Serbian Tribology Society

SERBIATRIB '13

13th International Conference on Tribology

Faculty of Engineering in Kragujevac

Kragujevac, Serbia, 15 – 17 May 2013

WEAR CHARACTERISTICS OF HYBRID COMPOSITES BASED ON ZA27 ALLOY REINFORCED WITH SILICON CARBIDE AND GRAPHITE PARTICLES

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Abstract: *The paper presents the wear characteristics of a hybrid composite based on zinc-aluminium ZA27 alloy, reinforced with silicon-carbide and graphite particles. The tested sample contains 5 vol.% of SiC and 3 vol.% Gr particles. Compocasting technique has been used to prepare the samples. The experiments were performed on a "block-on-disc" tribometer under conditions of dry sliding. The wear volumes of the alloy and the composite were determined by varying the normal loads and sliding speeds. The paper contains the procedure for preparation of sample composites and microstructure of the composite material and the base ZA27 alloy. The wear surface of the composite material was examined using the scanning electronic microscope (SEM) and energy dispersive spectrometry (EDS). Conclusions were obtained based on the observed impact of the sliding speed, normal load and sliding distance on tribological behaviour of the observed composite.*

Keywords: *ZA27 alloy, hybrid composites, wear characteristics*

1. INTRODUCTION

The composite material represents the solid connection of the two or more constituents, which are joined into the unbreakable connection, for obtaining the better mechanical, tribological and other characteristics.

Metal matrix composites (MMCs) have attracted considerable attention recently because of their potential advantages over monolithic alloys [1 - 3].

Zinc–aluminium (ZA) alloys have emerged as important material for tribological applications, especially suitable for high-load and low-speed applications. Commercially available ZA alloys are characterized by good tribomechanical properties, low weight, excellent foundry castability and fluidity, good machining properties, low initial cost, and environmentally friendly technology The zinc alloy with increased content of aluminium is one of the alloys, which can be used for manufacturing the metal matrix composites. The ZA27 alloy is considered as the most prospective for obtaining the composites, since it is convenient as a substrate for several methods of composites manufacturing. Besides, it is also convenient for the heat treatment and plastic forming, thus it is possible to a posteriori influence the mechanical properties of the final products [4 - 7].

Various methods and techniques were used to substantially improve wear behaviour of Zn–Al (zinc–aluminium) alloys without lowering significantly the mechanical properties of materials [6 - 8].

Thanks to mentioned properties and good characteristics, zinc-aluminium alloys have inspired researchers to reinforce them with different dispersed reinforcement materials (SiC, Al_2O_3, graphite and garnet) in order to obtain much more enhanced mechanical and tribological properties [9 - 16].

Considering the above, ZA27/SiC/graphite composites may be a good alternative to zinc-aluminium alloys in many industrial applications.

2. EXPERIMENTAL PROCEDURE

2.1 Preparation of the composites

Hybrid ZA27/SiC/Graphite composites have been successfully prepared using the compocasting procedure.

Hybrid ZA27/SiC composite reinforced with graphite was produced at the Laboratory for materials of the Institute for nuclear sciences "Vinca". The obtained chemical structure of ZA27 alloy that was used during experimental investigations coincides with the corresponding chemical structure defined by standard. Average size of SiC particles was 26 μm, while average size of graphite particles was 15 μm.

The applied compocasting procedure consisted of two phases. During the first phase, infiltration of the particles from the secondary phases into the semisolid melt of the basic alloy was conducted with constant mechanical blending. Obtained composite casts were then subjected to hot pressing during the second phase. This was done in order to decrease porosity and get better connection between the matrix and the reinforcement particles. At the same time, better mechanical characteristic of the composite material were obtained.

2.2 Structure of the sample materials

Microstructure of ZA27 alloy and obtained composite were observed by metallurgy microscope and presented in Figure 1 and 2. Stucture of the sample of ZA27 alloy is mainly dendrite (Figure 1). Distinct uniformity of the structure was present, which indicates a favourable ratio of mechanical properties of the tested materials.

