The rheological properties of lubricants containing bovine calf serum (BCS) for testing the wear behavior of the micro-textured carbide-CoCrMo alloy surface

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Statement of Purpose: Lubrication is a major factor affecting the results of *in vitro* wear testing of joint implants [1,2]. Bovine serum is a more appropriate lubricant than deionized (DI) water or other alternative synthetic lubricants for wear testing of artificial joints. Although the natural joint is surrounded by synovial fluid, bovine serum is commonly used for wear testing of artificial joint implants because synovial fluid is not readily available and it is expensive. It is not known how closely bovine serum simulates the rheological properties of human synovial fluid as a lubricant for wear testing. In the present study, the rheological properties of bovine calf serum (BCS) at different concentrations, with or without different additives, were compared. Preliminary investigations of lubricant viscosity at low shear rates showed a higher viscosity in the undiluted serum (100%) vs. diluted serum (75%, 50% or 25%). While this was an expected result, it is important to verify these findings with a steady-state viscosity at constant shear rate test of the undiluted bovine serum. The rheological characterizations from this investigation will aid in better controlling and understanding the wear properties of bearing surfaces used in an artificial joints.

Materials and Methods: The rheological properties of bovine calf serum (BCS) diluted to concentrations of 75,% 50% and 25% with distilled deionized water (DDW), and undiluted (or 100%) with and without additives were measured with a plate-on-plate rheometer (AR 2000EX, TA Instruments) at shear rates up to 30,000 s^{-1}. The two additives used in this study were 2% (v/v) penicillin/streptomycin antibacterial agent, and sodium azide.. Twenty ml of each lubricant composition was prepared, and less than one ml of test fluid was used for each test. The rheological tests were performed at a steady shear rate to allow the lubricants to reach steady state. Lubricant temperature was maintained at 37 ± 0.2°C to simulate body temperature by a temperature controlled water bath. Rheological experiments were conducted using software controlled stepped flow and oscillation flow on the instrument. The final analysis was done using TA Rheology Data Analysis software and importing the results to Excel. The apparent viscosity was calculated by:

$$\eta_{\min}(\dot{\gamma}) = \frac{\tau_{\min}}{\dot{\gamma}}$$

where η_{min} is the minimum viscosity, τ_{min} is the minimum shear stress and $\dot{\gamma}$ is the shear rate. The storage modulus and loss modulus were determined from oscillation flow data.

Results: The viscosity was linear or Newtonian for DWW and non-linear for BCS 100%, 75%, 50% and 25% at constant shear rates. The lowest viscosity and shear stress were for the DDW as expected, 1.64 Pa.s and 0.313 Pa, at a shear rate of 100s^{-1}. The storage modulus G' is greater than G'' the loss modulus for all five lubricants without additives. The rheological behavior of BCS and DDW indicated that the viscosity of BCS increases with increasing concentration (or decreasing amounts of DDW) (Figure 1). The presence of antibacterial additives affected the viscosity of BCS at different concentrations. The average viscosity for BCS 100% was 0.066 Pa·s (st dev: 0.00457 Pa·s). In contrast, the average viscosity of BCS 25% was 0.0151 Pa·s

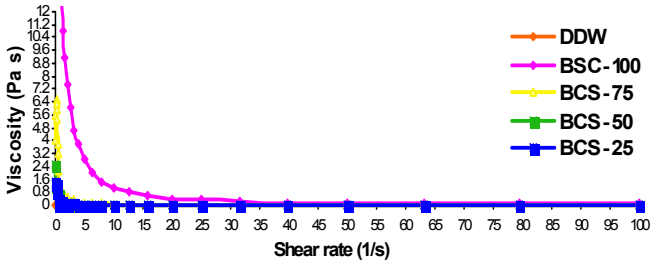

Figure 1. *The rheological behavior of BCS and DDW*

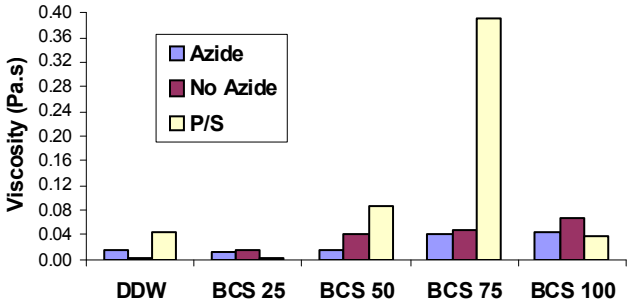

Figure 2. *The average viscosities for BCS 100, 75, 50, 25% & DDW with or without additives.*

(st dev: 0.0014 Pa·s). With the presence of additives, only BCS 75% with penicillin/streptomycin showed an increased viscosity. BCS 100%, 50% and 25% showed no increase in viscosity (Figure 2). Further analysis will be required to properly quantify the rheological behavior of BCS for wear testing of carbide-CoCrMo alloy bearing material.

Conclusions: The increase in concentration of bovine calf serum showed an increase in viscosity, which may affect wear testing results. Future studies should include measuring the viscoelastic properties of bovine calf serum with added hyualronic acid (HA), and conducting further studies on shear rate-controlled rheological properties of BCS at different concentrations to properly characterize the shear rate-dependent thermomechanical properties of BCS used in wear testing.

References:

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