Optimizing Design of Soil Mixing Equipment through COMSOL Simulations

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Introduction

Soil mixers are widely used to mix biochemical agents and additives to remediate contaminated soils or drill cuttings and sludges. Figure 1 shows a photo of a mixer performing remediation of percholoroethylene-contaminated soil by injecting and mixing sodium permanganate. For optimum remediation, uniformly mixing of these agents and additives with contaminated soil is needed. The ability of a mixer to achieve uniform mixing in the field depends on soil properties such as soil type (e.g., sand vs. clay) and water content, mixer specifications such as the geometric configuration of the blades and capacity of the motor, and mixer operations such as the rotational and translational speeds. The main objectives of this project are: (1) to evaluate the effect of geometric configuration of the blades and rotational speed on mixing performance; and (2) to optimize the tool design and operations of various soil mixers.

Figure 1. Example of soil mixer used for environmental remediation

Use of COMSOL Multiphysics

To achieve the project objectives, a numerical model is developed using COMSOL Multiphysics to simulate the complex interaction between fluid-solid mixtures and mixing tools during soil mixing. The developed model can account for the complex rheological behavior of fluid-solid mixtures during mixing and different geometric configurations of soil mixers. In this project, rheological models readily available in COMSOL Multiphysics are used to model the complex rheological behavior of fluid-solid mixtures. Various components of a mixer such as the main shaft and blades are modeled as interfaces or boundaries that can have rotational and translational motions. The mixing performance is monitored by injecting and tracing particles with the same density as the fluid. The torque developed on a mixer is calculated based on the pressure distributions on the mixer.

Results

For simplicity, a four-blade mixer and typical properties of fluid-solid mixtures are considered in this abstract as a proof of concept for the proposed numerical model. The shaft is 14 mm in diameter and 60 mm in length. Each blade has a dimension of 60×30×5 mm (Length×Height×Thickness). Figure 2 presents the torque vs. time at different rotational speeds. The torque on the shaft is induced by resistance from the fluid-solid mixture. Figure 2 indicates that the torque increases with the rotational speed. Figure 3 presents the contour of pressure distribution on the blades with red and blue indicating higher and lower values, respectively. Higher pressure concentration is observed on the edges of the blades, which is consistent with typical wear patterns of blades in the field. For evaluating mixing performance, tracer particles are introduced to the model. The paths of these tracer particles can be used to evaluate the mixing performance. As shown in Figure 4, the domain is divided into two regions and each region has tracer particles with different color. Figure 4 demonstrates that a good mixing is achieved after 10 seconds of mixing.

