



Serbian Tribology Society



University of Belgrade,  
Faculty of Mechanical Engineering

10<sup>th</sup> International Conference on Tribology  
**BALKANTRIB '20**

**PROCEEDINGS**

Editor: Aleksandar Vencel



Balkan Tribological  
Association

May 20 - 22, 2021, Belgrade, Serbia



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## Preface

The International Conference on Tribology – BALKANTRIB is supported by the Balkan Tribological Association and is organised every three years since 1993, each time in a different Balkan country. The previous conferences were held in Bulgaria (1993 and 2008), Greece (1996 and 2011), Romania (1999 and 2014), Turkey (2002 and 2017) and Serbia (2005). This 10<sup>th</sup> jubilee BALKANTRIB conference is organised in Belgrade, by the Serbian Tribology Society and the University of Belgrade, Faculty of Mechanical Engineering, on May 20-22, 2021.

The original date of the Conference was on September 24-26, 2020, but it was postponed due to the COVID-19 pandemic. Since the pandemic still significantly affects the world and makes the travelling difficult and unsafe it was decided to hold the 10<sup>th</sup> International Conference on Tribology – BALKANTRIB '20 entirely online.

Due to the postponing of the BALKANTRIB '20 conference there was an overlap with the SERBIATRIB '21 conference, which is also organised by the Serbian Tribology Society. The International Conference on Tribology – SERBIATRIB is organised every two years since 1989. The previous conferences were held in Kragujevac (1989, 1991, 1993, 1999, 2005, 2007, 2011, 2013, 2017 and 2019), Herceg Novi (1995), Kopaonik (1997) and Belgrade (2001, 2003, 2009 and 2015). Therefore, this year the 17<sup>th</sup> International Conference on Tribology – SERBIATRIB '21 is organised in the same period and included in the BALKANTRIB '20 conference.

Serbian Tribology Society (STS) is a full member of the International Tribology Council (ITC) and Balkan Tribological Association, as well. Organising Scientific Conferences, STS plays a significant role in helping engineers and researchers to introduce in the fundamentals of tribology and to present their experience, solutions and research results.

Tribology is one of the sciences and technical disciplines whose development has a great influence on the reliability and life of mechanical systems. Interdisciplinary character of tribology and presence of tribological processes in most of mechanical systems demand researches in all fields of industry, where tribological activities can achieve significant technical, economical and environmental effects. The scope of the Conference embraces the state of art and future trends in tribology research and application.

Altogether 92 papers of 275 authors from 31 countries (Argentina, Austria, Bangladesh, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Czechia, Egypt, France, Germany, Greece, India, Japan, Latvia, Lithuania, Mexico, Montenegro, Netherlands, Poland, Portugal, Romania, Russia, Serbia, Slovenia, Spain, Sweden, Taiwan, Turkey, Ukraine and USA) have been published in this Proceedings. Approximately 56 papers were submitted by the authors from Balkan countries and approx. 36 papers by authors from the rest of the World.

Besides presentations of these 92 papers, the Conference will have 3 presentations of the companies and 1 presentation of the paper that was not printed in the Proceedings, which make a total of 96 presentations scheduled in the Conference Programme.

All papers in this Proceedings are classified into eleven chapters:

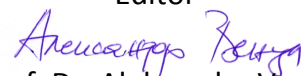
- Plenary Lectures (4)
- Tribological Properties of Solid Materials (12)
- Surface Engineering and Coating Tribology (12)
- Lubricants and Lubrication (10)
- Tribotesting and Tribosystem Monitoring (9)
- Tribology of Machine Elements (10)
- Tribology of Manufacturing Processes (8)
- Design and Calculation of Tribocontacts (6)
- Sealing tribology (3)
- Biotribology (6)
- Other Topics Related to Tribology (12)

The Conference is financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Bruker, Valvoline Europe, Ellis Enterprises East d.o.o., Fluidotehnic d.o.o., Labtim SE d.o.o., Lubricants, Messer Tehnogas AD and Rtec Instruments.

