Sealing Contact, Interfacial Separation, and Container Closure Integrity: A Preliminary Multiscale Contact Mechanics Approach for Predicting Prefilled Delivery System Performance

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One of the main functions of a prefillable drug delivery system is to protect the drug product from foreign matter ingress, bacteria, and contamination, in addition to avoiding weight loss through evaporation of liquid through the interfaces present in the container. This is referred to as maintaining Container Closure Integrity (CCI) in the pharmaceutical industry. For such prefillable delivery systems, the stopper-container interface plays a critical role in maintaining CCI and is dynamically challenged due to temperature and pressure fluctuations experienced during the drug filled system's storage and shipment over shelf life. This implies that the two surfaces may have to conform multiple times during storage while the mechanical properties and interfacial morphology changes because of the dynamic contact.

Multiscale Contact Mechanics (MCM), as discussed by Lorenz et. al. 2014[1] and developed by Persson [2,3,4] , addresses the contact and estimates the interfacial separation between, for example, a laminated/coated stopper[5] (Figure 1) and a glass barrel. The predictions from the presented model agreed with the results from simple leakage experiments. Subsequent microbial challenge of the system corroborated that the size of the channels was accurately predicted by the theory.

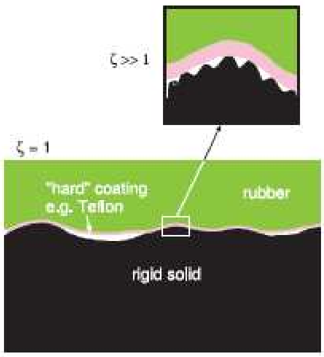

Figure 1. MCM approach to the contact between a rigid rough surface and rubber block coated with a thin film.

In this work, we expand the application of the model to analyze a similar system with different contact pressures and contact dimensions and compare the observed gas leakage to the predictions from MCM theory. In addition, we assess the impact of the different modes of stress relaxation and temperature variation by considering the results of DMA experiments mimicking the stopper-barrel contact. The outlined methodology allows the prediction of CCI on such systems far before prototypes and product development are undertaken, which results in a more efficient product development and use of resources.

References:

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