End Semester Presentation: Mechanical/ Tribological behavior of 8YSZ/MWCNTs composites under dry sliding conditions

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Content

1. **Introduction and motivation.**
2. **Experimental procedure.**
3. **Main semester Results.**
4. **Summary.**
5. **Future works and research activities.**

Semester motivations and introduction

Tribology:

Includes the study and application of the principles of
friction , **lubrication** and **wear**

Friction is the force that makes it difficult for one object to slide along the surface of another.

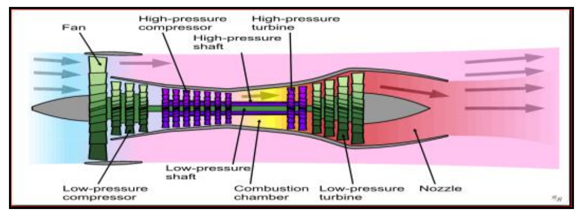
lubricant is a substance, usually organic, introduced to reduce friction between surfaces in mutual contact, which ultimately reduces the heat generated when the surfaces move.

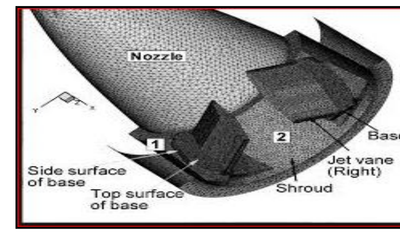
Wear is the damaging, gradual removal or deformation of material at solid surfaces.

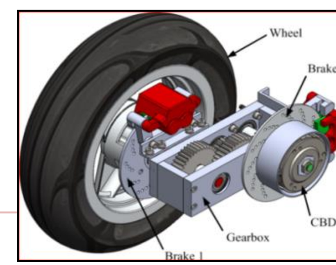
Applications:

❖Advanced nozzle jet vanes used in missiles or hot structures for spacecraft.

❖Terrestrial applications : brake systems in cars, trains, aircraft or elevators .







Motivation:

❖ Studying the tribological performance of 8YSZ/MWCNTs composites (under dry sliding condition, different speeds and carbon content) with the aim of providing a better structural and mechanical understanding to enable their technological maturation in the future.

Experimental procedure

Parameters

- ❖ Ball-on disk technique at room temperature (25°C, air humidity 50–65%) and dry conditions.
- ❖Conterepart: Si_3N_4 balls with 5mm in diameter.
- ❖Applied Load: 5 N.
- ❖Total sliding distance: 400 m.
- ❖ Sliding speed: V1= 0.036m/s , V2= 0.11m/s .

Fig.2 Wear track in the composite with 5 wt. % /MWCNTs recorded by Kenyence Microscopy

The wear rates (*W*) were calculated based on the volume loss (*V*) per total sliding distance (*d*) :