As a President of the Organising Committee I would like to thank members of the Scientific and the Organising Committee and all those who have helped in making the Conference and this Proceedings better. It was a great pleasure and new experience for me to organise this Conference and I hope that the Conference, bringing together specialists, research scientists and industrial technologists, and the Proceedings will stimulate new ideas and concepts, promoting further advances in the field of tribology.

Belgrade, May 2021

Editor



Prof. Dr. Aleksandar Venci

# Contents

---

## Plenary Lectures

- 1. Frontiers of superlubricity research: Recent developments and future prospects**  
Ali Erdemir .....3
- 2. The supreme lubrication power of glycerol for green superlubricity**  
Jean Michel Martin, Maria-Isabel De Barros Bouchet, Yun Long .....5
- 3. On the in-situ formation of transition metal disulphides in a lubricated tungsten nitride coating contact**  
Carsten Gachot .....7
- 4. Topological optimisation of slider bearing geometry**  
Andreas Almqvist, Kalle Kalliorinne .....9

## Tribological Properties of Solid Materials

- 5. Study of cavitation erosion phenomenon at stainless steel 304 base and with SiC coating**  
Manuel Vite-Torres, Arturo Villanueva-Zavala, Ezequiel A. Gallardo Hernández,  
Marisa Moreno-Ríos, Dario H. Mesa-Grajales .....13
- 6. Tribological characteristics of metal GFRP composite filled with SiC and Al<sub>2</sub>O<sub>3</sub> particles**  
Venkata Kasi Viswanadham Kolipakula, Ravinder Reddy Pinninti, Rakesh Kumar Gunda,  
Chandra Sekhara Kumar Aduru .....15
- 7. Wear of A356/Al<sub>2</sub>O<sub>3</sub> nanocomposites and optimisation of material and operating parameters**  
Sandra Gajević, Slavica Miladinović, Blaža Stojanović, Aleksandar Vencel .....17
- 8. Tribological investigation of ZA-27 alloy based micro/nano mixed composites**  
Dragan Džunić, Slobodan Mitrović, Darko Pešić, Vladimir Kočović, Marko Pantić,  
Aleksandra Kokić Arsić .....19
- 9. Optimization of tribological behaviour of hybrid composites based on A356 and ZA-27 alloys**  
Blaža Stojanović, Aleksandar Vencel, Nenad Miloradović, Sandra Gajević, Slavica Miladinović .....21
- 10. Friction coefficient during the reciprocating sliding of UHMWPE in different environments**  
Fatima Zivic, Dragan Adamovic, Slobodan Mitrovic, Nenad Grujovic, Jovan Tanaskovic,  
Nina Busarac, Ivan Stojadinovic .....23
- 11. Temperature studies of subsurface zone in pure titanium exposed to dry sliding test**  
Jerzy Dryzek .....25
- 12. Investigation on wear of biopolymer parts produced by 3D printing in condition of reverse sliding friction**  
Mihail Zagorski, Georgi Todorov, Nikolay Nikolov, Yavor Sofronov, Mara Kandeve .....27



<b>13. Investigation of friction in contact off shoe sole rubber on hard substrate</b>	
Milan Nikolić, Dušan Stamenković, Milan Banić .....	29
<b>14. Static and dynamic friction coefficient for glass surfaces</b>	
Bogdan Chiriac, Cezara-Mariuca Oprisan, Vlad Carlescu, Dumitru N. Olaru .....	31
<b>15. The investigate of running-in process based on surface roughness parameters, real contact area and tribological properties</b>	
Jeng-Haur Horng, Dipto Biswas, Adhitya, Qumrul Ahsan .....	33
<b>16. Influence of surface roughness on 1000 m/s high speed and 200 kA high current electric sliding contacts</b>	
Corinna Biethan, Farid Alouahabi, Markus Schneider .....	35

