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Load Effects on the Tribological Response of Zr-Based Bulk Metallic Glasses

Patricia Catalán Wic, Paschal Ateb Ubi, Zheming Ding, Martin Stiehler, Mohamed Kalifa, Muhammad Khan, Konstantinos Salonitis and Konstantinos Georgarakis

Faculty of Engineering and Applied Sciences, Cranfield University, United Kingdom

INTRODUCTION & AIM

Challenges of the space environment [1]

- Ultra-high vacuum.
- Cosmic radiation.

Extreme temperature gradients

Intense mechanical vibrations

BMGs in space applications.

Use of BMGs

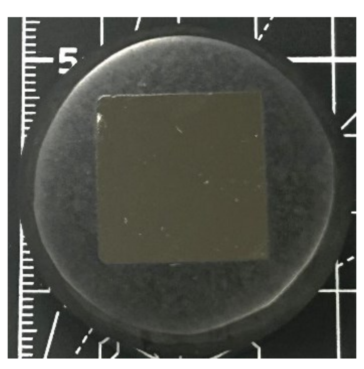
Exceptional mechanical strength and superior resistance to wear, corrosion, and scratching [3].

AIM AND OBJECTIVES

- Examination of friction characteristics of Zr-based BMG
- Comparing results with the existing literature

METHODOLOGY

Sample preparation	Pre-characterisation of the samples	Wear tests	Post-characterisation of the samples
• Resin embedding • Polishing	• XRD testing • Confirming amorphous structure and composition	• Ball-on-disc	• Use of XRD techniques • SEM-EDS techniques



BMG sample mounted in resin

BMG and countersurface materials

BMG material (at. %): $Zr_{55}Cu_{30}Al_{10}Ni_5$

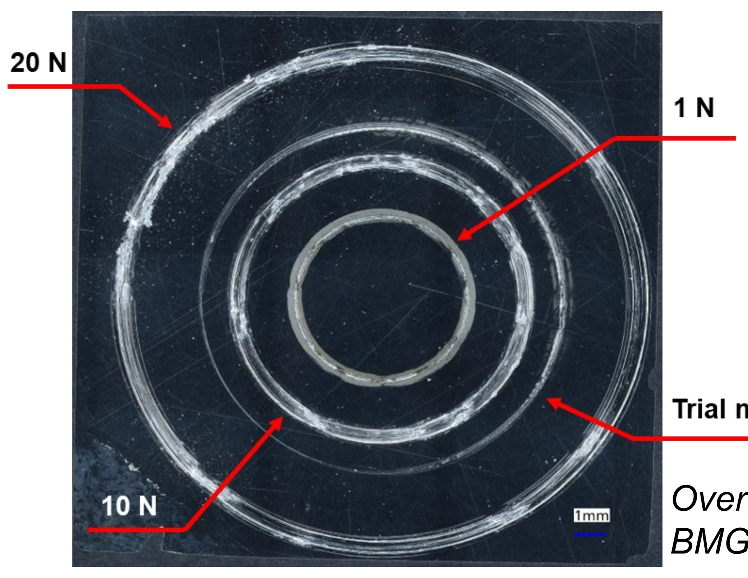
Counterpart material: Steel 100Cr6

Counterpart balls

Tribological setup (TR³ tribometer, Anton Paar, Austria).

Table 1. Friction tests key parameters for Zr-based sample.

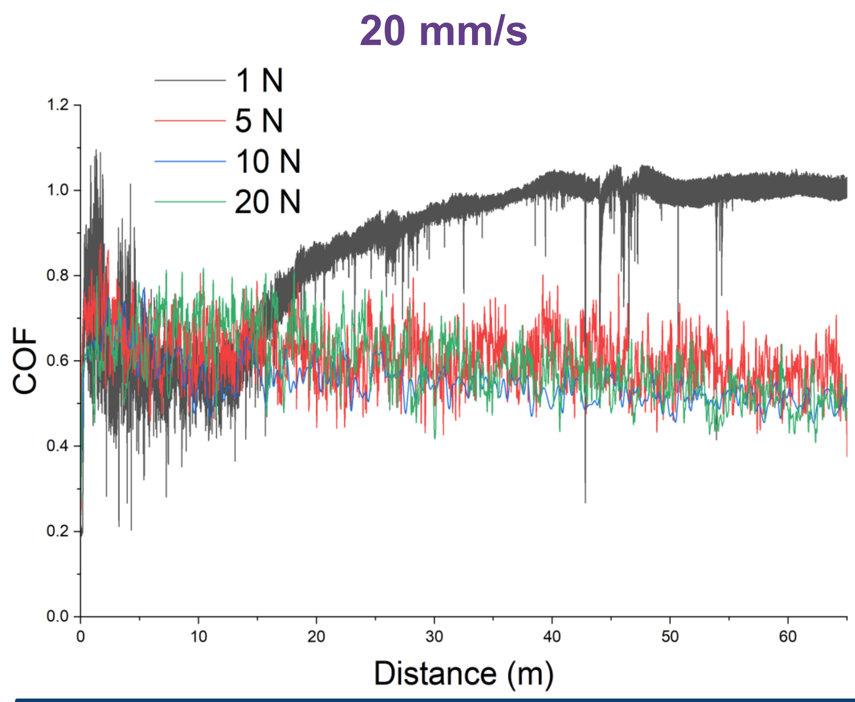
Load (N)	Speed (mm/s)	Radius (mm)	RPM	Distance (m)	Cycles
1	20	3	63.7	65	3448.4
5	20	5	38.2	65	2069.0
10	20	5	38.2	65	2069.0
20	20	9	21.2	65	1149.5
1	60	3	190.0	65	3448.4
5	60	5	114.6	65	2069.0
10	60	7	81.8	65	1477.9

