Evolutionary Multi-Objective Optimization of Shoe Sole Damper Geometry Using Surrogate Models and Data Mining

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IDEAS TO IMPACT

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Objectives

Develop a computer based system (Fig.1) to choose the best arrangement of dampers on a shoe sole to improve comfort (Fig. 2).

The straight-line segment, starting a time "0" defines the optimal solution (Fig. 4).

Obtain this behavior (or as close as possible) with the starting conditions for each case (Fig. 5).

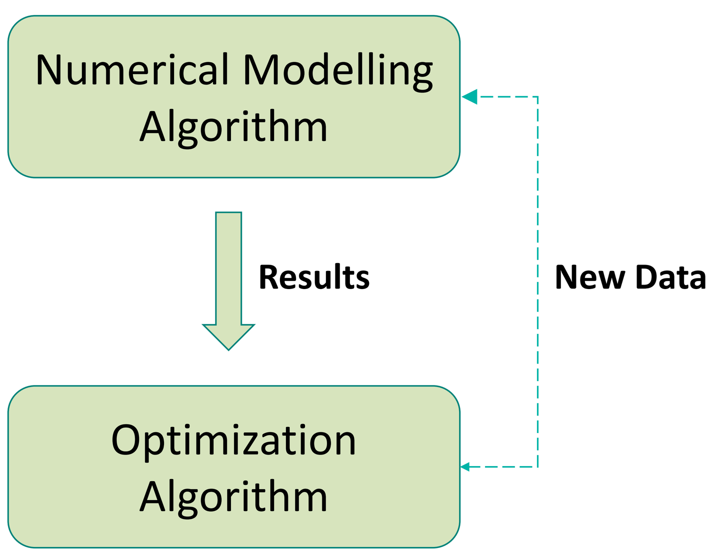

Figure 1. Proposed Software Model

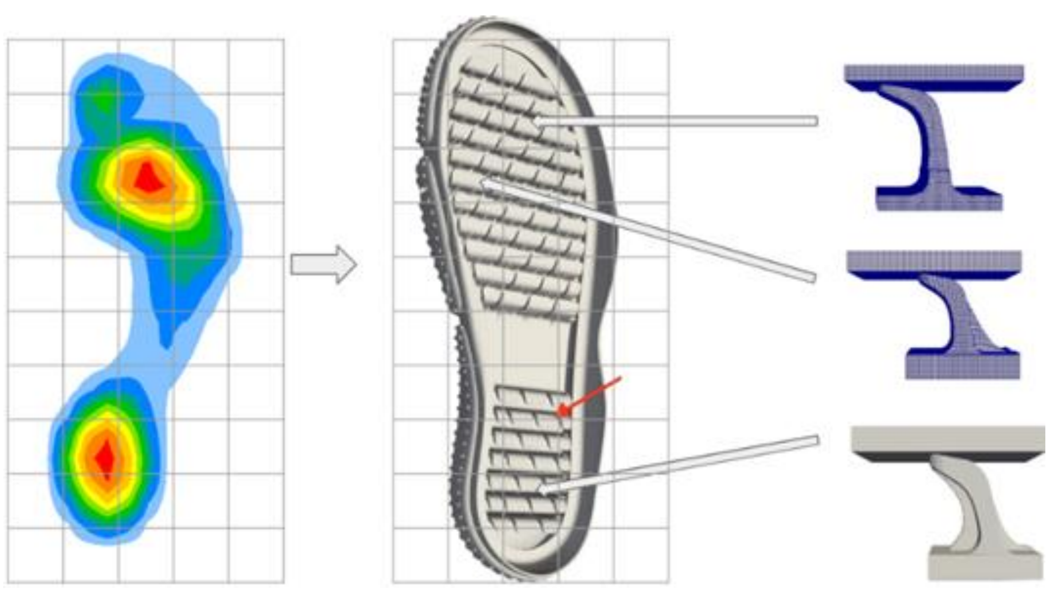

Figure 2. Pressure zones and sole shoe dampers distribution.

