Identification of Ogden Material Parameters using FEMtools

The Ogden Material Model

The Ogden material model is frequently used in finite element programs to simulate the behavior of non-linear elastomers. It is based on the following expression for the strain energy potential:

$$W = \sum_{n=1}^{N} \frac{\mu_n}{\alpha_n} J^{-\frac{\alpha_n}{3}} \left(\lambda_1^{\alpha_n} + \lambda_2^{\alpha_n} + \lambda_3^{\alpha_n} \right) + 4.5K \left(J^{-\frac{1}{3}} - 1 \right)^2$$

in which W is the strain energy potential, J is the total volume ratio, λ_1, λ_2, and λ_3, are the principal stretch components, K is the bulk modulus, μ_n and α_n the modulus and power material parameters. The coefficient N determines the number of parameters of the material model. The higher the number of parameters, the better the ability to match the extreme nonlinearities related to high strains. In case N is chosen equal to 1, the Ogden model requires 3 material parameters: K, μ_1, and α_1.

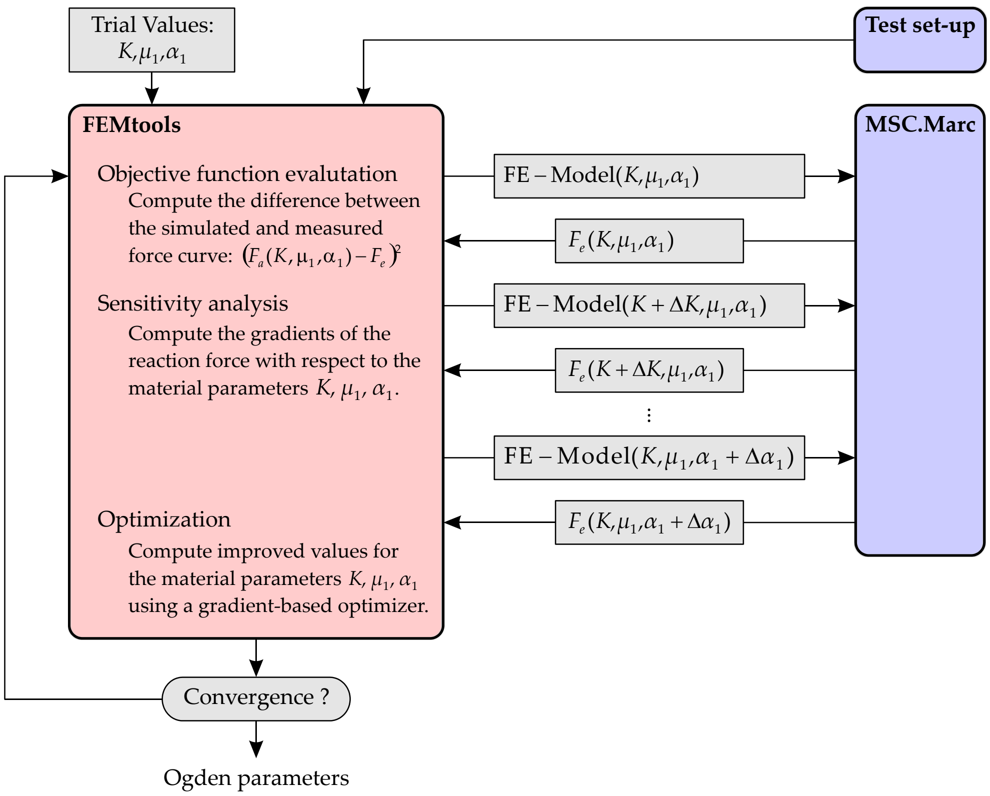
Parameter Identification

The values of the material parameters of the Ogden model are highly material dependent. The main challenge in using the Ogden model in finite element simulations, is to find reliable estimates for the values of the Ogden material parameters.

The relation between an imposed displacement and the resulting reaction force can be used to identify these material parameters using a mixed numerical-experimental approach. In this approach, the objective is to fit the simulated reaction force curve $F_a(K, \mu_1, \alpha_1)$ onto the measured reaction force curve F_e. The computationally most efficient way of doing that is by using a gradient-based optimization strategy.