## Surface Engineering and Coating Tribology

<b>17. Tribological behaviour of a micro-arcs oxidation coating formed on AA 5086 and effect of rectification</b>	
Louis Rodriguez, Jean-Yves Paris, Marion Balsarin, Philippe Combes, Jean Denape, Karl Delbe .....	39
<b>18. The study of nanoscale tribological properties of carbon- and nitrogen-based thin films prepared by bottom-up approach</b>	
Lukasz Kolodziejczyk, Witold Szymanski, Diego Martínez-Martínez, Roman Parkhomenko, Oreste De Luca, Mato Knez, Petra Rudolf, Luis Cunha .....	41
<b>19. Effect of nano-silica/alumina hybrid coating on erosion resistance of GFRP for application of wind turbine blades</b>	
Sarah S. H. Ibrahim, Nabil S. M. El-Tayeb .....	43
<b>20. Surface topography and roughness parameters of electrospark coatings on titanium alloy Ti6Al4V</b>	
Georgi Kostadinov, Pancho Danailov, Rayna Dimitrova, Mara Kandeve, Todor Penyashki, Valentin Kamburov, Antonio Nikolov, Blagoj Elenov .....	45
<b>21. Pulsed plasma nitriding of high velocity oxy-fuel sprayed Inconel 625 coatings</b>	
Harun Mindivan .....	47
<b>22. Abrasive wear resistance of electrospark coatings on titanium alloys</b>	
Mara Kandeve, Georgi Kostadinov, Rayna Dimitrova, Todor Penyashki, Valentin Kamburov, Seryoja Valcanov, Antonio Nikolov .....	49
<b>23. A comparative study on tribological behaviour of electroless Ni-P-B and Ni-P-B-W coatings</b>	
Harun Mindivan, Mehmet Sarioglu .....	51
<b>24. Comparative micro-scale abrasive wear testing of thermal sprayed and hard chromium coatings</b>	
Georgiana Chişiu, Roxana-Alexandra Gheţa, Alina Maria Stoica, Nicolae Alexandru Stoica .....	53
<b>25. Flexural properties and abrasive wear behaviour of plasma sprayed chromia and titania coatings</b>	
Angelos Koutsomichalis, George Loukas, Michalis Vardavoulias, George Chondrakis, Nikolaos Vaxevanidis .....	55

<b>26. Comparison of different high temperature tribological testings of TiAlN coating</b> Vladimir Terek, Aleksandar Miletić, Lazar Kovačević, Branko Škorić, Dragan Kukuruzović, Aljaž Drnovšek, Peter Panjan, Pal Terek .....	57
<b>27. Influence of the electrochemical anodization on the surface roughness of Ti-13Nb-13Zr medical alloy</b> Dragana Barjaktarević, Veljko Đokić, Sanja Stevanović, Marko Rakin .....	59
<b>28. Investigation of the surface properties of TiN coated Ti6Al4V alloy</b> Şengül Danişman, Emin Ersoy, Canan Doğan .....	63

## Lubricants and Lubrication

<b>29. Extended test campaign for rapeseed oil on four ball machine</b> Dionis Guglea, Traian Florian Ionescu, Constantin Georgescu, Dumitru Dima, Lorena Deleanu .....	67
<b>30. Investigation of tribological properties of environmentally friendly ionic liquids as a potential lubricity improving additives for water-based lubricants</b> Raimondas Kreivaitis, Milda Gumbytė, Jolanta Treinytė .....	69
<b>31. The importance of the electrical properties of hydraulic fluids</b> Darko Lovrec, Vito Tič .....	71
<b>32. The Stribeck curves and lubrication conditions of different lubricating greases</b> Rafal Kozdrach, Jolanta Drabik .....	73
<b>33. Effect of crossover stress of lithium soap grease on ball bearing torque</b> Ryosuke Sato, Keigo Nishizawa, Reo Miwa, Norifumi Miyanaga .....	75
<b>34. Influence of the structure of a hydrocarbon radical on the antifriction properties of phosphorothionates</b> Igor Mukhortov, Igor Levanov, Kseniya Yakunina, Elena Zadorozhnaya .....	77
<b>35. Influence of the amount of metal-containing additive on performance characteristics of lubricant based on rapeseed oil</b> Mara Kandeve, Zhecho Kalitchin, Elena Zadorozhnaya, Aleksandar Venci .....	79
<b>36. Experimental determination of the wear rate of anti-friction solid-film coating of journal bearings with boundary lubrication</b> Igor Levanov, Elena Zadorozhnaya, Maksim Prudnikov .....	81
<b>37. About the change of flow factors during the run-in process of lubricated contacts</b> Achill Holzer, Katharina Schmitz .....	83
<b>38. Squeeze flow through a compressible multilayered porous structure</b> Cătălin Enescu, Petrică Turtoi, Alice Marinescu, Traian Cicone .....	85

