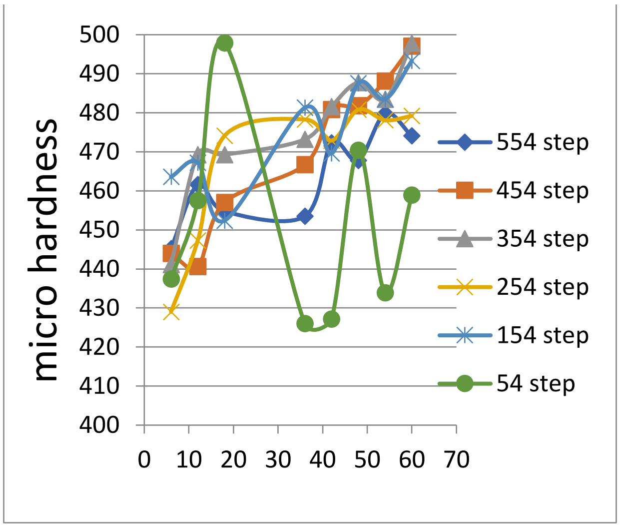

Fig. 6. Graph of the dependence of microhardness on the power of the laser beam

Out of the many measurements made, the results of only one sample are shown, due to the limited volume of the report. The results obtained from the overall study, which was carried out within 2 months, are many and could not be presented in such a small volume.

IV. CONCLUSIONS

The laser processing system developed for the purposes of this research work is based on a nanosecond ytterbium fiber laser on a multi-axis platform for the workpiece and the possibility of vertical movement of the laser scanning head. In the preliminary phase, the scanning system was calibrated and the specifications of the laser beam at the focal point were determined. In order to find the appropriate value of the power density, the distribution of the laser spot on the surface was measured. The dependence of the obtained colors on the parameters of the laser processing, including the scanning speed, pulse duration, radiation power and pulse repetition frequency, was studied.

Based on the analysis, 12 blanks were prepared for the three experiments, and a suitable matrix was developed for each experiment. Each blank from the first study consists of 49 squares with different power and laser beam path indicators and dimensions of 8×15 mm. The obtained oxide films were examined using optical microscopy and scanning electron microscope (SEM). The surface topology was established using atomic force microscopy (AFM).

In a similar way, the samples for the second and third experiments were prepared, and here the number of fields was 30. The results confirm that the created samples have appropriate consistency, brightness and cover approximately all spectral regions.

In the joint work of the representatives of the National Military University "Vasil Levski" and the Rezekne Academy of Technology, the algorithms for working and conducting the study to find the optimal parameters for marking different color spectra on chromium-nickel steel were initially compiled. The research was carried out during a practical training at the Academy in Rezekne and the obtained matrices were examined with the equipment available at the laser center. The results obtained contributed to finding the optimal marking mode on this material and obtaining the highest quality surface marking. The results obtained so far will be developed in subsequent experiments.

The results obtained are the basis for further research on marking chromium-nickel steel, taking into account the operating conditions of the obtained surface. Based on the results obtained, the most suitable speeds and beam path were selected to obtain excellent marking with good indicators of the obtained surface. Marking with a laser beam power higher than 11 watts was excluded from further research and, depending on the desired result, a corresponding step of the laser beam is selected. The participants in the study are ready to continue the research and find even more accurate marking values on other surfaces that are used in special production and are relevant in view of the current international situation.

REFERENCES

[1] Dolchinkov N., The laser – creation, development and perspectives, Annual Scientific Conference of Vasil Levski National University - June 27-28, 2019. ISSN 2367-7481 p. 456-465

[2] Dolchinkov N., Development of laser technologies, Innovations in technologies and education. Collection of articles of the participants of the XIV International Scientific and Practical Conference. Kemerevo, Belovo, Novosibirsk, Veliko-Tyrnovo, Shumen, 2021. S. 50-57

[3] Dolchinkov N., Practical research of marking and cutting of textiles with increased resistance, using CO2 laser, Journal of Physics: Conference Series, Volume 1681, 2020, 1681 012014 IOP Publishing The 6th International Conference on Chemical Materials and Process 2-4 July 2020, Warsaw, Poland, doi: https://doi.org/10.1088/1742-6596/1681/1/012014 Online ISSN: 1742-6596 Print ISSN: 1742-6588

[4] Dolchinkov N., M. Tortorikov, Investigation Of Laser Marking On Chromium Nickel Samples, Environment. Technology. Resources. Rezekne, Latvia, Proceedings of the 15th International Scientific and Practical Conference. Volume III, Print ISSN 1691-5402, Online ISSN 2256-070X, https://doi.org/10.17770/etr2024vol3.8175, pp 370-374

[5] Dolchinkov N., Shterev Y., St. Lilianova, D. Boganova, M. Peneva, L. Linkov, D. Nedialkov, Exploring the possibility of

laser cutting with CO2 laser on felt in the range from 1W to 26W power, International scientific journal: Industry 4.0 Issue 1/2019, ISBN 2534-8582, p. 29-31.

