Tribological model system testing of glycerol-water solutions as additives for consumer products

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Industrial use of glycerol and the need for tribological model system testing

Industrial applications of Glycerol

- Glycerol is used in pharmaceutical, food and personal care industry[1,2].
- Typical applications are:
  - Used as a sweetener[1]
  - Used to modify food viscosity[1]
  - Used as a lubricant in oral care and personal care products[2]
  - Contact lens solutions for hydration
  - Biocompatible gels for transdermal patches

Tribological testing

- In this study, a tribological model system testing approach is introduced.
- It is used to compare tribological system behaviour with the rheological properties of different glycerol-water solutions..

Fig. 1 Tribological model system testing is carried out to study the lubricating properties of glycerol in personal care products.

Glycerol-water solutions

- Water-glycerol solutions with different glycerol concentrations were tested.
- The glycerol-water mixing ratios were:

H_2O : Glycerol mixing ratio
1 : 0
0.75 : 0.25
0.5 : 0.5
0.25 : 0.75
0 : 1

Tab. 1 Water-glycerol solutions mixing ratios.

Tribological model system testing

- A Kinexus pro+ rotational rheometer equipped with a Tribology cell was used in combination with a round-on-flat geometry.
- The balls were made from stainless steel, measuring 12.7 mm in diameter.
- The discs were made from a silicone elastomer and glued to the sample holder using an adhesive.
- Measurements were carried out in the form of Stribeck curves.
- New specimen were used for each test.
- Measurements were carried out at 20 °C.

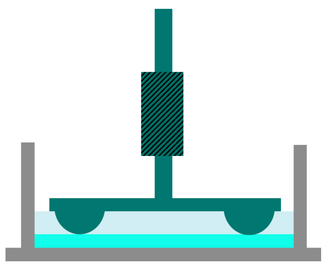

Fig.2 Schematic of the concentric cylinder geometry.

Complementary shear viscosity measurements

- A Kinexus pro+ rotation rheometer coupled with cone-plate geometries with 60 mm and 65 mm respectively in diameter and 1° angle.
- Measurements were carried out at 20 °C.
- Shear rates in the range from 10 to 10^3 s^{-1} were covered.

Fig. 3 Schematic of the cone-plate geometry.

Differences in the tribological behavior due to shear viscosity of the glycerol-water solutions

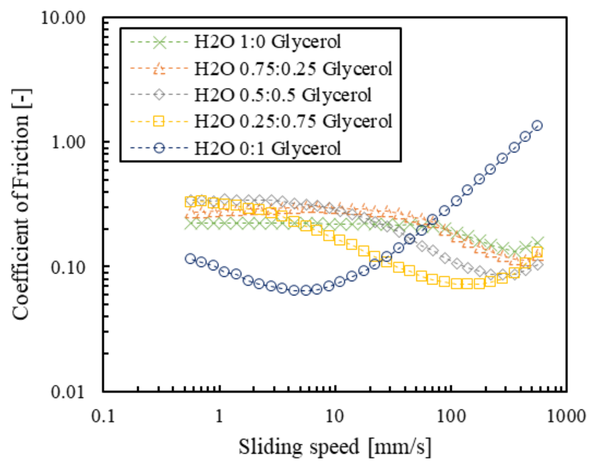

Fig. 4 Stribeck curves.

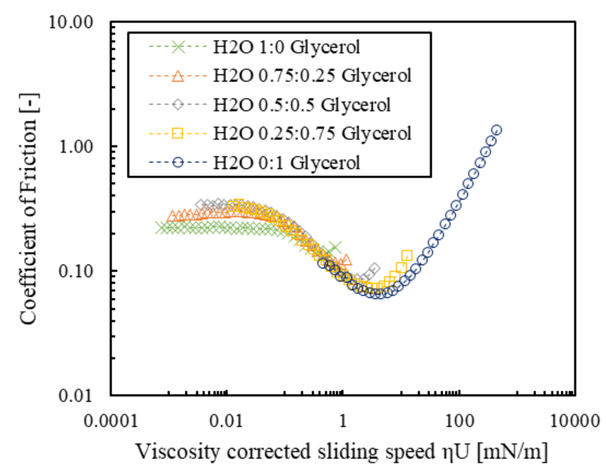

Fig. 5 Viscosity-corrected Stribeck curves.

Stribeck curve measurements

- Coefficient of friction as a function of sliding speed and viscosity-corrected sliding speed (i.e. Stribeck curves) are shown for multiple glycerol-water ratios (see Fig. 4).
- The curves approximately collapse onto a master Stribeck curve (see Fig. 5).
- The results from this study suggest that the differences in the tribological behaviour found between the water-glycerol solutions can mainly be explained by differences in shear viscosity.

Shear viscosity measurements

- The glycerol solutions showed Newtonian flow behaviour.
- Steady-state shear viscosity data from the entire shear rate range were used to calculate the average data below (see Tab. 2).

H_2O : Glycerol mixing ratio	Average shear viscosity [Pas]	Average shear viscosity [Pas]
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

Tab. 2 Average steady-state shear viscosity of different water-glycerol solutions

Conclusion and outlook

- It was possible to distinguish between different Newtonian solutions with a reasonable degree of accuracy.
- Higher glycerol content provided lower coefficient of friction values at lower sliding speeds.
- These results show the importance of formulation in the food and personal care industry, where tribological characterization can help to study product perception.

References

1. Chilakamarry, C.R. et al. (2021). Glycerol waste to value added products and its potential applications. Systems Microbiology and Biomanufacturing, 1, 378-396.
2. Goyal, S., Hernández, N.B. and Cochran, E.W. (2021). An update on the future prospects of glycerol polymers. Polymer International, 70, 911-917.