## Tribotesting and Tribosystem Monitoring

<b>39. Acoustic signature identification of damage mechanisms in a steel/glass sliding contact</b> Khouloud Jlaiel, Malik Yahiaoui, Jean-Yves Paris, Jean Denape .....	89
---	----

<b>40. Design of the twin-disc test rig for the study of wheel squeal noise</b>	
Milan Omasta, Václav Navrátil, Tomáš Gabriel, Radovan Galas, Milan Klapka .....	91
<b>41. Design of linear sliding tribometer</b>	
Milan Banić, Dušan Stamenković, Milan Nikolić, Nikola Korunović .....	93
<b>42. Materials durability testing by an application related approach to lab-scale tribology testing</b>	
Dirk Drees, Emmanuel Georgiou .....	95
<b>43. Software and hardware engineering for rotating machines fault diagnosis</b>	
Alexey Kornaev, Sergey Popov, Nickolay Kornaev, Ivan Stebakov, Elena Kornaeva .....	97
<b>44. An analysis of several 3D texture parameters for wear scars obtained in severe regime, on a four-ball tester</b>	
Lorena Deleanu, Traian Florian Ionescu, George Catalin Cristea, Cornel Camil Suci, Constantin Georgescu .....	99
<b>45. Influence of lubricants degradation level over tribological properties</b>	
Alexandru Valentin Rădulescu, Irina Rădulescu, Florin Petrescu .....	101
<b>46. Monitoring the degradation and contamination levels of hydraulic gear pumps</b>	
Alexandru Daniel Marinescu, Alexandru Valentin Rădulescu, Irina Rădulescu, Ana Maria Carla Popescu, Ștefan-Mihai Șefu .....	103
<b>47. Prevention of water ingress in hydraulic systems</b>	
Samo Goljat, Vito Tič, Darko Lovrec .....	105
<b>Tribology of Machine Elements</b>	
<b>48. Effects of dimple depth and processed area on lubrication properties of pad-type thrust bearings</b>	
Soh Akuzawa, Reo Miwa, Ryota Ishii, Norifumi Miyanaga, Toshiki Sato, Tatsuya Niimi, Yasuyuki Kanda .....	109
<b>49. Stiffness evaluation of a single-recess hydrostatic thrust bearing with a structurally compliant surface</b>	
Alice Marinescu, Traian Cicone .....	111
<b>50. Load capacity for self-lubricating sliding bearings</b>	
Aleksandar Marinković, Ivan Simonović, Tatjana Lazović .....	113
<b>51. Experimental investigation of the high speed roller bearing assembly lubricated by oil mist</b>	
Miloš Stanković, Nenad Kolarević, Nikola Davidović, Marko Miloš .....	115
<b>52. The lubrication regime factor of rolling bearing</b>	
Rade Grujičić, Milan Tica, Blaža Stojanović, Lozica Ivanović, Radivoje Mitrović, Radoslav Tomović .....	117
<b>53. Simulation program for sliding speeds and friction torque in high speed angular contact ball bearings</b>	
Andrei Zama, Ana Tufescu, Viorel Paleu, Dumitru N. Olaru .....	119