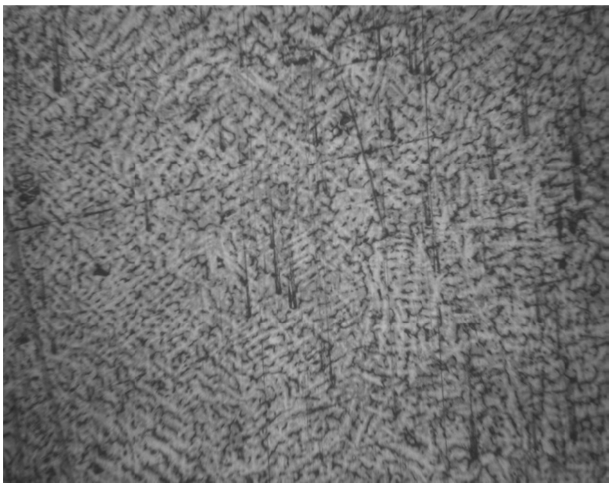

Figure 1. Microstructure of ZA27 alloy

Figure 2 shows the microstructure of the obtained composite.

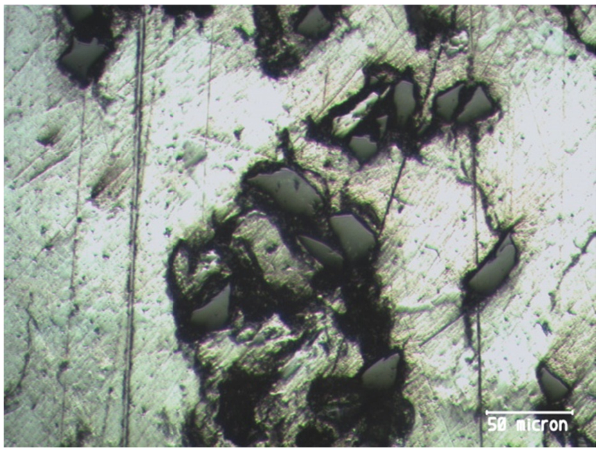

Figure 2. Microstructure of ZA27/3% SiC/3% Gr composite (magnification x 400)

A uniform distribution of SiC and graphite particles was present in tested composite materials.

2.3 Testing methods

Experimental tests were performed at the Centre for tribology of the Faculty of Engineering, University of Kragujevac.

The tests of the ZA27/SiC/Gr composite's tribological characteristics were performed on the computer supported tribometer with "block-on-disc" contact geometry (Figure 3). Tribometer provides variation of contact conditions in terms of shape, dimension and material of contact elements, normal contact load and sliding speed.

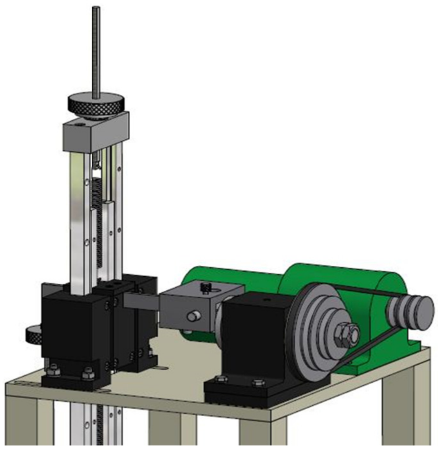

Figure 3. The "block-on-disc" tribometer

Based on the measured wear scar width on the contact surface obtained by variation of normal loads and sliding speeds, the material wear volume was calculated. The tests were performed in dry sliding conditions, with variation of sliding speed levels (0.25 m/s, 0.5 m/s and 1 m/s) and contact load levels (10 N, 20 N and 30 N). The observed sliding distances during tests were: 30 m, 60 m, 90 m, 150 m and 300 m.

The test contact pair meets the requirements of the ASTM G77-05 standard. It consists of the rotational disc with the diameter of D_d=35 mm and the width of b_d=6.35 mm and of the stationary block of the width of b_b=6.35 mm, the length of l_b=15.75 mm and the height of h_b=10.16 mm. The discs were made of 90MnV8 steel with hardness of 62 HRC and the surfaces roughness of R_a=0.40 μm. The blocks were made of the tested ZA27/5%SiC/3%Gr.

3. THE RESULTS AND DISCUSSION

The variations of dry sliding wear volume loss are presented in corresponding diagrams in the paper, depending on the sliding distance and for different values of sliding speeds and contact loads. The results of wear for given hybrid composite and for ZA27 alloy were presented in the same diagrams in order to understand the wear process evolution during tests and to make corresponding comparisons. Solid lines on the diagrams refer to the wear scar widths of the composite, while the wear scar widths of the ZA27 alloy are denoted by dashed lines.

