Abstract

A bulldozer is one of the construction equipment, which has a tractor/engine for supplying power and a metallic blade in its front for soil cutting. A bulldozer experiences enormous resistance due to adhesion, cohesion, and friction between soil and blade. Many studies in the literature focused on determining the cutting force on a blade and observing effect of various input parameters on the force. Except for a few handful studies, an effort has not been made to make the soil cutting operation by bulldozer and its blade economical and productive. In this thesis, the soil cutting operation is modeled as an optimization problem in which the operating conditions of a bulldozer and dimensions of a blade are chosen as decision variables.

Three multi-objective optimization formulations are proposed chronologically by making them realistic and practical in every attempt. In the first attempt, the cutting force is minimized and the volume capacity of a bulldozer blade is maximized with a constraint on the remaining power. In the second attempt, the optimization formulation is made more realistic by simultaneously minimizing the power requirement from a bulldozer to overcome resistance due to the cutting force, and the time required to fill a bulldozer blade with soil. Three problem-specific constraints are also included in this formulation. In the last attempt, the power required from a bulldozer, the time to fill a bulldozer blade, and the number of passes to cut a fixed volume of soil are minimized simultaneously so that different sizes of bulldozer blade can be evolved that can be operated at different operating conditions.

For solving the proposed multi-objective formulations, the existing evolutionary multi-objective (EMO) techniques are used. The classical multi-objective optimization method, that is, the $\epsilon-$constraint method is also used to generate the Pareto-optimal (PO) solutions. The post-optimal analysis is performed among the objectives and decision variables of the obtained PO solutions to develop important relationships among them. For improving convergence of the exiting EMO techniques, a hybrid procedure is proposed in which three challenges for the local search on `frequency`, `choice`, and `number` of solutions are addressed by using the idea of decomposing the objective space into the structured reference points.

The results demonstrate different nature of the obtained PO solutions for the proposed optimization formulations. The results of the $\epsilon-$constraint method, the perturbation analysis and comparison with the experimental results from the literature suggest that the obtained PO solutions are converged to or very close to the true PO front. The post-optimal analysis deciphers useful and non-intuitive relationships among the objectives and decision variables, which otherwise are difficult to obtain. Some common design principles and dissimilar relationships are extracted that are responsible for trade-off among the PO solutions. The guidelines are then suggested for selecting an appropriate solution and its optimal decision variable values from the set of PO solutions so that a practitioner can choose input parameters for the optimal soil cutting. The results of a hybrid procedure demonstrate that the convergence can be made faster as twice as compared to the exiting EMO technique.

The originality of this work lies in formulating realistic multi-objective optimization formulations, validating the obtained PO solutions through various analysis and from the experimental results, deciphering important relationships from the obtained solutions that can be used for making the guidelines, and a hybrid procedure for improving convergence of the exisiting EMO techniques.