<b>54. Modelling the thermal state of a turbocharger bearing housing when calculating the rotor dynamics at transient modes</b>	
Elena Zadorozhnaya, Vlad Hudyakov, Sergei Sibiryakov, Elizaveta Polyacko .....	121
<b>55. Technologies of coating the brake disc's friction surface in order to reduce wear intensity and particulate formation</b>	
Saša Vasiljević, Jasna Glišović, Blaža Stojanović .....	123
<b>56. Methods for quantification of the abrasive wear at steel ropes used in drum devices</b>	
Grzegorz Olszyna, Vlada Gasić, Andrzej Tytko .....	125
<b>57. Numerical simulation of the operation of a viscous coupling</b>	
Andrei I. Stoicescu, Mihai Stoicescu, Adrian Predescu .....	127

## **Tribology of Manufacturing Processes**

<b>58. Theoretical and experimental studies on the cut zone generated by AWJ process</b>	
Iulian Patirnac, Razvan George Ripeanu, Ibrahim Naim Ramadan .....	131
<b>59. Evaluation of tribological studies of solid lubricants on Ti-6Al-4V alloy</b>	
Rakesh Kumar Gunda, Suresh Kumar Reddy Narala .....	133
<b>60. Analysis of the influence of contact friction on the stability of steel welded tube forming process</b>	
Marko Delić, Vesna Mandić .....	135
<b>61. Investigation of the penetration of the counter-body in the nitride zone of nitrided steels and analysis of concomitant characteristics</b>	
Angel Zyumbilev, Nikolay Tonchev, Emil Yankov, Iliya Zyumbilev, Valentin Gaidarov .....	137
<b>62. Comparative analysis of milling strategies of complex geometry surfaces</b>	
Gordana Globočki Lakić, Branislav Sredanović, Goran Jotić, Stefan Gotovac .....	139
<b>63. Experimental and statistical study of surface roughness in CNC slot milling of Al7075 alloy using full and fractional factorial design</b>	
Nikolaos Fountas, Kyriaki-Evangelia Aslani, John Kechagias, Panagiotis Kyratsis, Nikolaos Vaxevanidis ...	141
<b>64. Effect of surface roughness on the behaviour of the galling adhesive severe wear phenomenon between ASTM 6061 aluminium and tool grade D2 steel in the stamping process in automotive manufacturing</b>	
Erick Martínez-Méndez, Daniel Antonio-Aguirre, Manuel Vite-Torres, Ezequiel A. Gallardo-Hernández, José F. Márquez-Santiago, Walter R. Tuckart .....	143
<b>65. Experimental investigation of surface roughness in 3D printed PLA using design of experiments</b>	
Nikolaos Fountas, Kostas Kitsakis, Kyriaki-Evangelia Aslani, John Kechagias, Nikolaos Vaxevanidis .....	145

## **Design and Calculation of Tribocontacts**

<b>66. Erosion modelling of coated gate valves</b>	
Jong Hyok Ri, Razvan George Ripeanu, Alin Dinita .....	149

<b>67. A simplified FE model of the four ball tester for evaluating the stress and strain distributions</b>	
Catalin Pirvu, Traian Florian Ionescu, Constantin Georgescu, Lorena Deleanu .....	151
<b>68. Modelling of transient flow of piston ring-liner contact using synthetic lubricants</b>	
Anastasios Zavos, Pantelis G. Nikolakopoulos .....	153
<b>69. Wear and stress analysis of soil chisel tine by DEM</b>	
Egidijus Katinas, Rostislav Chotěborský .....	155
<b>70. Investigation of Lode angle parameter evolution for cutting mechanism of scratch abrasion</b>	
Dhanraj Rajaraman, Stijn Hertelé, Dieter Fauconnier .....	157
<b>71. A journal bearing performance prediction method utilizing a machine learning technique</b>	
Georgios N. Rossopoulos, Christos I. Papadopoulos .....	159