$$W = \frac{V}{d}\left[\frac{mm^3}{m}\right]$$

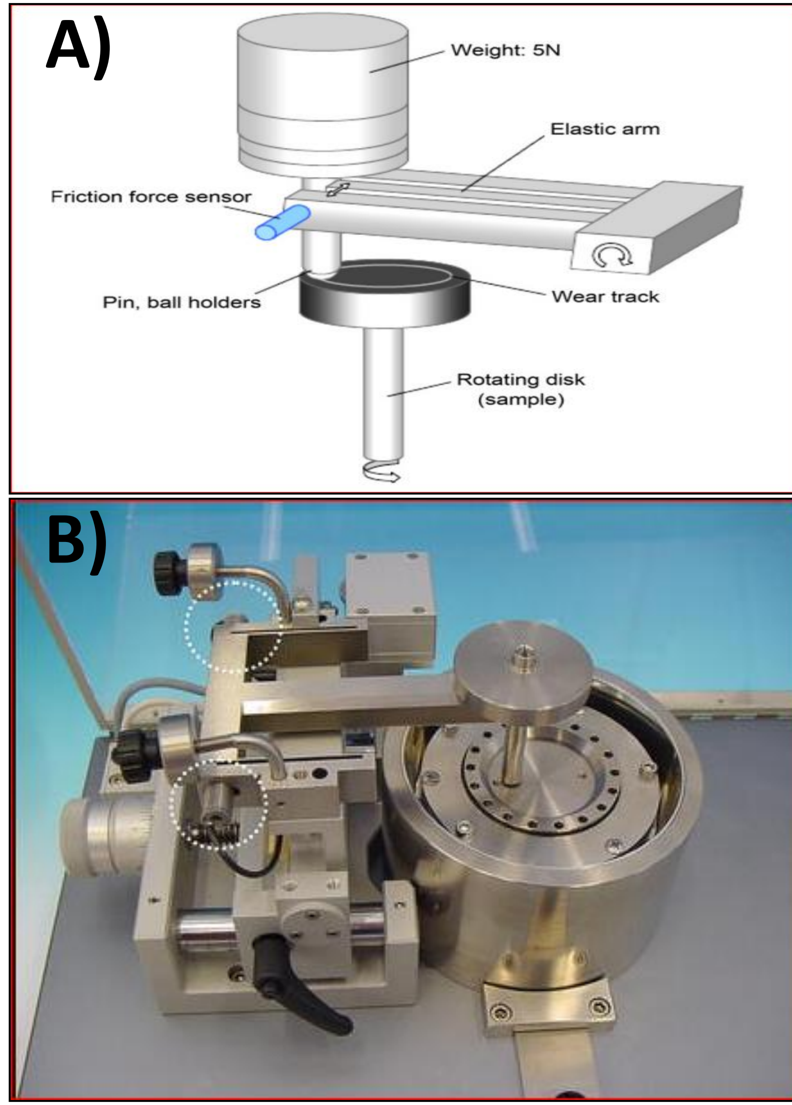


Fig.1 A) shematic design and B) real instrument of High temperature Tribometer.

Main semester Results

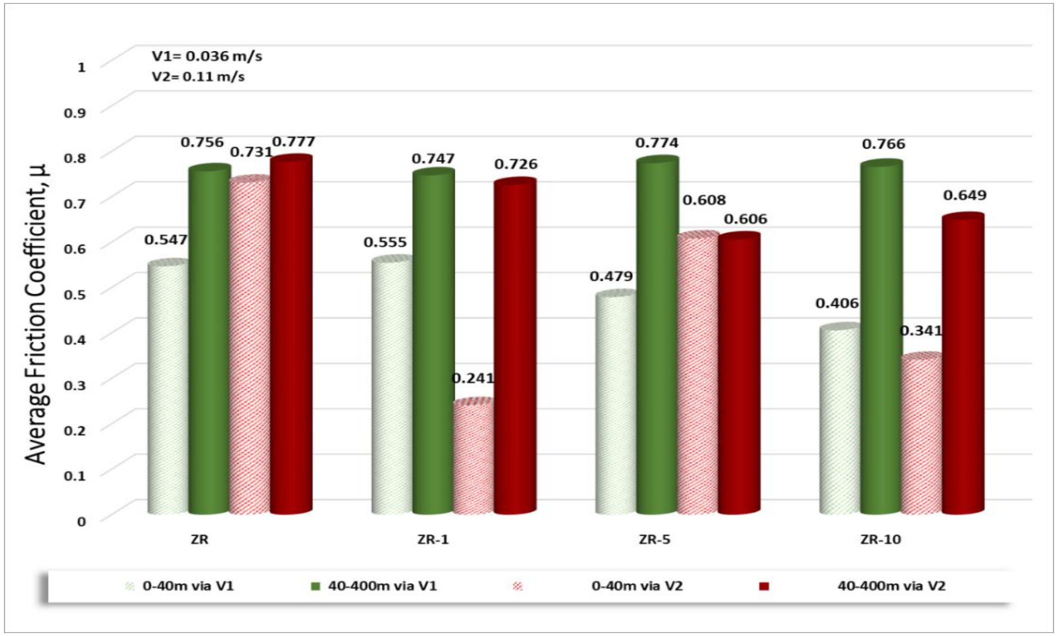


Fig.3 Average Friction Coefficient (μ) during transitory state (0-40m) and steady state (40-400m) at V1 and V2.