The variation of dry sliding wear volume loss with the sliding distance for different applied loads and for a sliding speed of 0.25 m/s is presented in Figure 4. All diagrams are given for the sliding distance of 300 m.

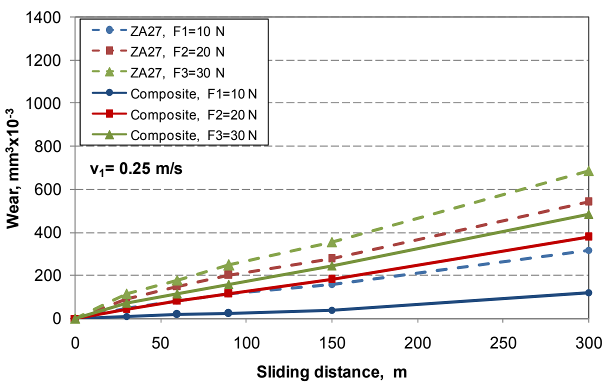

Figure 4. Variation of wear volume of ZA27 alloy and ZA27/5%SiC/3%Gr composite against sliding distance for different contact loads and for sliding speed of v=0.25 m/s.

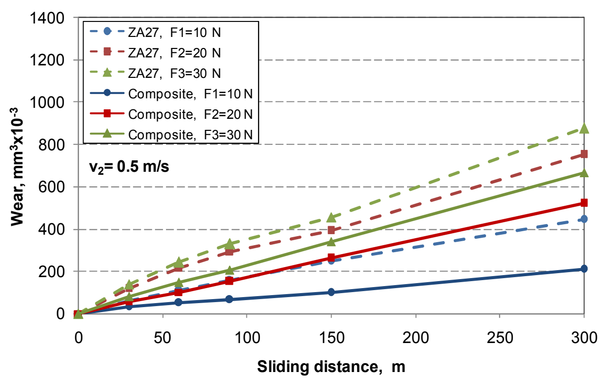

Figure 5. Variation of wear volume of ZA27 alloy and ZA27/5%SiC/3%Gr composite against sliding distance for different contact loads and for sliding speed of v=0.5 m/s.

The variation of wear volume loss of ZA27 alloy and ZA27/5%SiC/3%Gr composite depending on the sliding distance and for different applied contact loads and the sliding speed of 0.5 m/s may be seen in Figure 5.

Diagram in the Figure 6 presents the variation of wear volume loss of ZA27 alloy and ZA27/5%SiC/3%Gr composite depending on the sliding distance and for different applied contact loads and the sliding speed of 1 m/s.

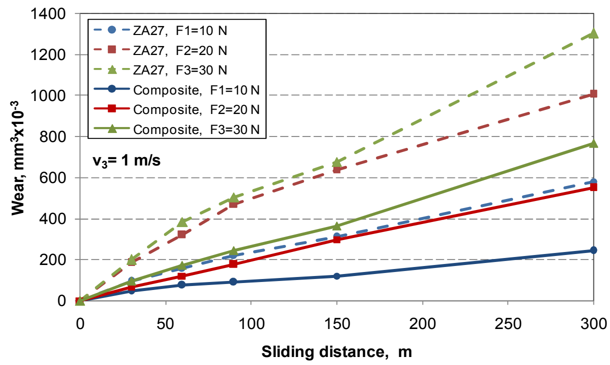

Figure 6. Variation of wear volume of ZA27 alloy and ZA27/5%SiC/3%Gr composite against sliding distance for different contact loads and for sliding speed of v=1 m/s.

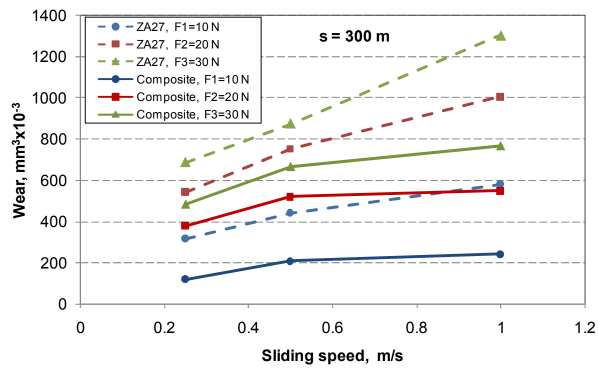

Figure 7. Wear volume of ZA27/5%SiC/3%Gr composite and ZA27 alloy depending on sliding speeds, for different contact loads and for sliding distance of 300 m.