Implementation in FEMtools

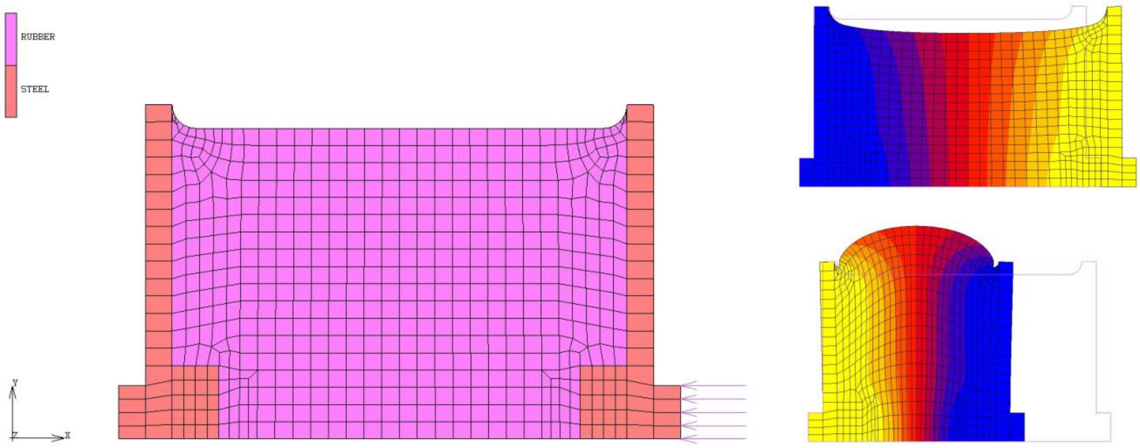
The identification routine was implemented in the FEMtools Optimization module, and used MSC.Marc to compute the reaction force curves. The flowchart of the identification process is presented below.



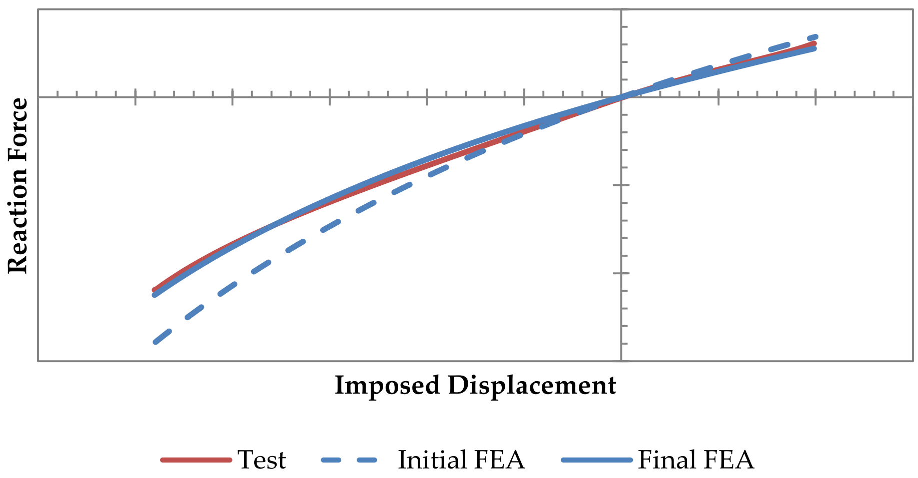
The FEMtools procedure started by reading the experimental force curve. Then, a set of trial values for the Ogden parameters were inserted in the FE-model, and the modified FE-model was sent to MSC.Marc to compute the reaction forces. In the next step, the Ogden parameters were perturbed, one by one, in order to compute the gradients of the force curve. Finally, the force gradients were used to compute optimal parameter corrections by minimizing the difference between the simulated and measured reaction force curves using the general non-linear optimizer of the FEMtools Optimization module. The improved material parameters were inserted into the FE-model and a new iteration cycle was started. Once the improvement of the objective function, i.e. the difference between the two force curves, was smaller than the convergence criterion, the Ogden parameters were considered to be converged and the iterative procedure was aborted.

Experimental Test Case

The identification procedure described above was applied to a real test case where a block of rubber was deformed between two steel plates. The figure below presents the FE-model of the experimental set-up (left), together with deformation of the rubber for the minimal (top right) and maximal (bottom right) value of the imposed displacement.



The parameter identification process converged to stable values for the Ogden parameters in five iteration steps. The overall improvement in correlation between the simulated and measured reaction force curves, due to the optimization of the Ogden material parameters, is presented below. The satisfactory correlation for the reaction force curve of the optimized FE-model shows that the Ogden parameters were correctly identified.



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