## Sealing Tribology

<b>72. Influence of alternating temperature levels on the wear behaviour of radial lip seals: Test rig design and wear analysis</b>	
Lukas Merkle, Matthias Baumann, Frank Bauer .....	163
<b>73. The sealing mechanism of radial lip seals: A numerical study of the tangential distortion of the sealing edge</b>	
Jeremias Grün, Simon Feldmeth, Frank Bauer .....	165
<b>74. Considerations on optimizing mechanical face seals to minimize losses</b>	
Mihaela Istrate, Nicolae Popa, Viorel Nicolae .....	167

## Biotribology

<b>75. Effect of normal load on friction characteristics of bio-inspired elastomeric surfaces</b>	
Charchit Kumar, Thomas Speck, Vincent Le Houerou .....	171
<b>76. Theoretical approach of studying human fingers modelled as inflated membranes and experimental validation of study</b>	
Andrei Călin, Andrei Tudor, Petrică Turtoi, Marilena Stoica .....	173
<b>77. Wear and friction characterization of some dental restorative materials</b>	
Florencio S. Martínez-Cruz, Manuel Vite-Torres, Alejandra Moran-Reyes, Jorge A. Bravo-Mejía .....	175
<b>78. Tribology and video capillaroscopy methods in application to study flows in blood vessels</b>	
Elena Kornaeva, Ivan Stebakov, Dmitry Stavtsev, Alexey Kornaev, Victor Dremin .....	177
<b>79. Modularity of total hip prosthesis and its tribological implications</b>	
Liliana-Laura Badita, Virgil Florescu, Constantin Tiganesteanu, Lucian Capitanu .....	179
<b>80. Influence of changes elastic characteristics of UHMW polyethylene on the contact pressure in hip endoprosthesis</b>	
Myron Czerniec, Jarosław Zubrzycki .....	181

## Other Topics Related to Tribology

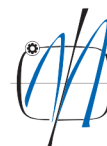
<b>81. Energy balance of friction and regularities of static and dynamic energy dissipation</b> Sergey V. Fedorov .....	185
<b>82. Contact approach and green tribology in the study of natural processes</b> Nyagol Manolov, Emilia Assenova, Evgenia Kozhoukharova .....	187
<b>83. Contact deformations and convergent contacts in geotribological systems</b> Evgenia Kozhoukharova, Emilia Assenova .....	189
<b>84. Numerical and experimental evaluations of the elbows corrosion used for the interconnection of the pipes</b> Razvan George Ripeanu, Adrian Lospa, Cristian Dudu, Alin Dinita .....	191
<b>85. Experimental study regarding the corrosion behaviour of heat exchanger copper tubes in the presence of different aggressive environments</b> Maria Tănase, Ibrahim Ramadan .....	193
<b>86. Catalytic behaviour of iron-based metallic glasses improved by mechanochemical treatment</b> Zara Cherkezova-Zheleva, Daniela Paneva, Martin Tsvetkov, Elzhana Encheva .....	195
<b>87. Surface oxidation of Al-Si alloys</b> Adelina Miteva, Anna Petrova, Georgi Stefanov .....	197
<b>88. Influence of magnesium addition on properties of rapidly solidified aluminium alloys</b> Anna Petrova, Adelina Miteva, Georgi Stefanov .....	199
<b>89. FTIR spectroscopy analysis of mechanochemically activated Na<sub>2</sub>CO<sub>3</sub> during relaxation time</b> Nataša Đorđević, Milica Vlahović, Slavica Mihajlović, Sanja Martinović, Nenad Vušović .....	201
<b>90. Determination of the optimal mode of laser surface marking of aluminium composite by CO<sub>2</sub> laser</b> Emil Yankov, Roussi Minev, Nikolay Tonchev, Lyubomir Lazov .....	203
<b>91. Simulation of the aging process of the material from which the flame ports of the burner are made by intensive heat load</b> Miroljub Adžić, Aleksandar Milivojević, Vuk Adžić, Bojan Ivljanin .....	205
<b>92. Software development solution for prediction on tribological properties of dental glass ceramics based on JavaScript web frameworks</b> Aleksandar Đorđević, Marko Pantić, Dragan Džunić, Slobodan Mitrović, Milan Erić, Miladin Stefanović, Aleksandra Kokić Arsić .....	209
<b>Authors Index</b> .....	211



