Numerical simulations of a plunger-syringe system for cold storage drugs in medical applications

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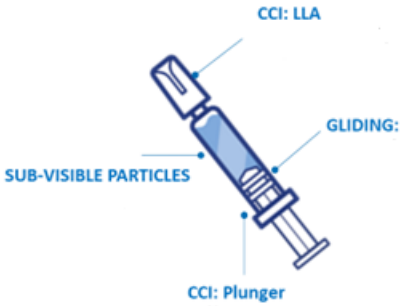
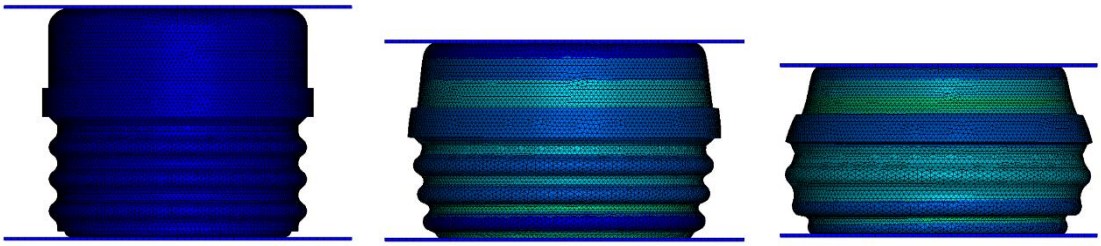
The storage of many pharmaceutical products takes place at low temperatures. In particular, RNA vaccines are kept at a temperature of -80 degrees. The need arises to contain not only vaccines, but lately also other types of drugs, directly in the syringes for future inoculation, avoiding the intermediate step between vial and syringe, to optimize the times and costs of the operations. The seal of the mechanical closure system is essential to prevent drug leakage or the entry of contaminants, such as CO2. It has to carried out the analysis of container closure systems, in particularly plunger-syringe system made of off the shelf components, where following functional and mechanical performances are granted, during and after storage and distribution of products, in both static and dynamic conditions, at temperatures of -80°C.

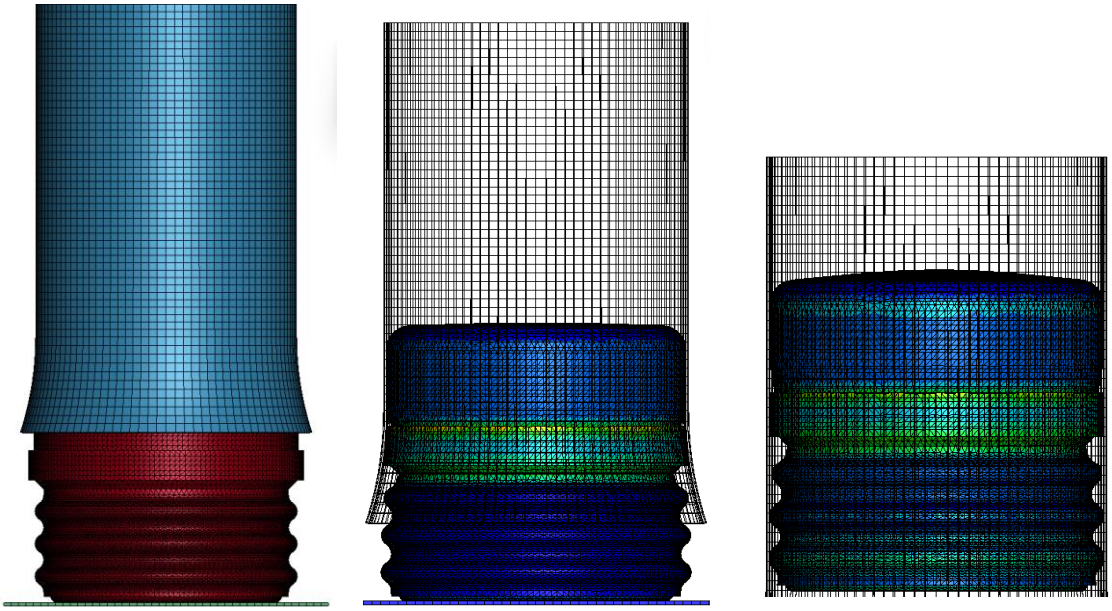


The aim of this project is obtain a good characterization of the closure system by numerical simulations. They has to replicate the real process of storage during cooling of the syringe and should predict possible system failure. The analysis allows to understand which physical parameters is involved directly in the closure system. In particular, the glass transition temperature of the plunger material (thermoplastic polymer) represents a significant element. In fact, a first step of the project concerns the investigation of a material model that can replicate the behaviour of rubber at different temperatures, also passing through the critical point of the phase transition.



Deformation of plunger under loading compression

The simulation includes the compression of the plunger to characterize the values of stresses and strain and try to verify the material model at room temperature making a comparison with experimental test. The insertion of plunger in syringe is also simulated to replicate the real conditions; particular attention is addressed to the phase following the insertion, during the relaxation of the stresses. The temperature variation begins in this phase and is not investigated directly but is present in the model parameters of the material, and in particular in the volumetric coefficient of thermal expansion.



Insertion of the plunger simulation: evaluation of the stresses

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