# Lubricating Properties of Personal Care Ingredients by Means of Tribological Testing

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## Introduction

The field of tribology (specifically, bio-tribology) is gaining more attention from the Fast Moving Consumer Goods sector in recent years due to a wide range of potential insights it can deliver [1]. Recent work has shown the importance and relevance of tribological measurements to consumer perception of personal care products [2], and it's critical that tribologists have tools to measure a range of lubrication regimes with good accuracy and sensitivity.

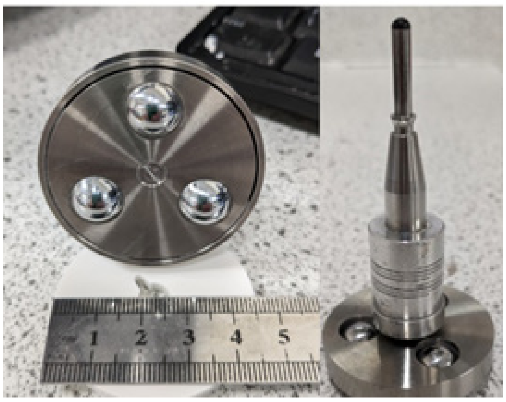
This Application Note summarizes a study of the tribological testing of water-glycerol solutions, ingredients common in personal care products.

## Tribology Cell Configuration

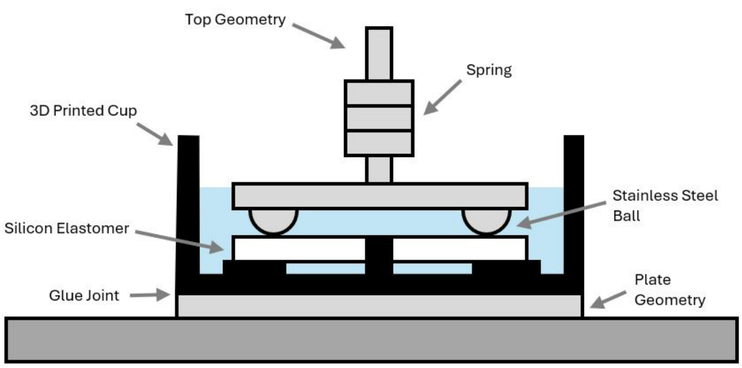
The configuration consisted of a 3-Ball Tribology Upper Geometry (ball midpoint radius = 11.25 mm from center) and 3D-printed cup (see Figures 1 and 2), attached using an adhesive to a flat plate geometry for easy mounting. The 3D-printed cup allows the contact surfaces to be under full immersion which has the benefits of a) removing potential artefacts for poorly covered surfaces, and b) better replicates real-world environments like the mouth (e.g., for food and toothpaste) where tribology is important. Measurements were conducted at laboratory temperature (20°C).

The bottom geometry is designed to allow bottom surfaces to be swapped out easily. The bottom surface material was a silicone elastomer (Silicone Elastomer type: vmq, SAMCO), punched from a sheet material and cleaned with isopropanol before use. A fresh surface was used for every measurement. The material lends itself to producing repeatable samples and was selected as it has been used as a mouth surface analogue in previous research.

The three-ball attachment has the benefit of providing cyclical surface contact during steady state measurement. This allows more 'realistic' simulation of scenarios experienced in personal care, such as rubbing a dermatological cream onto the skin, where material is unequally transported and compressed between contacts. Although, this can result in poor measurement reproducibility if materials are difficult to spread consistently, like those with a yield stress, during initial, low sliding speed measurements.




1 Images of typical tribology geometry configuration and silicone elastomer substrate.




2 Schematic of tribology geometry set-up

NGB · Application Note 326 · EN · 1224 · Technical specifications are subject to change.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## 1-Ball Versus 3-Ball Tribology Cell

The one-ball tribology cell is a resonable choice for simulating some personal care applications, but due to the nature of this design, it prohibits radial and tangential movement of material, only inducing tangential distribution, which is marginally less realistic. The one-ball tribology cell would be well suited to very model systems where minimization of measurement artefacts is preferred over appplication simulation.

## Measurement Conditions

Tests were conducted with an approximate 3/4 fill level (~25 g) in the 3-ball geometry to allow constant replacement of lubricating material, and to reduce the likelihood of a thin lubricant layer being removed from the surface at high speed, due to centrifugal force.

## Results and Discussion

The following calculations were performed to elucidate Coefficient of Friction (CoF) and (linear) sliding speed, $U$, in mm/s.

$$CoF = \frac{\Gamma}{RF_N}$$

where Γ is Torque, $R$ is radius to ball midpoint (11.25 mm) and $F_N$ is normal force.

$$U = \omega R$$

where ω is angular velocity in rad/s.