- At V1= 0.036m/s: the average steady state friction coefficient (μ_{AFS}) is seen to be significantly high ÷ **0.76** and quit similar in all the composites .
- At V2= 0.11m/s : (μ_{AFS}) dependent on mechanical properties of the composites and their grain size:
  - ➢ (μ_{AFS}) decreased to **0.608** with 5 wt. % MWCNT and to **0.649** with 10 wt. % MWCNT.

- **Reference**: Sever wear behavior about at V1.
- **Composite with 1 wt. % of MWCNT**: marked a fascinated wear improvement exceeding all the studied composites at V1.
- Low wear rate is also well recognised **with 5 wt. % of MWCNTs**, which increased slight in case of **10 wt.% MWCNT** but still remained low compared to the monolithic composite.

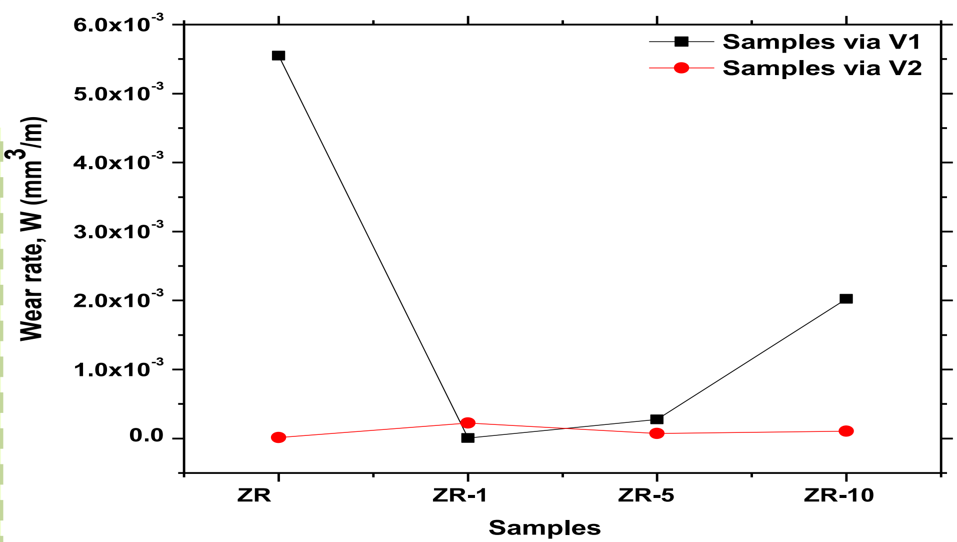


Fig.4 Wear rate (W) of the composites via V1=0.036 m/s and V2=0.11 m/s sliding speed.

Wear Mechanism

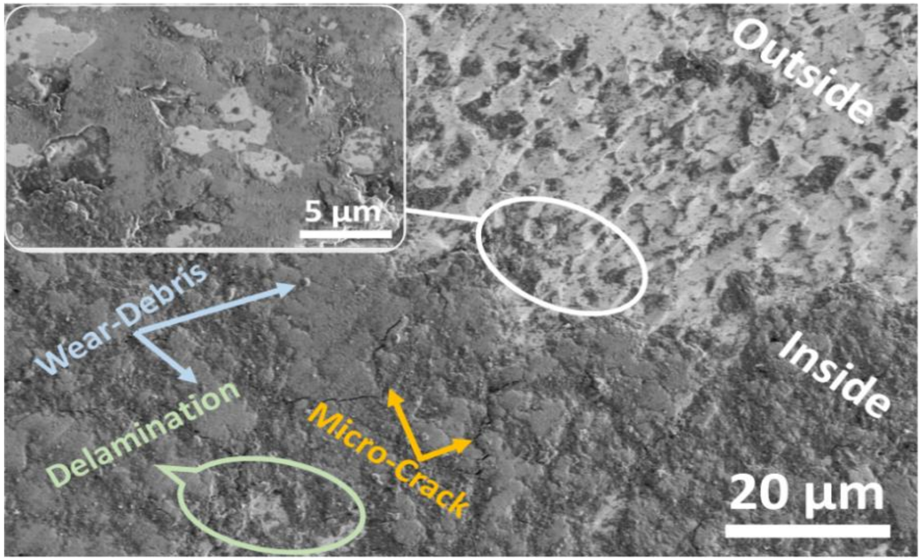


Fig.5 SEM micrograph inside and outside the wear track profile of (refrence) via V1

REFERENCE :

- The formation of a fractured and abrasively damaged ultra-thin tribo-film.
- Zirconia grain pull-outs, delaminated areas, micro cracks and high amount wear debris.
- Abrasive grooves due to the difference in the mechanical properties of phase composition or from surface polish process were seen at V2.