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## **FTIR SPECTROSCOPY ANALYSIS OF MECHANOCHEMICALLY ACTIVATED Na<sub>2</sub>CO<sub>3</sub> DURING RELAXATION TIME**

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*Sodium carbonate was mechanically activated for 7 minutes in a vibro mill at a frequency of 3000 oscillations per minute. Activated samples were stored in the air at room conditions for 31 days. To monitor the kinetics of the transformation process of sodium carbonate to bicarbonate, Fourier-transform infrared (FTIR) spectroscopy analysis was used and was performed as a function of relaxation time for characteristic groups observed: CO<sub>3</sub><sup>2-</sup>, HCO<sub>3</sub><sup>-</sup> and OH<sup>-</sup>. The obtained results provided kinetics parameters for the transformation of carbonate into bicarbonate as a result of chemisorption of moisture and carbon dioxide from the atmosphere.*

**Keywords:** mechanical activation, sodium carbonate, mechanochemical transformation, FTIR.

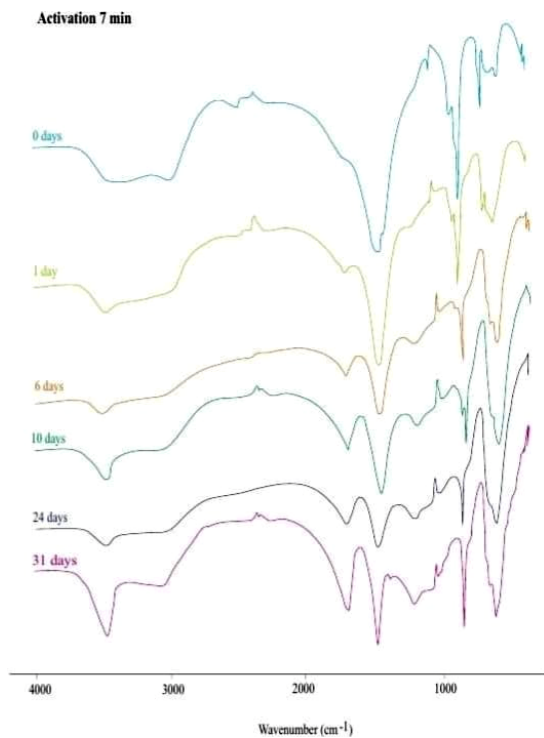
### **1. INTRODUCTION**

The sodium carbonate used in this study was anhydrous and in p.a. quality and was mechanically activated in the high-energy mill KHD Humboldt Wedag AG for 7 minutes at a frequency of 3000 rpm. Engine power is 0.8 kW, discontinuously in an air atmosphere, with rings leads to its heating up to a temperature of 80 °C. After activation, the samples were stored at room conditions for 1, 6, 10, 24 and 31 days (relaxation time). The effects of mechanical activation were monitored by FTIR spectroscopy analysis. FFT infrared spectra of the samples were recorded on a spectrometer Bomem-Hartman & Braun Michelson MB-100, in the wave numbers range of 4000 – 300 cm<sup>-1</sup> and at a resolution of 2 cm<sup>-1</sup>. Samples were prepared in the form of a suspension using “Nujol”. Changes in the peaks’ areas, as well as the widths at the half-heights for groups: CO<sub>3</sub><sup>2-</sup>, HCO<sub>3</sub><sup>2-</sup> and OH<sup>-</sup>. The method of mechanical activation, which, in various technical and technological ways, brings mechanical energy to solid materials thus changing