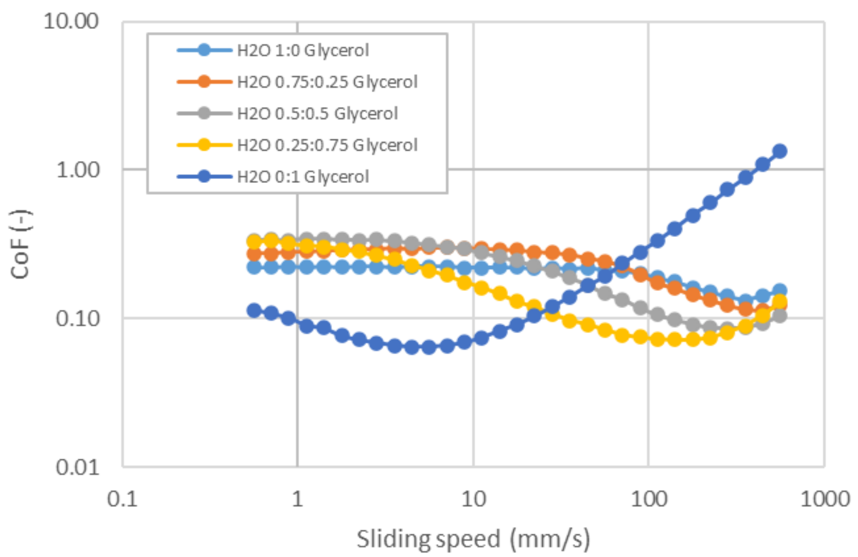
Most data shown has good agreement with traditional lubricating behaviour (see Figures 3 and 4). At low sliding speeds, sliding speed independence is present which indicates a total surface contact regime. At increasing sliding speeds, CoF reduces, which is indicative of mixed regime where there is partial surface(s) asperity contact and lubrication. Finally, an increase in CoF is observed, indicative of the hydrodynamic lubrication regime where full surface separation is achieved and tribological properties are determined by bulk rheology of the lubricant, predominantly viscosity. CoF values are within sensible ranges, values above 1 are possible even in well-lubricating systems with high-viscosity lubricants.

With increasing glycerol concentration, there is an increase in CoF at low sliding speeds that is immediately reversed when glycerol content is 100 w/w%. In addition, with increased glycerol concentration the onset of the hydrodynamic regime shifts to lower sliding speeds and are therefore better lubricants. CoF values for all solutions, other than 100 w/w% glycerol, are similar at high sliding speeds.

To detangle viscosity and surface-surface interaction effects, data can be plotted as viscosity-corrected sliding speed product, $\eta U$.

**Table 1** Steady-state apparent viscosity of different water-glycerol solutions

| $H_2O$: Glycerol Ratio | Average Viscosity (Pa.s) | ±σ |
|---|---|---|
| 1:0 | 0.0013 | 0.0004 |
| 0.75:0.25 | 0.0021 | 0.0009 |
| 0.5:0.5 | 0.0064 | 0.0012 |
| 0.25:0.75 | 0.0230 | 0.0028 |
| 0.1 | 0.8259 | 0.0392 |




**3** Coefficient of Friction variation with sliding speed for different water-glycerol solutions.





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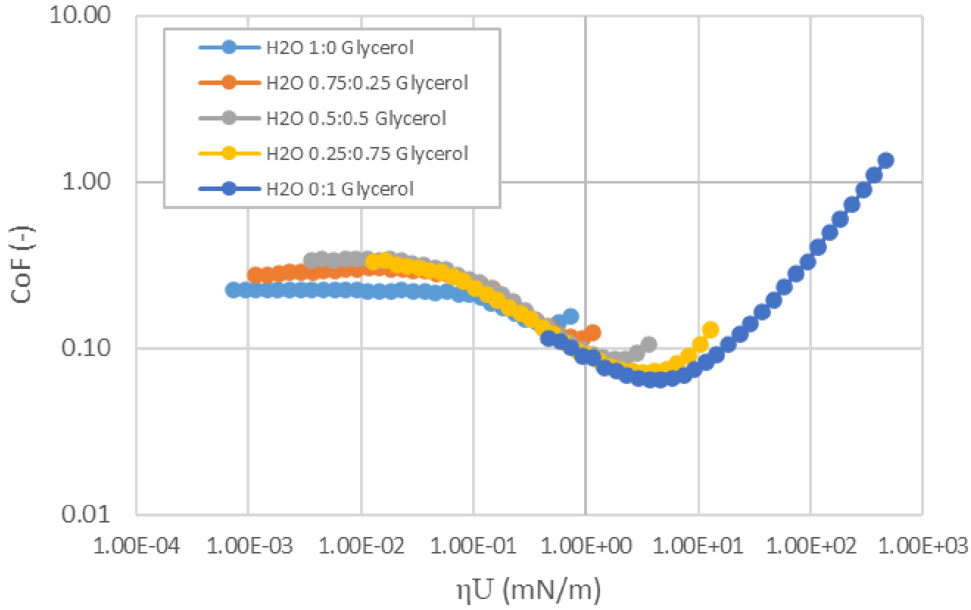


4 Coefficient of Friction variation with viscosity-corrected sliding speed.

The different solutions partially collapse onto a master curve with evident deviation appearing at high sliding speeds; this could indicate that a large portion of the differences between samples could be attributed to solution viscosity. More viscous solutions can support higher normal loads, low-viscosity solutions can be easily rejected from between surfaces, leading to surface contact and a higher CoF.

The variation at high sliding speeds shown in the viscosity-corrected plots may well be down to the differences in bulk viscosity driving more significant changes in torque readings.

## Conclusions

The 3-ball Tribology geometry can distinguish between different Newtonian solutions with a reasonable degree of accuracy. Higher glycerol content appears to provide better lubricity at lower sliding speeds for a stainless steel-silicone elastomer contact.

These results show the importance of formulation in the food and personal care industry, where factors such as mouth feel or product perception on the skin are relevant. Therefore, the tribological properties are important to understand for products such as lotions (emulsions), ointments, creams, toothpastes and even foods.

## References

[1] Meng Y, Xu J, Jin Z, Prakash B, Hu Y. A review of recent advances in tribology. Vol. 8, Friction. 2020. 221–300 p.
[2] Lee J, Lu J, Potanin A, Boyke C. Prediction of Tactile Sensory Attributes of Facial Moisturizers by Rheology and Tribology. Biotribology. 2021;28 (September).




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