Composite with 1 wt. % MWCNTs :

- The formation of a perfectly continuous and uniform tribo-film at both sliding speeds V1 as well as V2 as without severe film fragmentations, wear debris or micro cracks but only minor plastic flows and light pits.

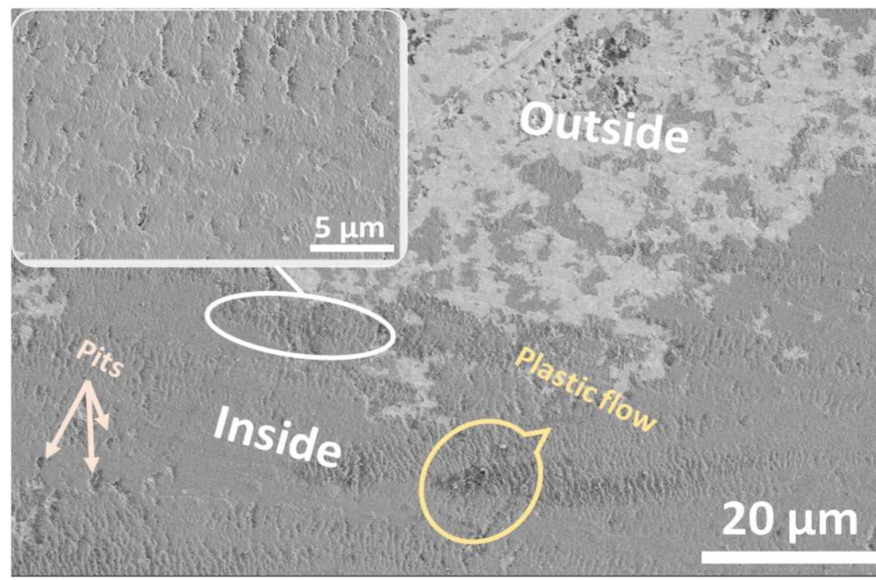


Fig.6 SEM micrograph inside and outside the wear track profile of (composite with 1 wt. % MWCNTs) via V2

Composites with 5 wt. % MWCNTs at V1:

- Surface removal caused by severe peeling .
- Non continuous tribo-film only tick (islands) and MWCNTs pull-out acting as intrinsic lubricant.

Composites with 10 wt. % MWCNTs at V1 :

- More or less coherent tribo layer with some delaminated areas, wear debris and micro-cracks were also observed.

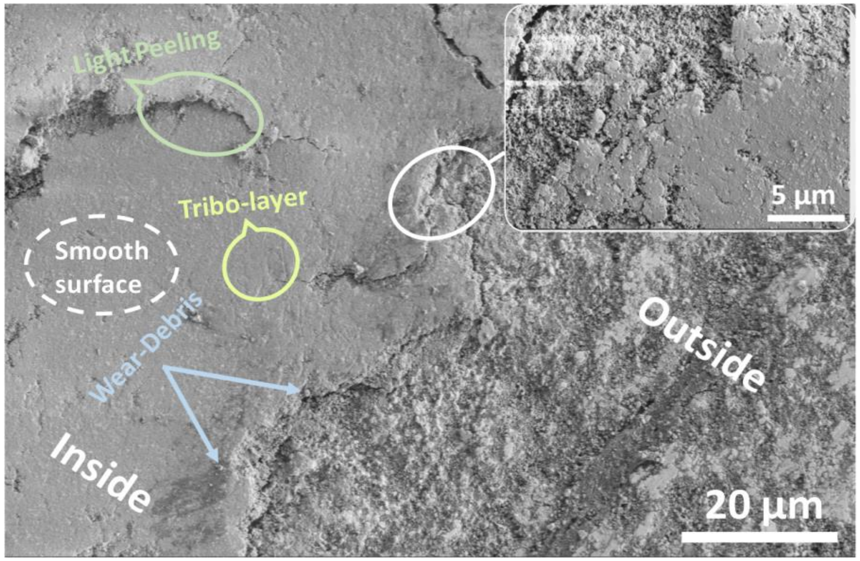


Fig.7 SEM micrograph inside and outside the wear track profile of (composite with 5* wt. *% MWCNTs) via V2