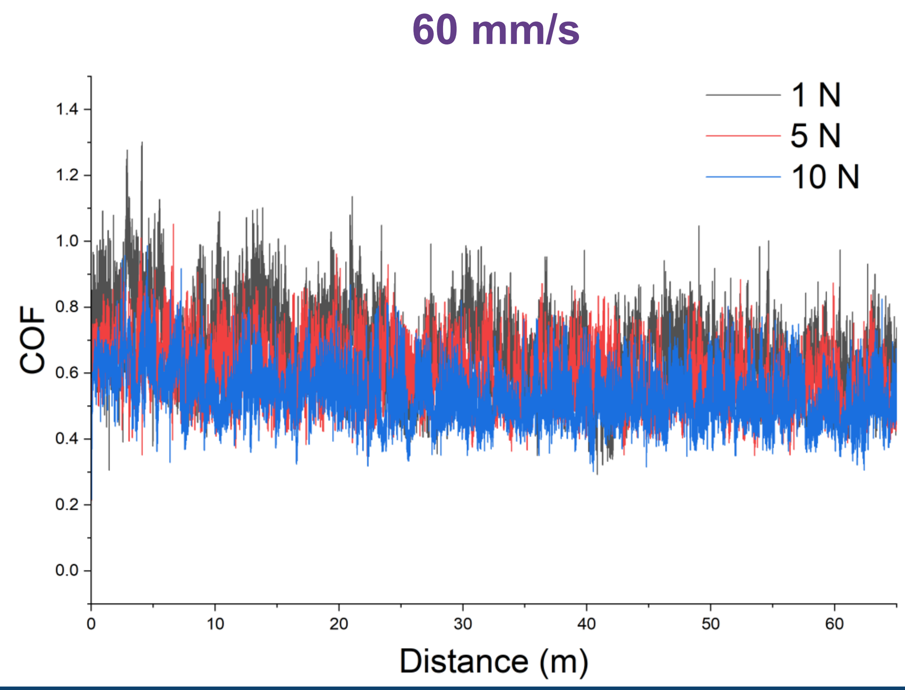


Overview micrograph of Zr-based BMG with wear tracks.

RESULTS & DISCUSSION

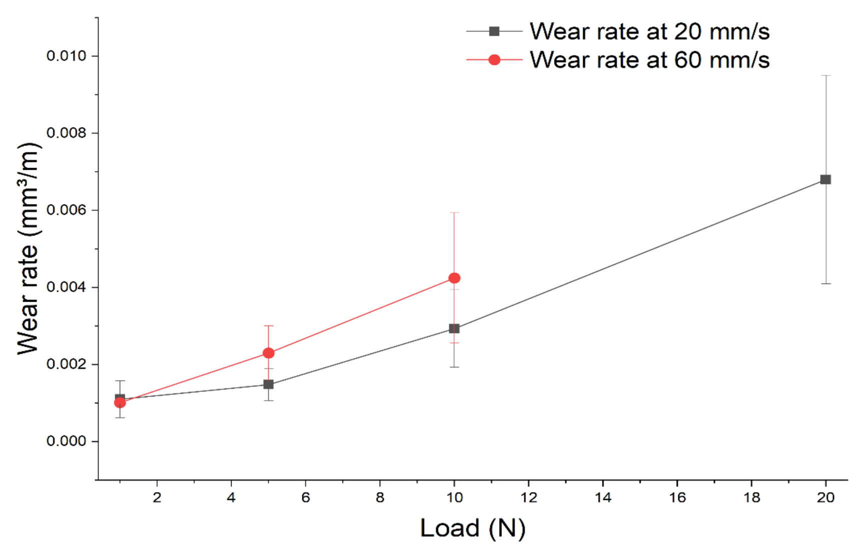
1. Coefficient of friction





- Elevate contact pressures → Uniform plastic deformation → More stable wear process [4].
- Low loads and low speed → Characteristic behaviour due to abrasive and oxidative wear mechanisms [5].

