Fluid Flow Behavior in Steady and Transient Force Medical Injection Systems

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Abstract

Syringes were first conceptualized in 1650, but were invented in 1853 by Dr. Alexander Wood. As of 2011, nearly 8 billion syringes are used each year in the United States for medical purposes (not including veterinary services). These syringes are used for diseases like diabetes, rheumatoid arthritis, multiple sclerosis, and HIV. As injected medication is becoming increasingly more common, alternative injection methods have been developed. Automated-injectors inject with a higher force than a manual syringe, which significantly increases the uptake of the injected drug. These auto-injectors typically use a linear spring as their source of force, which subsequently has a decreased force as the injection proceeds due to its elongation. There is thus a clear need to understand the fluid flow properties of a syringe so as to reduce risk for the users, shorten development times, and develop more robust designs. Although syringe fluid flow models have been developed, few models displaying the fluid's behavior during the course of the injection with auto-injectors are available. By developing an auto-injector model and a manual syringe model, one could directly compare the fluid behavior within these two systems to assess any potential impacts these injections systems could have on the patient.
Syringe models were created using COMSOL Multiphysics for a manual syringe injection and an auto-injector injection. The manual syringe was assumed to have a constant pressure, and thus was modelled in steady state. The auto-injector was modelled in a transient state that had a changing inlet pressure over time due to assuming a spring force. The two models were verified by comparing the pressure drops and velocity fields of the barrel, hub, and needle with analytical calculations using Poiseuille's Law and Poiseuille's velocity field for laminar pipe flow. The pressure drops for both models had about a 1% difference when compared to their analytical counterparts, suggesting that the overall pressure of the model is accurate. Additionally, the velocity fields all were similar to their respective calculated velocity fields, varying at most by 0.9m/s at the ending pressure peak needle velocity in the transient auto-injector model.