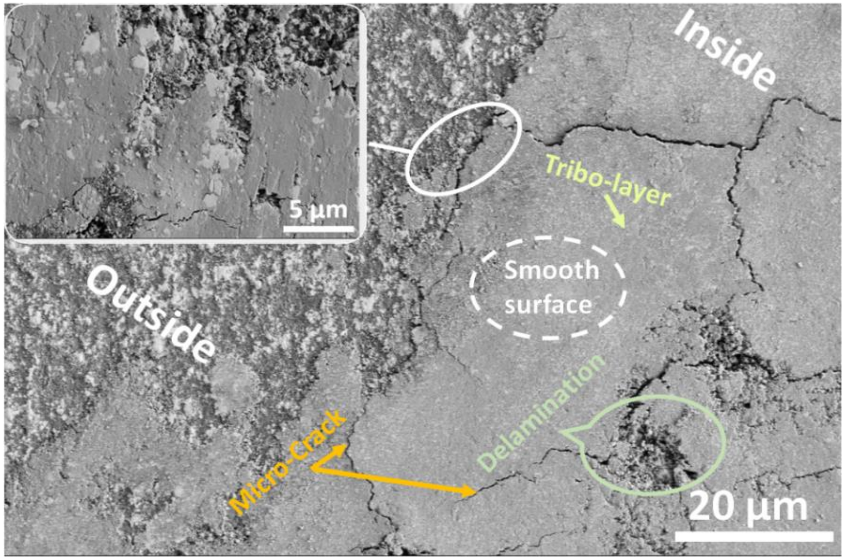


Fig.8 SEM micrograph inside and outside the wear track profile of (composite with 10* wt. *% MWCNTs) via V2

Composites with 5 wt. % and 10 wt. % MWCNTs at V2:

- The formation of a dense, smooth and continuous lubricant coating on the worn surface resulting from 5 wt. % and 10 wt. % MWCNTs addition, which is in good agreement with friction decrease .

Energy dispersive X-ray spectroscopy (EDS)