[6] Jurčs, V. E. Yankov, N. Angelov, A. Pacejs, I. Adijāns, Influence of technological parameters on laser marking process of copper surfaces, Vol. 3 (2024): Environment. Technology. Resources. Proceedings of the 15th International Scientific and Practical Conference. Volume 3, https://doi.org/10.17770/etr2024vol3.8179, pp. 393-398

[7] Mežinska S., A. Pacejs, I. Adijāns, E. Zaicevs, L.Lazov, Study of adhesion of physical vapor deposition coatings on functional textile with laser post-processing, Vol. 3 (2024): Environment. Technology. Resources. Proceedings of the 15th International Scientific and Practical Conference. Volume 3, https://doi.org/10.17770/etr2024vol3.8178, pp. 425-429

[8] Lazov L,, H. Deneva, E. Teirumnieka, Study of Auxiliary Gas Pressure on Laser Cutting Technology, Environment. Technology. Resources, Rezekne, Latvia Proceedings of the 11th International Scientific and Practical Conference. Volume III, 159-162

[9] Lazov L., E. Teirumnieks, Application of laser technology in the army, Proceedings of International Scientific Conference "Defense Technologies", Faculty of Artillery, Air Defense and Communication and Information Systems, Shumen, Bulgaria, 2018

[10] Shterev Y., N. Dolchinkov, St. Lilianova, D. Boganova, M. Peneva, L. Linkov, D. Nedialkov, Examining the possibility Of marking and engraving of textile using CO2 laser, International journal for science Machines, Technologies, Materials 12/2018 p. 491-493

[11] Shterev Y., N. Dolchinkov, St. Lilianova, D. Boganova, M. Peneva, L. Linkov, D. Nedialkov, Laser marking and cutting of plexiglas with CO2, International journal for science Machines, Technologies, Materials 4/2018 pp. 494-496.

[12] Lazov L., Angelov N., Scanning the contrast in function of velocity in laser marking of samples of steel, International Scientific Conference, Gabrovo, 2010.

[13] Lazov L., Dolchinkov N. T., Shterev Y., Boganova D., Peneva M, Study of laser cutting and marking on the felt with the help of a CO2-laser, 12th International Scientific and Practical conference Environment. Technology. Resources. ISBN 1691-5402, Vol 3, 20-22.06.2019, Rezekne, Latvia, p. 143-147, https://doi.org/10.17770/ETR2019VOL3.4202;

[14] Lazov L., Dolchinkov N. T., Shterev Y., Lilianova St., Pacejs Anton, Use of CO2 laser for marking and clearing of textile materials for manufacture of military equipment, 12th International Scientific and Practical conference Environment. Technology. Resources. Vol 3, 20-22.06.2019 Rezekne, Latvia, ISBN 1691-5402, p. 32-36;

[15] Lazov L., Dolchinkov N. T., Shterev Y., L. Linkov, D. Nedialkov, Study of cutting and labeling of polymethylmethacrylate using a CO2 laser, 12th International Scientific and Practical conference Environment. Technology. Resources. ISBN 1691-5402, Vol 3, 20-22.06.2019 Rezekne, Latvia, p. 37-40.

[16] Tonchev N., V. Georgiev, N. Dolchinkov, N. Padarev, E. Yankov, Methodology and model for the study of relative accuracy deviation in laser cutting of c 235 steel, Vol. 3 (2024): Environment. Technology. Resources. Proceedings of the 15th International Scientific and Practical Conference. Volume 3, DOI: https://doi.org/10.17770/etr2024vol3.8171, pp. 445-448

[17] Lazov L., T. Karadzhov, E.Teirumnieks, A. Pacejs, C. Conev, Methods for measurement of pulse parameters of fiber lasers, Vol. 3 (2024): Environment. Technology. Resources. Proceedings of the 15th International Scientific and Practical Conference. Volume 3, pp. 406-412

[18] Petrova, D., Vlahova, B., Lengerov, A., Zlateva-Petkova, T., Improvement of Constructive-Technological Approaches Reducing Innovative Obsolescence of Industrial Technologies in the Context of Industry 4.0, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2023, 1, pp. 180–186.

[19] Petrova, D., Vlahova, B., Lengerov, A., Zlateva-Petkova, T., Study of the State of Innovation Development and Obsolescence in the Republic of Bulgaria of Companies from the Mechanical Engineering Sector, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2023, 1, pp. 187–194.

[20] Petrova, D., Innovative Obsolescence in Mechanical Engineering and Singleness of Indicators, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2024, 3, pp. 221–224.

[21] Toneva, D., Dimitrova, D., Some aspects of the water crisis in Bulgaria, 5th International Scientific Practical Conference „Environment. Technology. Resources ", Published by Rezekne Academy of Technologies, Latvia. Volume I, pp. 373-377, ISSN 1691-5402, ISBN 978–171389957–0.

[22] Rachovski, T., Petrova, D., Ivanov, I., Automated Creation of Educational Questions: Analysis of Artificial Intelligence Technologies and Their Role in Education, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2024, 2, pp. 465–467.

[23] Petrova, D., An Approach to Modeling Innovation Obsolescence, Vide Tehnologija Resursi Environment Technology ResourcesOpen source preview, 2023, 1, pp. 175–179.

[24] Padarev N. I. , Adjusting the Quantity of Surfactants in Decontamination Solutions. Environment. Technology. Resources. Rezekne, Latvia, Proceedings of the 16th International Scientific and Practical Conference. 2025. Volume V, 219-223, DOI: https://doi.org/10.17770/etr2025vol5.8469