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Abstract

This work aims to design a numerical platform based on machine learning to characterize, predict, optimize and guide [high power] laser-rock interaction in subsurface. Advanced statistical analysis is essential to identify key variables and relations in the thermal-mechanical-electromagnetic coupling in heterogeneous and anisotropic rocks. The outcome is vital to build supervised-learning algorithms that predict, optimize, adapt, and evaluate the process according to environmental conditions, rock properties, and laser parameters.

Advanced statistical analysis and elements of supervised-learning are used to characterize the dynamics of [high power] laser-rock interaction. The algorithms used data generated from laboratory experiments conducted using different rock types. Classification and correlation methods are used to identify key variables, their interconnection, and assess their overall contribution to the process' outcome and energy balance. Regression algorithms are used to build a prediction model based on the key parameters. Kalman filters are discussed for real-time control and prediction. Finally, the results are compared to the multiphysics model and a review of the challenges at integrating the numerical platform is presented.

Numerical models of laser-rock interaction can be based on the solution to a set of coupled partial differential equations that fully describe the physical dynamics, or in the supervised-learning and analysis of experimental and field data. The former are highly sensitive to dynamic rock properties, environmental conditions, and laser parameters. In addition, it is challenging to characterize the rocks' properties over the wide spectrum of temperatures and pressures observed in the problem. A machine learning method provides an ever-improving alternative that learns from the available data to build a model that can predict, optimize, and guide the process. Advanced statistical analysis was used to determine key variables and identify correlations between them. Based on elements of machine learning a model is derived to predict the process' outcome as a function of known input parameters. Alternatively, the model can be also used to find the set of parameters required to attain a particular outcome. Finally, a method to derive rock properties using machine learning is also discussed.

Machine learning and advanced statistics provide a compelling alternative to build numerical tools to predict, optimize, and control physical processes. This work describes a numerical approach to identify the essential variables in the process of laser-rock interaction, predict their impact, and optimize the process for subsurface applications. Combined, the methods described in this work can guide the control of the governing dynamics and parameters for use in multiple applications, ranging from heat treatment to stimulation. This numerical platform can be extended to other applications, enhance experimental prototypes, and advance the design of a comprehensive numerical tool for downhole laser operations.