Mesh complexity influence

Solid mechanics models the deformation and stress distribution within solid bodies (Fig. 3).

Thus, while the damper was under significant compression, the mesh cell deformation (strain) is very small.

This means that the mesh can often be coarser without significantly affecting the results (Fig. 4), shortening the computer simulation time (Table1).

Table 1. Mesh reduction test parameters.

Damper min/max CellSize (mm)	Num. cells	Skewness (ref 2.8)	Non-orthog. (ref <64)	Sim time (s)
0.14	296762	1.518	60	61200
0.76	4312	1.097	62.571	1200

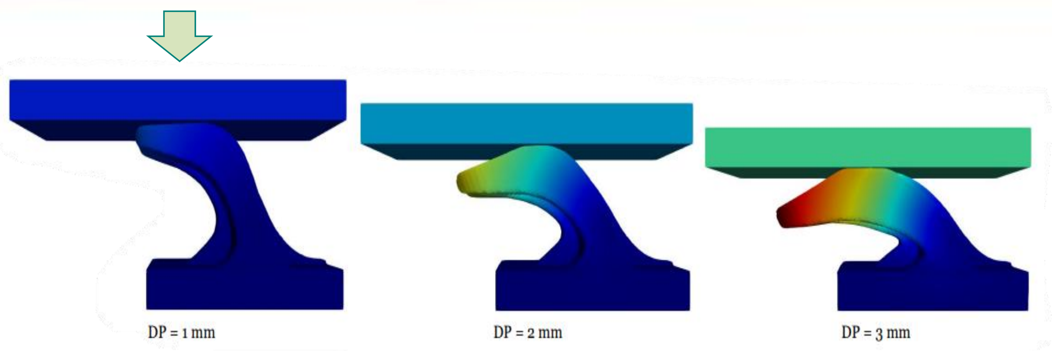

Figure 3. CFD (Computational Fluid Dynamics) Mechanical Simulation

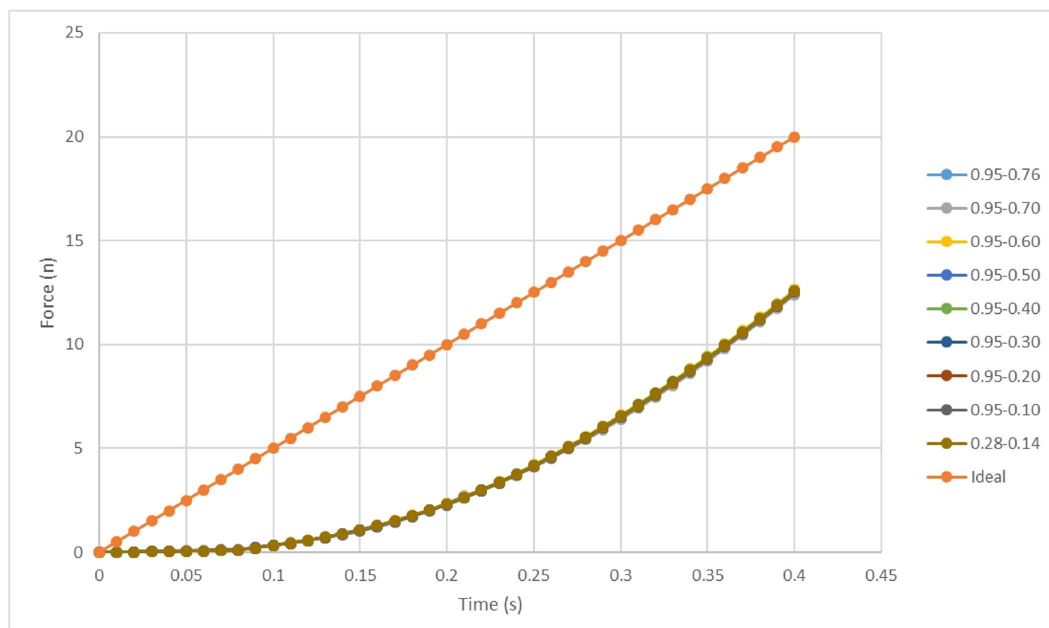

Figure 4. Simulation results for different mesh refinement

Geometry influence

To test and learn the behavior of the proposed model several simulations runs were executed with different damper geometries (Fig. 5).

