ElectroForce® 3330 Dental Wear Simulator

Advanced Simulation of
Wear Motion Profiles

The Bose® ElectroForce® 3330 test instrument can be configured with an additional horizontal ElectroForce linear actuator to simulate the masticatory cycle (chewing) for the evaluation of dental biomaterials and/or restoration techniques. Now the effectiveness of sealants or enamel replacements can be more accurately assessed in the laboratory. For example, the full potential of esthetic ceramic-based dental restorations has not yet been realized. Shaping-induced damage, exacerbated by fatigue damage during normal chewing, dramatically reduces the initial strength of these inherently brittle materials.

The ElectroForce 3330 dental wear simulator is ideal for the evaluation of the fatigue and wear characteristics of these inherently brittle materials, such as all-ceramic dental crowns. The wear simulator can effectively run hundreds of thousands of cycles for the evaluation of two-body wear investigations.

The masticatory cycle can be characterized in three phases:

1. The preparatory phase during which the mandible is positioned
2. The crushing phase during which the molars compress the bolus
3. The gliding (grinding) phase during which the bolus is ground between the molars.

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The three phases of mastication operate under different system control modes. The preparatory and crushing phases (vertical motion) are accomplished under load control while the gliding phase (horizontal) is carried out in displacement control as defined by the tooth anatomy. Mastication during the gliding phase is described by eccentric contact of the mandibular buccal cusps with the inner inclines of the maxillary buccal cusps followed by the working movement to the centric occlusion.

The three-dimensional masticatory motion can be simplified into two-dimensional motion by aligning the two linear motors to the desired planes of motion. One linear motor is positioned vertically to provide frontal plane motion that is defined by the occlusal anatomy, while the second linear motor provides a straight-line approximation of horizontal motion.

Tooth Sample being Tested

Dental Wear Simulation Software

Bose has developed user-friendly application software to set up and accurately simulate complicated wear profiles and test conditions. The software can be used to simulate tooth wear over a variety of test situations. The wear simulation software allows the user to easily define test conditions and automatically adjust the system variables to maintain these test settings. The Designer Test Language, a proprietary Bose application tool, was used to create a user interface specifically for the wear application. It allows easy definition of the complex parameters of the test, display of the test status, and the ability to pause the test during the test execution. In addition, through the use of this software, the researcher can create wear profile templates, which can be archived and retrieved later for different test programs. This application is an excellent example of how the advanced features the WinTest® Controller can be used to accurately simulate complicated test conditions.

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Test Software Features and Benefits

The application software uses a combination of advanced features that are critical for effective simulation of wear profiles, such as:

- Multiaxial control and synchronization;
- Ramp-to-level control mode that allows the initial ramp to occur in displacement control up to an applied force value;
- Bumpless mode switch to quickly and easily change from displacement to force control and back again;
- A user interface (based on the Bose® Designer Test Language), and run-time software to simplify the test setup, and to easily program the multi-axis test conditions and data acquisition.

The following plot measured by the WinTest® digital scope provides an impression for the complexity of the test conditions for simulating the masticatory cycle, and the time frame for the test sequence. In this example, the biaxial complex waveform is repeated approximately every 3 seconds.
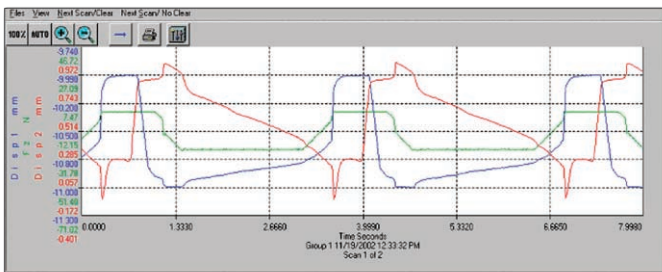
Masticatory Cycle Waveform Setup

Vertical loading during the glide phase is accomplished by programming a load profile (waveform) to the linear motor that is under closed-loop load control. This load waveform is a haversine constant load, which closely simulates anatomical loading. Typical load profiles range from 5 -1000 N, although the system is capable of providing up to 2250 N.

Mastication is dictated by the horizontal motion that is under displacement control while the vertical actuator is under load control during the glide phase. The system can provide a glide phase duration ranging from 0.1 to 0.4 seconds but 0.25 - 0.30 seconds is typical. Control of the vertical motor switches to displacement control in the preparatory and crushing phases and back to load control on contact with the opposing tooth during the gliding phase. The control loops for the ElectroForce® linear motors are synchronized to provide accurate 2-dimensional motion mastication cycle frequencies up to 2 Hz. The following is a graphical representation of the test sequence for the vertical axis of the test system.
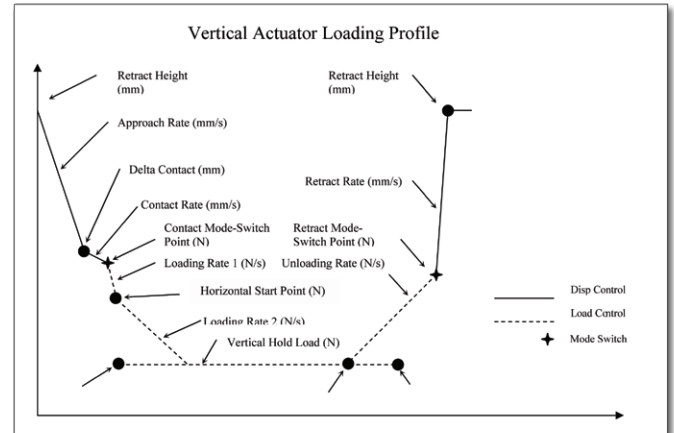
Summary

The compact ElectroForce dental wear simulator system allows researchers to perform advanced studies faster and more accurately. The simulator is ideal for the evaluation of the effectiveness of sealants and enamel replacements through wear studies, and other research that requires simulation of wear motion profiles.

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