The wear volume losses of the alloy and the composite increase with the increase of the sliding distance. The wear volume loss curves are of the same character, both for alloy and for the observed composite material. The only difference may be seen in level of wear. At the beginning, a larger slope of the curves is noticeable, so there is the intensive initial wear of the composite material. A rapid increase of wear volume loss is characteristic for sliding distance of approximately 35 m. After reaching the zone of constant wear, the wear volume loss has slight, almost linear increase.

Generally, the wear behaviour of the tested materials is characterized by very intensive wear during initial period, after which there is a period of stabilization. Wear of the composites was always significantly lower when compared to wear of the matrix ZA27 alloy.

The influence of the sliding speed on wear volume for both materials is shown in Figure 7, for different values of normal loads.

The effects of the normal load on wear volume of both composite and alloy is presented in Figure 8, for different values of sliding speeds and for sliding distance of 300 m

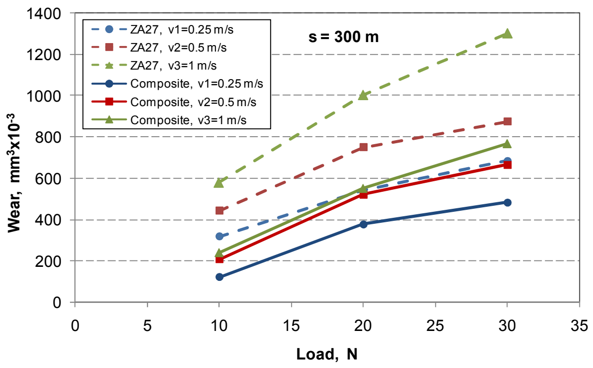

Figure 8. Wear volume of ZA27/5%SiC/3%Gr composite and ZA27 alloy depending on contact loads, for different sliding speeds and for sliding distance of 300 m.

Analytical and graphical variations in wear rate due to changes of sliding speeds and normal loads in dry sliding conditions are presented in Figures 9 and 10. Exponential regression functions were adopted. Corresponding regression functions coefficients and curvilinear correlation indices were obtained showing the good correlation between experimental data and used empirical distributions.

Wear rate of ZA27 alloy in dry sliding conditions is presented in Figure 9 and wear rate of ZA27/5%SiC/3%Gr composite in dry sliding conditions is shown in Figure 10. Variations of the wear rate as a function of the sliding speed and normal load are graphically presented for the ZA27 alloy and composite materials.

Both tested materials share basically the same nature of wear process development in all contact conditions. The observed composite material has better wear resistance, under the same test conditions.

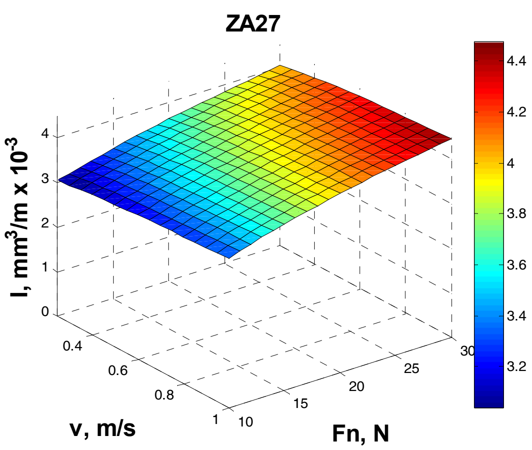

Figure 9. Wear rate of ZA27 alloy in dry sliding conditions.