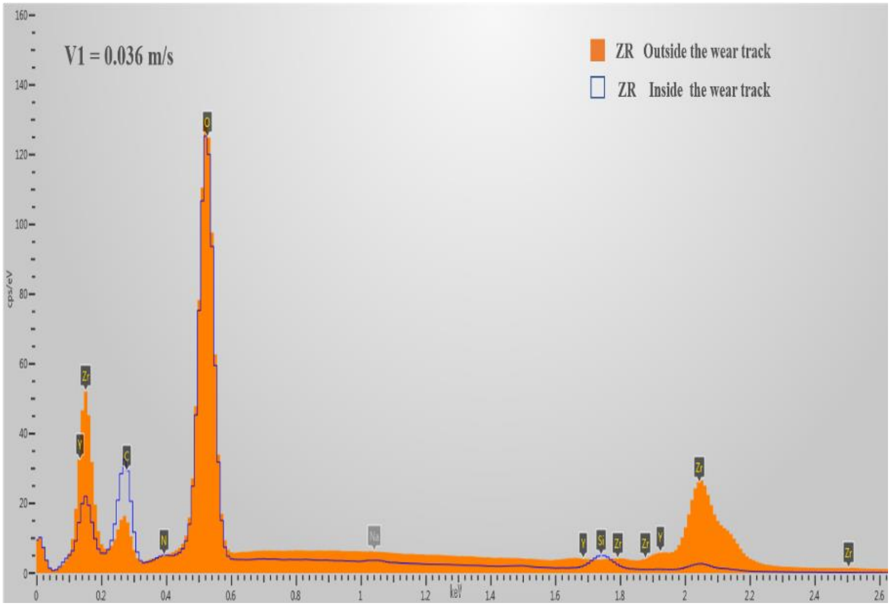


Fig. 9 (EDS) inside and outside the wear track profile of reference via V1

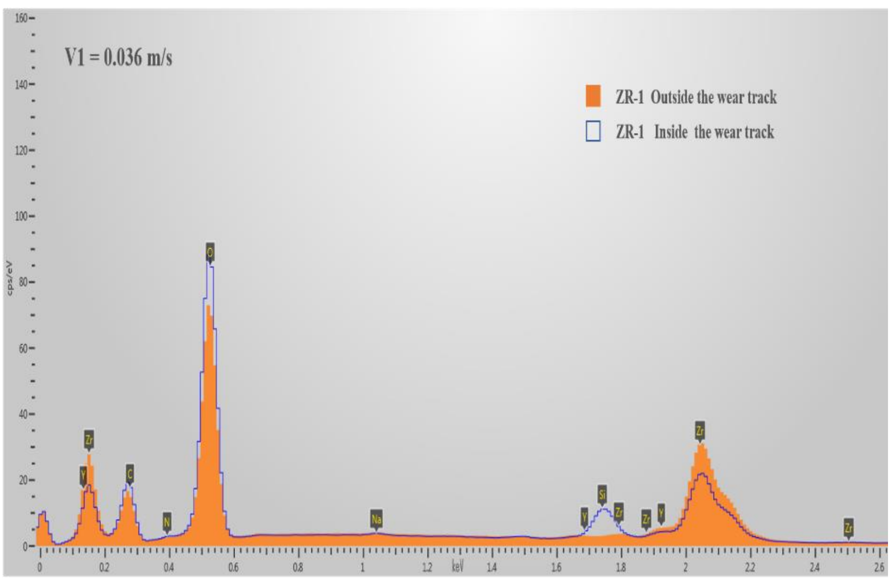


Fig.10 (EDS) inside and outside the wear track profile of (composite with 1 wt. % MWCNTs) via V1

REFERENCE at V1:

- The intensity of **(Zr)** peak decreased significantly while, the intensity of **(O)** peak remained practically identical.

REFERENCE at V2:

- The intensity of **(O)** highly increased and **(Zr)** peak slightly decreased inside the wear track.
- Appearance of **(Si)** peak.

Composite with 1 wt. % MWCNTs at V1 :

- Observation of minor decrease of **(Zr)** which systematically induced a slight increase of **(O)** peak due to debounding mechanism with presence of **(Si)** peak.
- **(C)** peak kept similar intensity as the unworn surface.

Composite with 1 wt. % MWCNTs at V2 :

- Similar peak tendency is approved when increasing the speed, with intensive **(Si)** and **(O)** peaks, therefore **(Zr)** peak lowered.

• The intensities of **(Si) peak and (O) peak are recorded to increase simultaneously with MWCNTs content till attending its highest values with 10 wt. % /MWCNTs** addition at V1.

• **(Si)** peaks were intensified essentially by **the increase of sliding speed.**

• A **sharp decrease of (C) peak intensity** with both 5 wt. % and 10 wt. % /MWCNTs.

• Composite with 5 wt. %/MWCNTs manifested the lowest decrease of **(C)** peak at **V2 justifying the improved friction (Lubrication effect)**.

• **(Zr)** peak increased slightly despite the high increase intensity of **(O)** peak with 10/MWCNTs addition:

➢ **(Zr)** particles were not scattered to form wear debris but were induced into the so-formed SiO_2 layer giving rise **to compacted and dense tribo-film as confirmed by SEM.**

