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Reduction of Pneumatic Tyred Roller Fuel Consumption

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Abstract: This article deals with optimization of operational parameters of an energy regeneration module for a heavy vehicle. Recently there was developed energy regeneration module for a pneumatic tyred roller with hydrostatic drive. It was necessary to optimize its operational parameters to achieve good results in experimental tests on the actual vehicle. Optimization process was based on a numerical model of the vehicle using a parallelized modification of the differential evolution algorithm as an optimizer. Suggested parameter values were subsequently verified experimentally on the vehicle by analysis of the fuel consumption.

Introduction

In order to fully utilize the potential of the energy regeneration module [1] and considering the low operational speed of the vehicle, various operational parameters of the module – such as timing of control processes or the pressures in accumulators – needed to be optimized. A lumped parameter numerical model tyred roller created in Matlab was used for simulation of vehicle operation [2]. Concurrently, the differential evolution algorithm was applied for optimization of the operational parameters of the energy regeneration module.


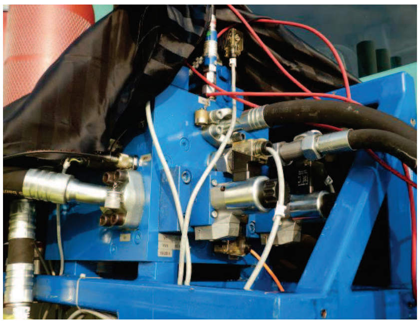

Fig. 1: Energy regeneration module prototype mounted to the vehicle

Optimization

One iteration of optimization consists of two stages. The first stage ensures proper setting of initial conditions for assessment of total fuel consumption through the second stage of simulation.

The input parameters were

$$\boldsymbol{x} = (p_{acH0};\, p_{acHAccelStop};\, T_{HM};\, R_{HM}). \tag{1}$$

The objective function is defined as follows:

$$f(\boldsymbol{x}) = \frac{q}{s}\ , \tag{2}$$

where q [g] is the total mass of fuel consumed through second stage of simulation and s [m] is the distance driven by the vehicle by defined conditions.

The asynchronous parallel optimizer [3] (based on the differential evolution algorithm [4]) was applied to minimize the objective function (2). The optimizer is implemented outside Matlab/Simulink platform using the simulation model in Matlab/Simulink to evaluate the objective function.

Optimization process and results

Several operational modes of the vehicle drive were optimized. The default operational mode (*Free Run*) is without active regeneration. The other two modes utilize the energy regeneration module: deceleration with energy regeneration enabled (*Decel*) and acceleration of the vehicle with the use of the energy stored (*Accel*).

Utilizing the optimizer the fuel consumption of the vehicle was reduced from 2.76 g/m of fuel to 2.54 g/m (by 7.97 %) while maintaining the performance of the vehicle (see Fig. 2) during simulation.

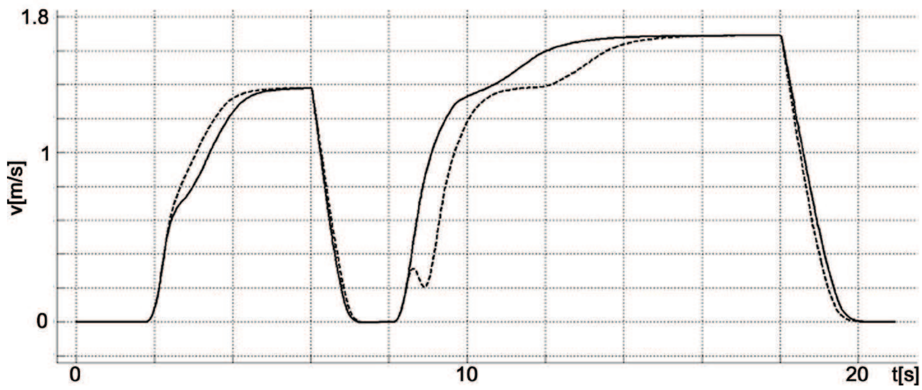

Fig. 2: Time response of the vehicle speed with default setting of the regeneration module (dashed) and optimized setting (full line)

Conclusions

The optimizer was used with the simulation model of the vehicle. The results of the optimization process suggested the settings of the operational parameters of the energy regeneration module on the vehicle. These settings need to be experimentally verified by driving the vehicle. Although there are expected some limitations of suggested settings beyond the capability of the control system of the vehicle, there is good potential for further lowering the fuel consumption and increasing the efficiency of the regeneration process as verified by a preliminary driving test.

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