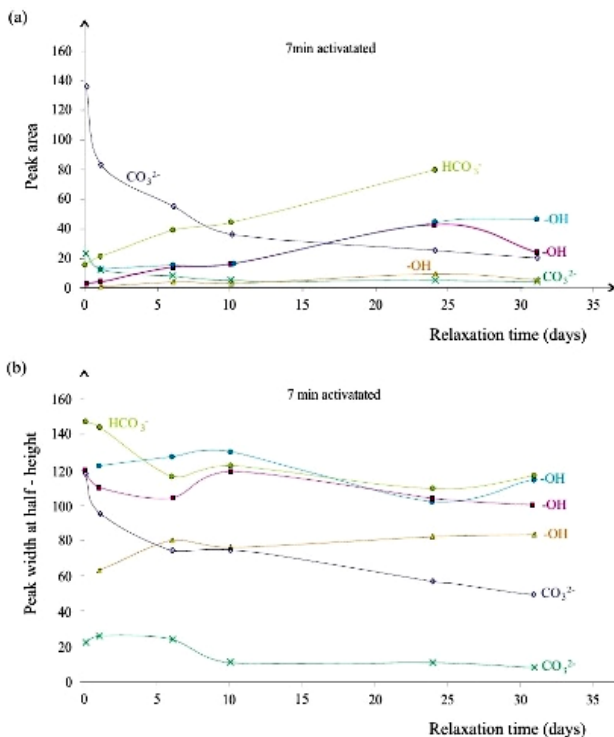
and regulating many physico-chemical characteristics related to increasing the system’s reactivity, is becoming more and more topical [1-5].

### **2. RESULTS AND DISCUSSION**

The change in the characteristic peaks as a function of relaxation time is clearly noticeable in the diagrams in Figure 1. The initial curves (0 days of relaxation) for all four activation times, at a wavelength of 3500–3600 cm<sup>-1</sup>, do not have clearly defined peaks, and with the increasing relaxation time. The appearance of the OH group in the activated sodium carbonate sample, as well as changes in the peak area of the OH group, can be explained by the fact that the Na<sub>2</sub>CO<sub>3</sub> sample, due to the energy obtained by mechanical activation and disturbed crystal structure had increased adsorption and chemisorption affinity to moisture from the atmosphere during relaxation. A similar change is observed at a wavelength of 1645 cm<sup>-1</sup>, and the database revealed that these changes are also related to the OH group.



**Figure 1.** FTIR spectrograms of  $\text{Na}_2\text{CO}_3$  samples activated for 7 min during relaxation time (0, 1, 6, 10, 24 and 31 days) at room conditions



**Figure 2.** (a) areas of peaks characteristic for ion groups and (b) widths at peak half-height, for  $\text{Na}_2\text{CO}_3$  sample activated for 7 min as a function of relaxation time

At a wavelength of  $1420\text{ cm}^{-1}$ , which characterizes  $\text{Na}_2\text{CO}_3$ , that is  $\text{CO}_3^{2-}$  ion, a tendency of peak decrease with the increasing relaxation time can be seen (Fig. 2). Similar changes are observed at a

wavelength of  $873\text{ cm}^{-1}$ . This is a consequence of the conversion of carbonate to bicarbonate ion due to the absorption of moisture and carbon dioxide from the air. Parallely with this change, a peak characteristic for the bicarbonate ion at a wavelength of  $1800\text{ cm}^{-1}$  appeared. This peak is more pronounced with the increasing relaxation time.

At wavelengths from  $2300$  to  $2400\text{ cm}^{-1}$ , a peak that principally disappears gradually with the progress of relaxation time can be observed. These wavelengths are typical for adsorbed moisture and carbon dioxide. During relaxation, chemisorption of moisture and carbon dioxide occurs and the conversion of carbonate to bicarbonate, which explains the decrease and disappearance of this peak on the observed curves.

#### ACKNOWLEDGEMENT

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