Data Article

Data set for determination of lubrication film thickness and lubrication state between bone and Ti–6Al–4V interface under three biolubrications

Chenchen Wang\textsuperscript{a}, Gangqiang Zhang\textsuperscript{b}, Zhipeng Li\textsuperscript{a}, Xiangqiong Zeng\textsuperscript{c}, Yong Xu\textsuperscript{a}, Shichang Zhao\textsuperscript{d}, Hongxing Hu\textsuperscript{e}, Yadong Zhang\textsuperscript{f},\textsuperscript{,*}, Tianhui Ren\textsuperscript{a,\textsuperscript{,**}}

\textsuperscript{a} School of Chemistry and Chemical Engineering, Key Laboratory of Thin Film and Microfabrication Technology (Ministry of Education), Shanghai Jiao Tong University, 200240 Shanghai, China
\textsuperscript{b} Institute of Functional Textiles and Advanced Materials, College of Textiles & Clothing, Qingdao University, 266000 Qingdao, Shandong, China
\textsuperscript{c} Lubricating Materials Laboratory, Shanghai Advanced Research Institute, Chinese Academy of Sciences, 201210 Shanghai, China
\textsuperscript{d} Department of Orthopaedics, Shanghai Sixth People's Hospital of Shanghai Jiao Tong University, 201400 Shanghai, China
\textsuperscript{e} Department of Orthopedic Surgery, The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, 325027 Wenzhou, China
\textsuperscript{f} Department of Orthopaedics, Shanghai Fengxian Central Hospital, South Campus of Shanghai Sixth People's Hospital, 201499 Shanghai, China

\textbf{A B S T R A C T}

The lubrication states between the friction pairs in lubrications have an important effect on its tribological behavior. Therefore, the aim of this complementary data article is to identify the corresponding lubrication states between bone and Ti–6Al–4V interface in three biolubricants in reciprocation sliding by the Stribeck theory. Among that, three biolubricated film thicknesses at the stroke center and stroke end were separately calculated using the elastohydrodynamic theory. The current data are considered as a complementary for the main work “Tribological behavior of Ti–6Al–4V against cortical bone in different biolubricants” (Wang et al., 2018).

© 2019 Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Value of the data

- The data were utilized to be a basis on understanding the tribological behavior under different biolubrication conditions in this main work.
- The data can be used to select the suitable lubrications by calculating the thickness of the lubricating film at the range of velocity and load, according to application requirements.
- This data will be useful to researchers and scientific community wanting to interpret the variation of tribological behavior under lubrication conditions.

1. Data

This data article presents data on the correlation of the biolubricated film thicknesses and the lubricated states. These data of biolubricated film thicknesses were investigated using the elastohydrodynamic theory [2]. Further, the lubrication state was determined using the Stribeck theory [3] by introducing a proportional coefficient $\lambda$, related to film thickness and composite surface roughness $R_s$. The calculated results at the stroke center and stroke end are listed in Tables 1 and 2, respectively. In addition, the Stribeck curve [3] is shown in Fig. 1.

Table 1
The calculated results of proportional coefficient at the stroke center.

| Biolubricants | $h_{\min}(\mu m)$ | $\lambda$ |
|---------------|------------------|-----------|
| PS            | $5.07 \times 10^{-5}$ | $8.46 \times 10^{-6}$ |
| SBF           | $5.47 \times 10^{-5}$ | $9.12 \times 10^{-6}$ |
| FBS           | $5.19 \times 10^{-5}$ | $8.65 \times 10^{-6}$ |

Notation: PS (physiological saline), SBF (human simulated body fluids), and FBS (fetal bovine serum).

Table 2
The calculated results of proportional coefficient at the stroke end.

| Biolubricants | $h_{E\min}(\mu m)$ | $\lambda$ |
|---------------|--------------------|-----------|
| PS            | $1.01 \times 10^{-4}$ | $1.69 \times 10^{-5}$ |
| SBF           | $1.09 \times 10^{-4}$ | $1.82 \times 10^{-5}$ |
| FBS           | $1.04 \times 10^{-4}$ | $1.73 \times 10^{-5}$ |
2. Experimental design and methods

In this main work, the lubrication film thicknesses between the bone and Ti–6Al–4V plate interface in three biolubricants of PS, SBF, and FBS were calculated during two periods: stroke center and stroke end [4,5]. Thus, the lubrication form should be confirmed from the above two periods.

At the stroke center of reciprocation sliding, the lowest load (1 N) and the highest velocity (1 mm/s) are selected within the range of load and velocity in the biolubricants. Further, the corresponding lubricated film thicknesses \( h_{min} \) were calculated by Eq. (1). At the stroke end, based on previous findings [5], the film thickness \( h_{emin} \) at the stroke end is twice as thick as that at the stroke center \( h_{min} \). Thus, the proportional coefficient \( \lambda \) at the stroke center and stroke end can be calculated by Eq. (2), respectively

\[
 h_{min} = 2.789 \left( \eta \mu \right)^{0.65} R^{0.77} E^{-0.44} W^{-0.21}, \tag{1}
\]

where \( \eta \) is the viscosity of the biolubricant; \( u \) is the velocity during the friction test; \( R \) is the radius of the bone sample hemisphere; \( E \) is the equivalent elastic modulus, based on Poisson’s ratios and the elastic moduli by Hertz’s contact stress analysis theory; and \( W \) is the normal load.

\[
 \lambda = \frac{h_{min}}{R_a}. \tag{2}
\]

Notation: when \( \lambda \geq 3 \), it is called fluid lubrication; when \( 1 \leq \lambda < 3 \), it is called mixed lubrication; and when \( \lambda < 1 \), it is called boundary lubrication. \( R_a \) is the composite surface roughness, calculated using

\[
 R_a = \sqrt{R_{a1}^2 + R_{a2}^2}. \tag{3}
\]

3. Data analysis

As shown in Tables 1 and 2, the values of \( \lambda \) in both periods are all less than one. According the following notation of \( \lambda \), it can be inferred that the lubricated forms in the three biolubricants are all in boundary lubrication. Further, the trend of boundary lubrication in Fig. 1 could explain the variation of tribological behavior under different loads and velocities between bone and Ti–6Al–4V interface in different lubrication conditions in the related paper.
Acknowledgements

This work has been possible thanks to the Innovation Fund of Precision Medicine, China (Grant no. IFPM2016A003) and National Natural Science Foundation of China (Grant nos. 21272157, 51672191).

Transparency document. Supporting information

Transparency document associated with this article can be found in the online version at https://doi.org/10.1016/j.dib.2018.11.052.

References

[1] C.C Wang, G.Q. Zhang, Z.P. Li, X.Q. Zeng, Y. Xu, S.C. Zhao, H.X. Hu., Y.D. Zhang, T.H. Ren, Tribological behavior of Ti-6Al-4V against cortical bone in different biolubricants, J. Mech. Behav. Biomed. Mater. 90 (2018) 460–471.
[2] M. Esfahanian, B.J. Hamrock, Fluid-film lubrication regimes revisited, Tribol. Trans. 34 (1991) 628–632.
[3] S.T. Wen, P. Huang, Principles of Tribology, third ed., Tsinghua University, Beijing, 2008.
[4] H.L. Costa, I.M. Hutchings, Hydrodynamic lubrication of textured steel surfaces under reciprocating sliding conditions, Tribol. Int. 40 (2007) 1227–1238.
[5] H. Nishikawa, Kohtaroh Handa, Motohiro Kaneta, Behavior of EHL films in reciprocating motion, JSME Int. J. Ser. C Dyn. Control Robot. Des. Manuf. 38 (1995) 558–567.