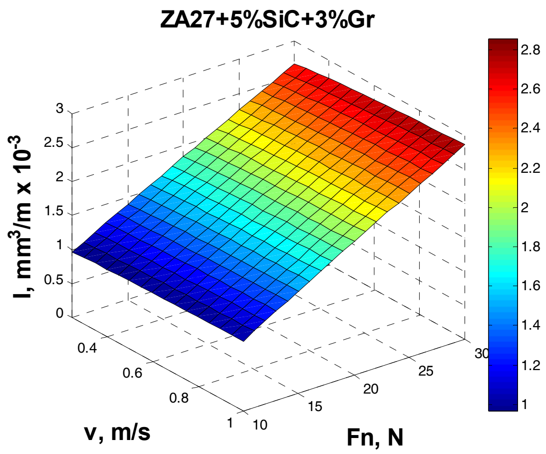

Figure 10. Wear rate of ZA27/5%SiC/3%Gr composite in dry sliding conditions.

The comparative histograms of the wear volume formed after 300 m of sliding distance, depending on the contact conditions (the sliding speed and the normal force) for the basic ZA27 alloy and ZA27/5%SiC/3%Gr composite materials are shown in Figure 11.

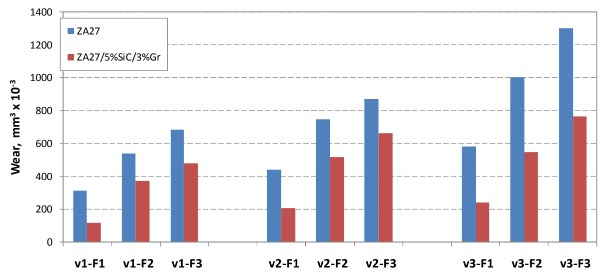

Figure 11. Comparative histograms of wear volume of ZA27 alloy and ZA27/5%SiC/3%Gr composite.

Analysis of histograms in Figure 11 shows that a trend of increase of wear with the increase of normal load may be observed. The increase of sliding speed induces also the increase of wear. This observation is valid for both tested materials. It may be noticed that the wear of the tested ZA27 alloy is always significly higher compared to wear of the composite with addition of the SiC and graphite particles.

From the Figure 11, the influence of the normal load and sliding speed on the wear magnitude may be clearly noticed. The wear rate increases both with the increase of the normal force the increase of the sliding speed. The largest value of wear corresponds to the highest sliding speed ($v_3 = 1$ m/s) and to the highest value of the normal contact load ($F_3 = 30$ N). For the lowest sliding speed ($v_1 = 0.25$ m/s) and the lowest load ($F_1 = 10$ N), the smallest wear values were recorded.

Characterization of the microstructure of wear surface for metal matrix composites is more complex than that of the metals or alloys and an understanding of wear mechanisms is far from complete. The SEM analysis may contribute to better understanding of this mechanism.

The SEM micrograph of the worn surface at load of 10 N and at speed of 0.25 m/s for a sliding distance of 300 m is presented in Figure 12 for the tested composite material.

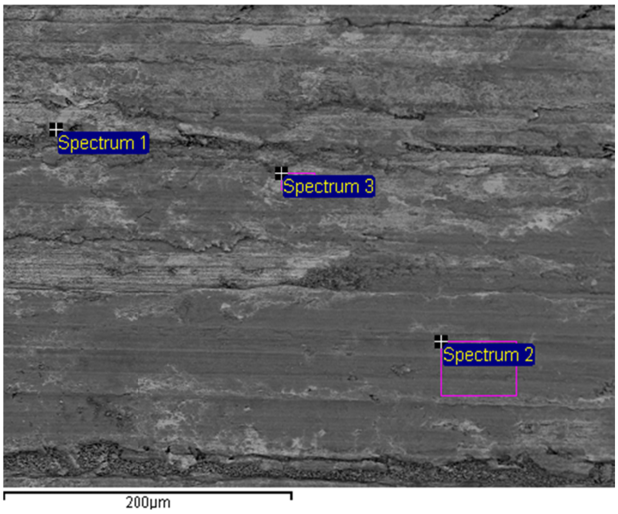

Figure 12. SEM micrographs of worn surfaces of the ZA27/5%SiC/3%Gr composite

Qualitative and quantitative chemical analyses of micro-constituents were performed using energy dispersive spectrometry (EDS), Figure 13.

Analyses confirm the presence of constituent elements like: Zn, Al, SiC, Gr (C), as well as the presence of Fe as a consequence of material transfer from the counterpart to the composite block.