Dampers with front ribs tend to offer more resistance to applied force.

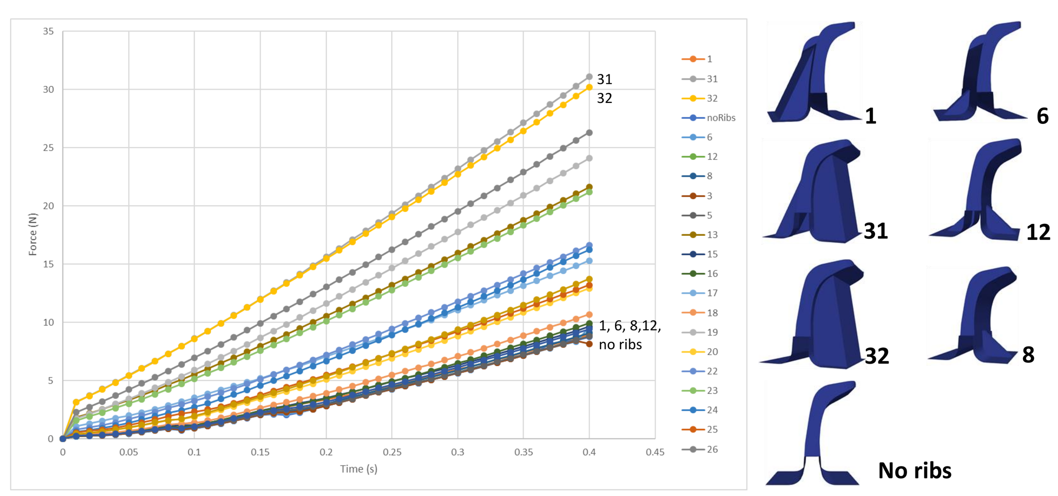

Figure 5. CFD Simulation results, different geometries

Artificial Intelligence

DECISION VARIABLES:
Front Rib, Back Rib and Damper :
width (x); thickness (y); height (z).

OBJECTIVES (minimize):
tmax - Maximum spring displacement;
fmax - Maximum spring reaction force;
f1 - Average distance to optimal (all points);
f2 - Average distance to optimal (n max points).

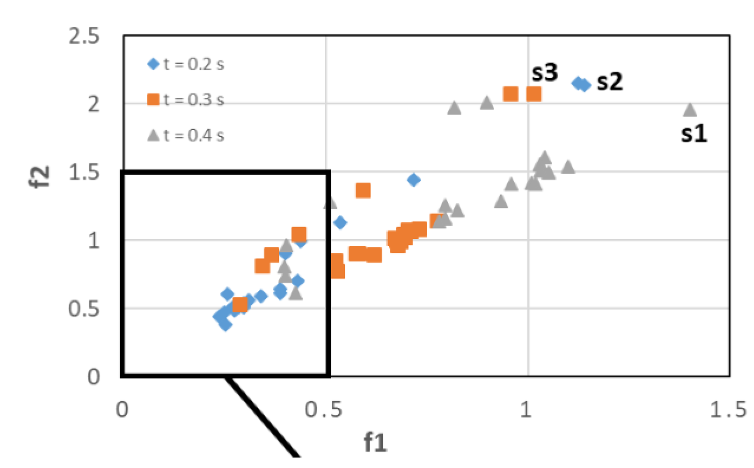

Figure 6. Objectives relationship f1 and f2

Data analysis

DAMICORE:
Data analysis technique, able to define important interrelations between all variables (Fig. 7).

