A VISCOELASTOPLASTIC MODEL TO INTERPRET DENTAL CEMENTS RESPONSE TO A NANOINDENTATION TEST

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Introduction

Nowadays employment of dental resins of different types has become a standard procedure. Providing a complete characterization of their mechanical behaviour is mandatory to improve their characteristics, design, and usage. In this study we applied the nanoindentation technique to obtain experimental data to be fitted. Then, a genetic algorithm combined with a gradient algorithm were applied to find the best set of the mechanical parameters that characterize the Burger model in series with a frictional element (figure 1), able to predict the nanoindentation process [1]. Furthermore, with this approach one type of test permits to obtain mechanical parameters useful to characterize the viscoelastoplastic response of these materials.

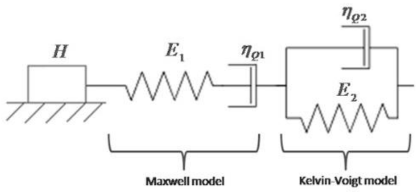

Figure 1: Lumped parameter system used to predict the viscoelastoplastic behavior of the analysed cements.

Materials and methods

Three different commercial cements were tested, i.e., two temporary cements Temp Bond and Telio C.S. and the Harvard cement, the permanent one. Cement samples were produced following the manufacturing guideline, embedded into epoxy resin, cut and, fine polished. All tests were performed with the Nanoindenter XP equipped with a diamond Berkovich indenter. The nanoindentation curves were characterized by a loading phase, and a holding phase of 5 s before the onset of the unloading phase. Different loading condition were explored imposing 4 values of strain rate: 0.5; 1: 5; 10 s^{-1} during the loading and unloading phase. The tests were performed in load control imposing a maximum load value of 10 mN. A total of 40 nanoindentation tests were performed for each cement and strain rate value. However, only few representative curves were analysed for each condition and cement.

A number of 15 sets of the initial parameters were randomly generated and, for each set an iterative application of a genetic algorithm and gradient minimization approach were applied. The convergence criteria were: (1) a value of the cost function lower than 0.0001 (2) or the number of iteration equal to 100. For each iteration 10^4 generation were created through the genetic algorithm refining then, the solution with a gradient algorithm. As stated in the work of [2,3] only the loading and holding phase (where the contact area increases) ca be analysed.

Results

Representative results of the fitting procedure were reported in figure 2. Although the behaviour of the cement at the microscale strongly depends on the strain rate, as highlighted by the displacement registered during the loading and holding phase, the model was able to fit both the examined phases of the nanoindentation process.

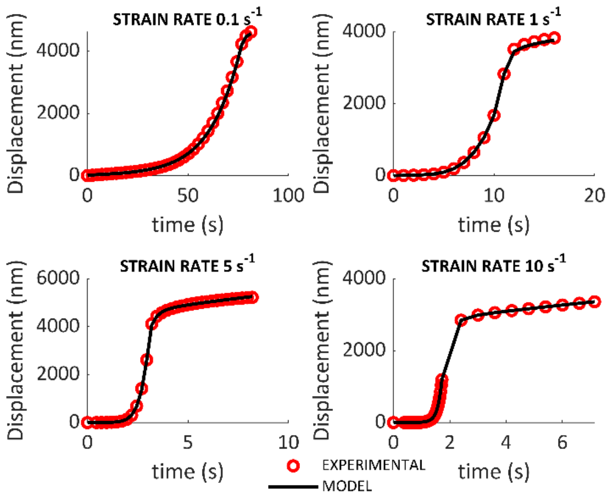

Figure 2: Representative curves of fitting process obtained for the Telio C.S. cement, imposing 4 values of strain rate

Discussion

Performing the tests with a constant strain rate, implied the use of an input loading curve that follows an exponential law over time, making it necessary to fit the experimental curves through a Burgers model [3] in series with a frictional element. Indeed, the elastic and viscous behaviour can be properly explained by the spring and dashpot in the maxwell model; whilst the Kelvin Voigt model and the frictional element take into account respectively the viscoelastic response and dissipative phenomena, related to the plasticization, of the cements.

References

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