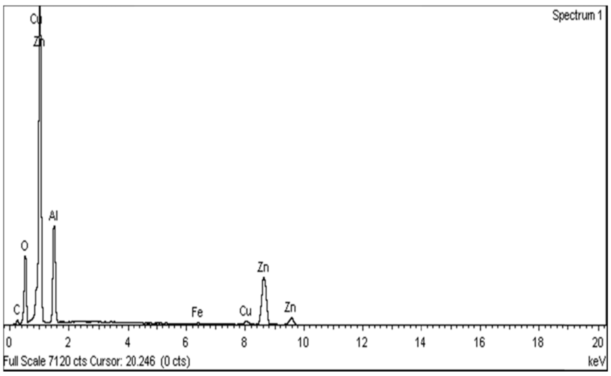

Figure 13. EDS analysis of worn surface on the ZA27/10%SIC/1%Gr composite

Microstructure of worn surface of ZA27 alloy is shown in Figure 14.

Microstructure of worn surface of ZA27/5%SiC/3%Gr composite is given in Figure 15.

Generally, the parallel grooves and scratches can be seen over all the surfaces in the direction of sliding. These grooves and scratches resulted from the contact between the worn surface of the tested material and the counter disc of significantly higher hardness.

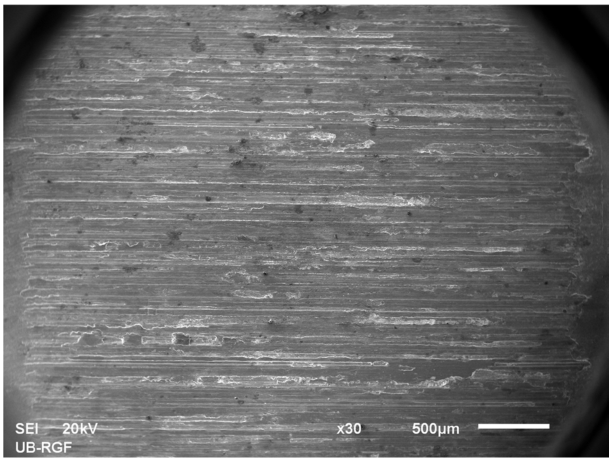

Figure 14. Appearance of the worn surface of ZA27 alloy photographed by SEM in dry sliding conditions (v_1 = 0.25 m/s, F_1 = 10 N)

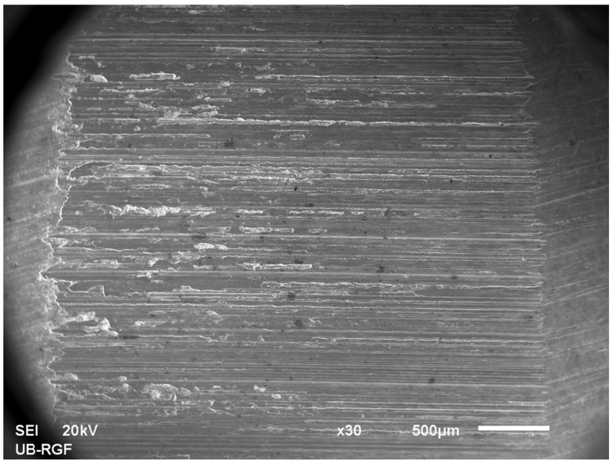

Figure 15. Appearance of the worn surface of ZA27/5%SiC/3%Gr composite photographed by SEM in dry sliding conditions (v_1 = 0.25 m/s, F_1 = 10 N)

4. CONCLUSION

This research was conducted in order to complete the tribological knowledge on developed composite materials with ZA27 alloy reinforced by the SiC and graphite particles. The goal was to confirm the further possibilities for broader application of given composites as advanced tribo-materials, in different technical systems because they have excellent wear resistance when compared with the base ZA27 alloy.

By monitoring the wear process through observation of wear volume in dry sliding conditions, the following conclusions can be made:

- Wear of the tested composite is smaller than wear of ZA27 alloy for all applied sliding speeds and normal loads.
- Wear process evolution has the same character for both tested materials (basic ZA27 alloy and ZA27/10%SiC/1%Gr composite).

- Values of the wear volume of the observed composite material increase with the increase of normal loads.
- Wear volume also increases with the increase of the sliding speed.

ACKNOWLEDGMENTS

This paper presents the research results obtained within the framework of the project TR-35021, financially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia

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