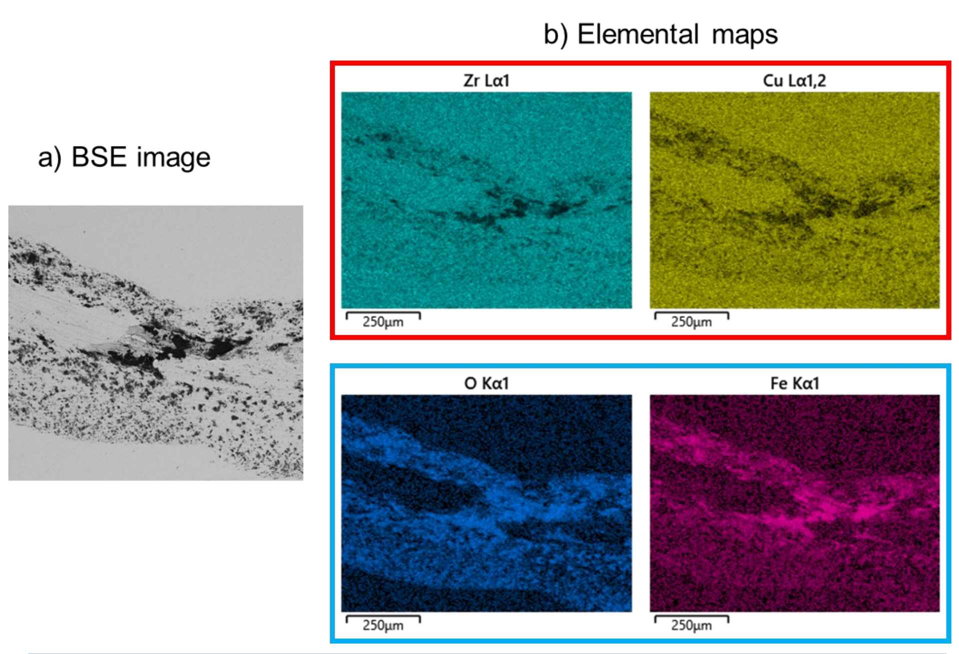
2. Wear rate



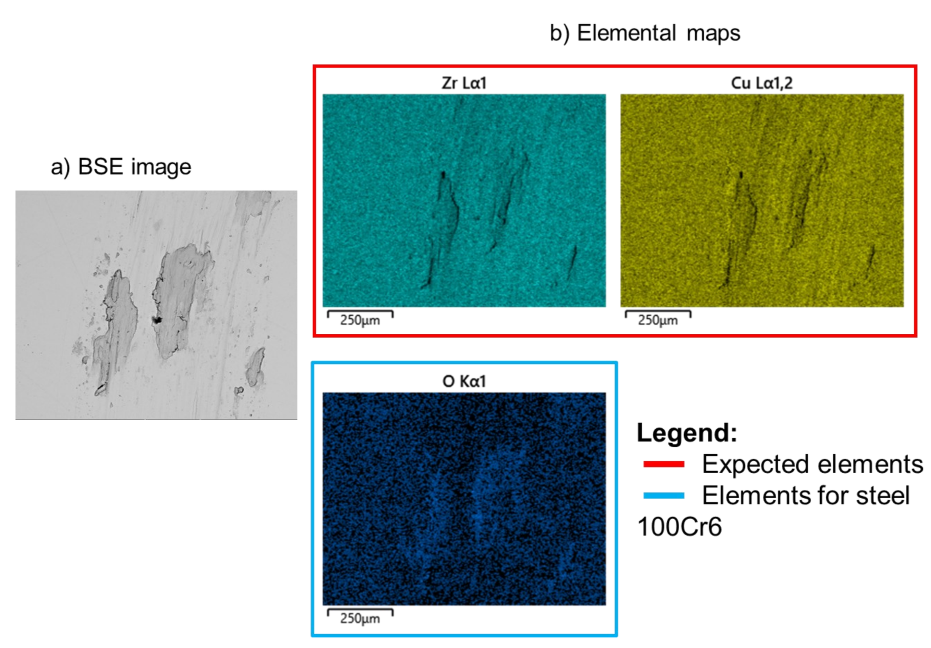
- Correlation between increased contact pressure and the enlargement of width and depth of wear tracks [4].
- Xie et al. present wear rates consistently below $3.0 \cdot 10^{-4}$ mm³/N·m [5].

3. Wear mechanisms

Results for 1 N



Results for 5 N, 10 N and 20 N



- Material transfer from the counterpart to the surface of the base material.
- Zhou et al. found that oxidation can lead to the formation of hard particles.
- Principle wear mechanism: mixture of abrasive and oxidative wear [4].

- No detectable presence of elements from the counterpart material into the sample.
- Material transfer to the counterpart balls.
- Evolution from abrasive to adhesive wear mechanism [6, 7].

CONCLUSION

Coefficient of friction

- Inverse relationship between COF and applied load.
- At low loads (1 N) → Bigger initial adaptation phase.
- At high loads (5N, 10 N, 20 N) → More stable COF values and behaviour.

Wear rate evaluation

- BMGs maintain low wear rates even under high contact pressures.
- More influence of sliding speed.

Wear mechanisms

- At low loads (1 N) → Abrasive and oxidative wear mechanisms.
- At high loads (5N, 10 N, 20 N) → Adhesive wear mechanism.

FUTURE WORK / REFERENCES

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[5] C. Xie, et al, Journal of Non-Crystalline Solids, 646 (2024) 123266.
[6] T. Rose, Cranfield University, 2005.
[7] Y. Wang, et al, Materials & Design, 111 (2016) 213-221.