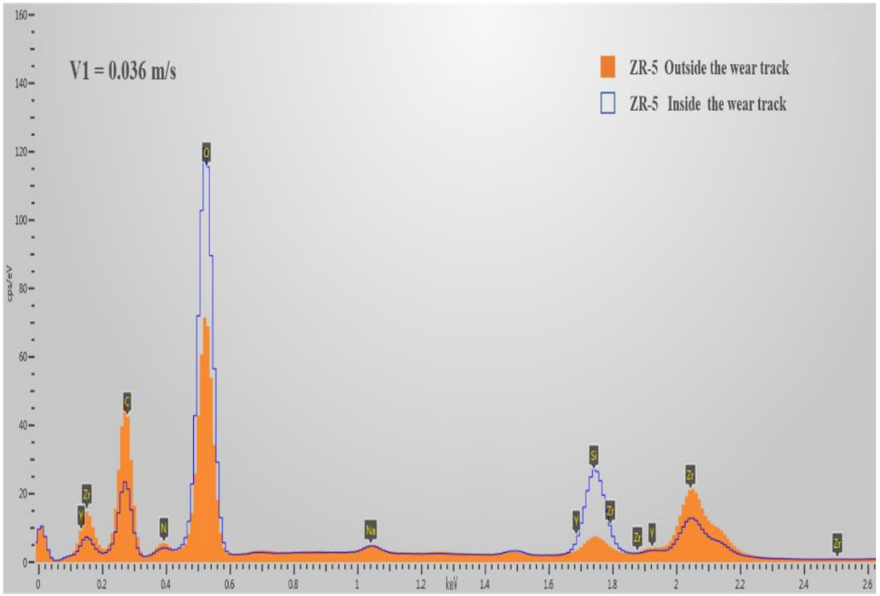


Fig.11 (EDS) inside and outside the wear track profile of (composite with 5* wt. *% MWCNTs) via V1

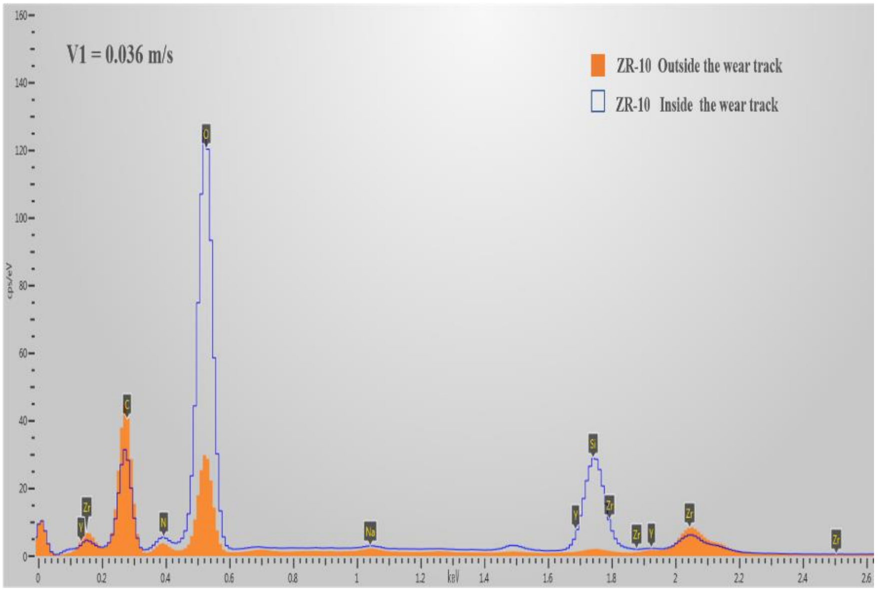


Fig.12 (EDS) inside and outside the wear track profile of (composite with 10* wt. *% MWCNTs) via V1

Semester summary and perspectives

- Fractographic Analysis after three point binding test : determination of the conducted fracture mode according to MWCNT content into the matrix (trans-inter granular fracture mode), grain size and geometry.
- Evaluation of surfaces Roughness after tribo-test at low and high sliding speed to confirm the direct surface Roughness influence on the overall friction properties.
- Evaluation of tribological behavior of the composite and their specific relationship with structural and mechanical properties of the composites.
- Evaluation of Wear mechanism generated under the testing condition and different sliding speeds using Keyence and SEM.
- Evaluation of the chemical modification accompanied the structural changes after tribo test using comparatives EDS spectra inside and outside the worn surfaces.
- Article submission in journal with IF by the end of January.

Future works, and research activities

Future works

❑ Stability investigation in oxidized atmosphere of 8YSZ/ MWCNTs composites sintered at 1200 °C and 1300 °C .

❑ Start writing the thesis.

Research activities

❑ Acceptence of two publications in **Ceramic International** and **Boletin de la sociedad espanola de ceramica y viderio** journals **with IF.**

❑ Oral presentation in **2019 ECerS Conference.**

❑ Member of Hungarian Scientific Society of the Silicate Industry and European Ceramic Society.


Thank you for your attention!