Framework based on Normalized Compression Distance (NCD) metric, to generate a distance matrix from the data.

Models based on phylograms able to deal with any type of data. (integer, real and complex numbers, categorical, images, sound, etc., and mixtures of them).

Uses a distance reconstruction algorithm called Neighbor Joining (NJ). Quality of the models is improved by a systematic resampling strategy.

Apply a Complex Network approach called Fast Newman (FS) to perform community detection by analyzing the phylograms found previously to extract significant and reliable information from them.

For this initial study, damper values x, y, and z are fixed, as is the ribs x value.

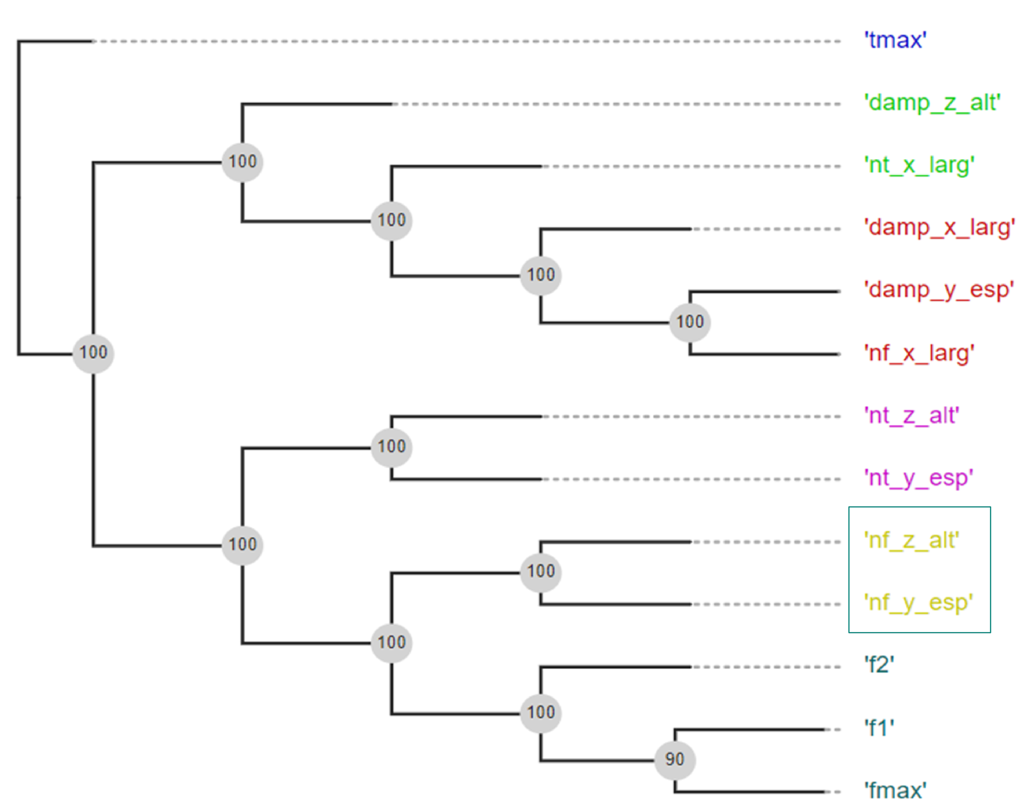

Figure 7. DAMICORE, most influential variables.

Conclusions

The geometry influence and DAMICORE results indicate that the front rib is the most influent studied characteristic of the damper to obtain optimal comfort.

After the data analysis results (Fig. 6), we conclude that this problem can be optimized. A group of better results can be obtained using an optimization process.

The next step is the study of the optimization algorithm. Test a multi-objective evolutionary algorithm and/or a neural network to find a pool of the best results to help both a human or an automatic decision-making process.

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