Cr content of the sliding counterpart as a way to control friction of $Ni_{62}Nb_{33}Zr_5$ Bulk Metallic Glass

Solène Stoens [1)]*, Rémi Daudin [2)], Alexis Lenain [3)], Sébastien Gravier [3)], Guillaume Colas [1)], Pierre-Henri Cornuault [1)]

[1)] Univ. Bourgogne Franche-Comté FEMTO-ST Institute CNRS/UFC/ENSMM/UTBM, Department of Applied Mechanics, 24 rue de l'Epitaphe, F-25000 Besançon, France
[2)] University of Grenoble Alpes, CNRS, SIMaP, 38000, Grenoble, France
[3)] Vulkam Inc. Amorphous metal micro casting / www.vulkam.com / France
*Corresponding author: solene.stoens@femto-st.fr

Bulk Metallic Glasses (BMG) are known to demonstrate exceptional mechanical properties combining very high yield stress and fracture toughness with large elastic strain limit. There is, however, no consensus regarding the suitability of BMG for tribological applications, because they are said to exhibit erratic behavior in friction. The present study proposes to control friction of $Ni_{62}Nb_{33}Zr_5$ BMG by controlling the Cr content of the sliding steel ball. Different steels demonstrating similar C content, but different Cr contents were chosen. Results confirm that Cr can greatly influence the friction coefficient while keeping very low wear.

Keywords: Tribology, Bulk Metallic Glass, Friction, Wear

1. Introduction

Metallic glasses (MG), also known as amorphous metallic alloys (AMA), were first obtained as ribbons in the 60's by quenching an AuSi melt [1]. They are now produced in bulk form (BMG) which opens up the possibilities of applications. The wear resistance of BMGs as compared to crystalline alloys is highly debated and somewhat unpredictable. Nonetheless two recent studies conducted respectively at the nanoscale [2] and at the macroscale [3] are suggesting that it is possible to control friction and wear of BMG by carefully selecting the counterpart based on its elemental composition. The present paper focuses on $Ni_{62}Nb_{33}Zr_5$ BMG and on the Cr content of the steel counterpart to verify experimentally if such assumption is relevant.

2. Methods

One Ni-based ($Ni_{62}Nb_{33}Zr_5$) and three different steels compositions (C90, 100Cr6, and X105CrMo17) are used in this study. Those alloys were chosen because of their respective content in Cr and C (Table 1). They also demonstrate similar mechanical properties.

Table 1: Counterparts chemical composition

Steel	C	Cr
X105CrMo17	0.95-1.20	16.00-18.00
100Cr6	0.95-1.05	1.40-1.65
C90	0.9	0

$Ni_{62}Nb_{33}Zr_5$ plate were tested under dry sliding condition against 5 mm steel ball, in reciprocating linear motion with a ± 1 mm displacement stroke at 1 Hz, and during 10,000 backward-and-forward friction cycles. A constant normal force $F_N = 0.25$ N was applied using dead loads.

After the test, surface topography characterization of every friction tracks were performed using a variable focus optical microscope. Wear volumes of the ball and the plate are tentatively calculated. Friction track were also analyzed by SEM and EDS.

3. Results and discussion

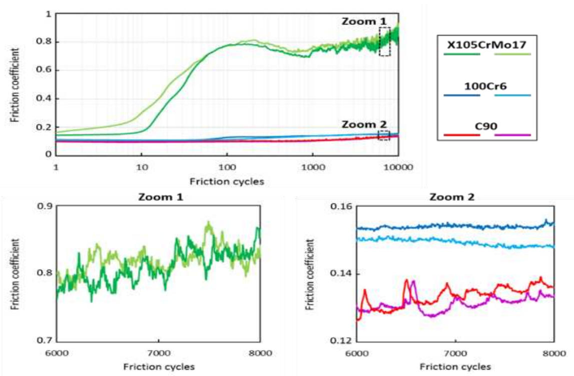

Figure 1: Friction coefficient of the $Ni_{62}Nb_{33}Zr_5$ sliding against different steel balls.

The Cr content of the counterpart appears to greatly drive the friction coefficient (Fig 1). The higher the friction is, the higher the Cr content is. This observation is all supported by Cr/Fe ratio that is higher inside the friction track as compared to the initial composition of the steel. Meanwhile, attempts to quantify the wear of both BMGs and steel counterparts revealed infructuous even through highly resolved measurement method.
The study shows that BMG can exhibit low friction and low wear, and in a reproducible manner, which opens up many possibilities for tribological applications where they are foreseen to be used.

4. References

[1] W. Klement, *et al*, Non-crystalline Structure in Solidified Gold–Silicon Alloys, Nature. 187 (1960) 869–870.
[2] A. Caron, *et al*, Structure vs chemistry: Friction and wear of Pt-based metallic surfaces, ACS Appl. Mater. Interfaces. 5 (2013) 11341–11347.
[3] P.-H. Cornuault, *et al*, On the diversity of accommodation mechanisms in the tribology of Bulk Metallic Glasses, Tribol. Int. 41 (2020) 105957.