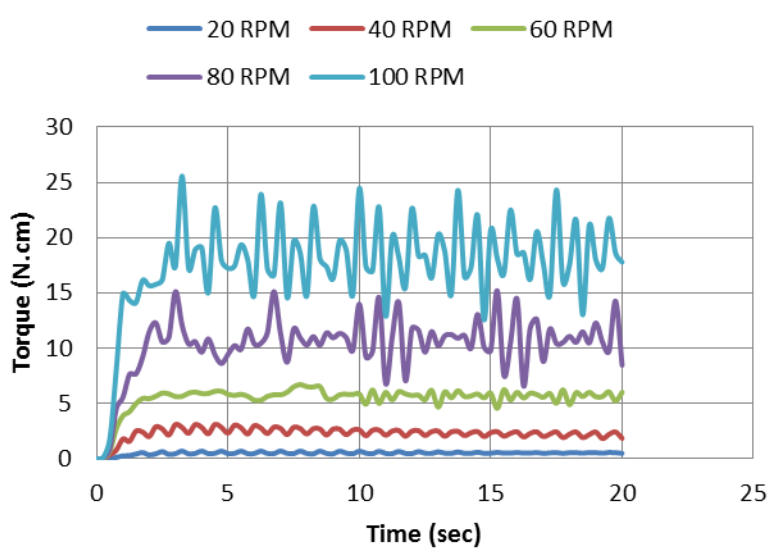

Figure 2. Torque vs. time at difference rotational speeds

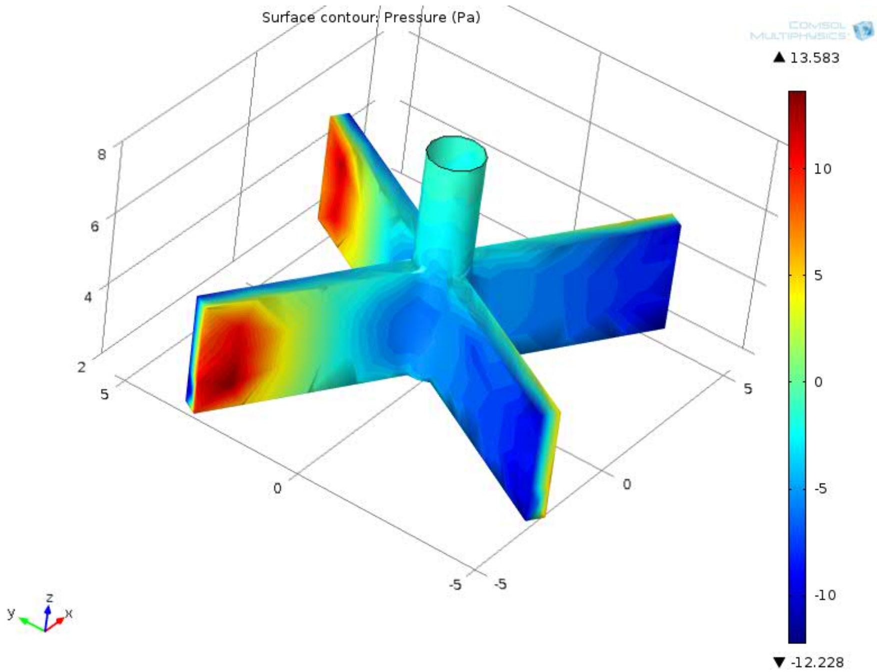

Figure 3. Contour of pressure distribution on the blades

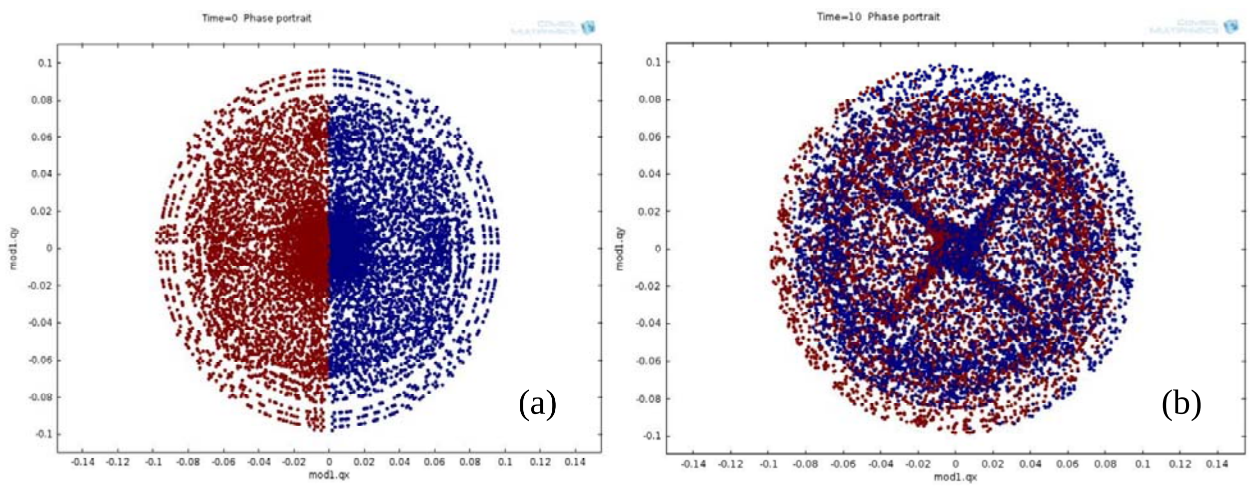

Figure 4. Particle tracing to evaluate mixing performance: (a) at the beginning of mixing; (b) after 10 seconds of mixing

Conclusion

Preliminary results of this project demonstrate that COMSOL Multiphysics can be used to model the complex interactions between fluid-solid mixture and mixing tools during soil mixing, and can be utilized to perform simulations to optimize the design of mixing tools and operations.