Dynamic Response Optimization of Structural Components within a Multibody System Approach

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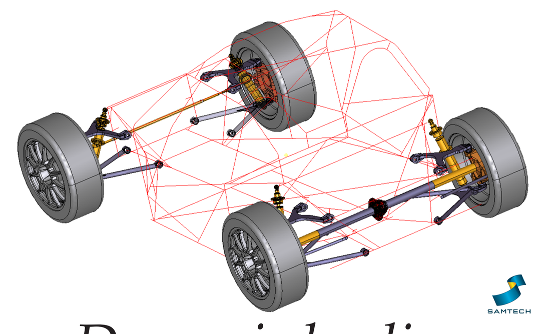
Motivations

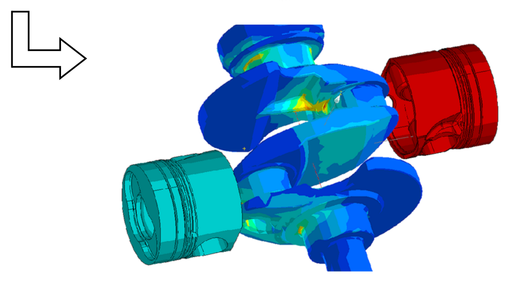
The optimal design may strongly depend on the supports and loading conditions [1]. In the optimal design of mechanical systems, the precise representation of the dynamic interactions between the component and the complete mechanical is thus an essential aspect.

The objective is to carry out the optimization with the time response coming directly from the flexible multibody system (MBS) simulation.

Structural optimization **Flexible MBS**



Static or quasi-static loading *Dynamic loading*

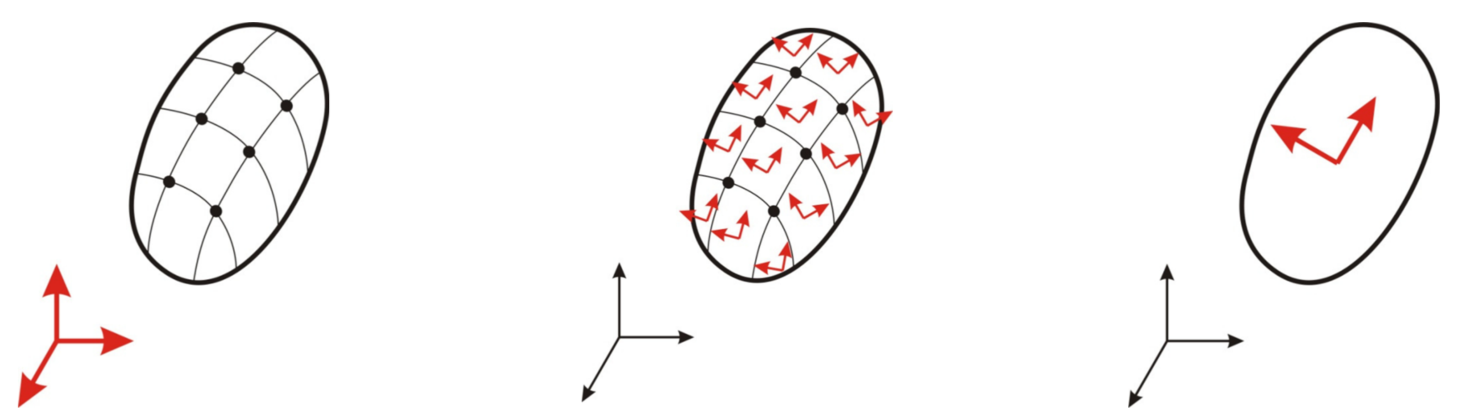


Integrated optimization of flexible components

Flexible Multibody System

Several parameterizations can be exploited to analyze the dynamics of multibody systems. Below are introduced the best known.

Inertial Frame | Corotational Frame | Floating Frame



No distinction	Rigid motion + small deformation	
Absolute Coordinates (FE)		Rigid + Elast. Coord.

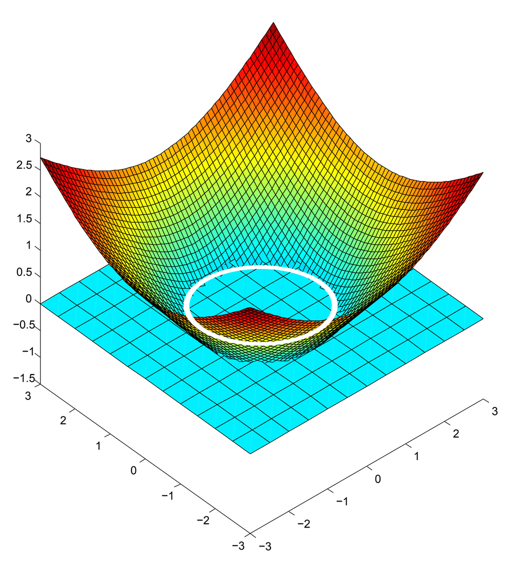
In this study, a nonlinear finite element based formalism is employed with an inertial frame of reference.

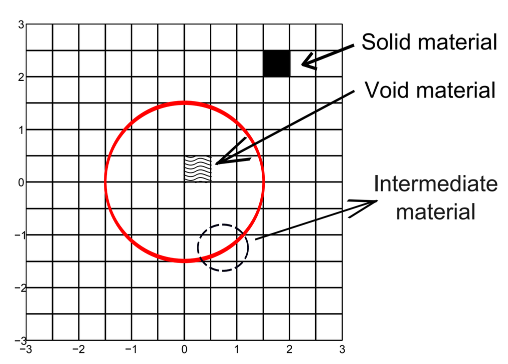
Level Set Description

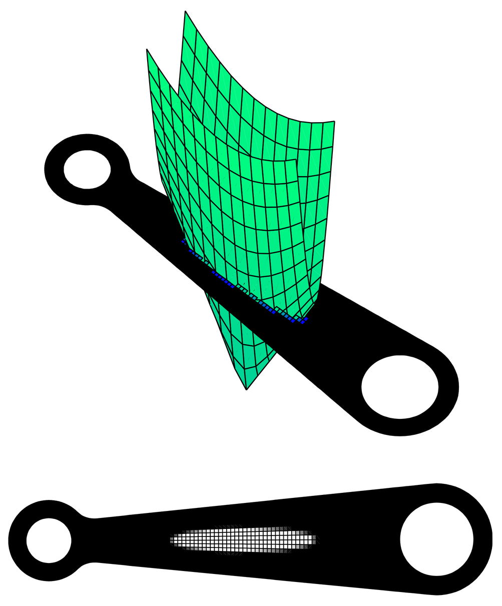
A Level Set description of the geometry enables to combine the advantages of shape and topology optimizations:

- + Fixed mesh grid (No mesh distortion, no re-meshing);
- + The geometry is based on CAD entities;
- + Modifications of the topology;
- – Development of specific tools for the LS construction.

The design variables are the Level Set parameters. For the element cut by the Level Set, a SIMP approach is adopted to define an intermediate material.



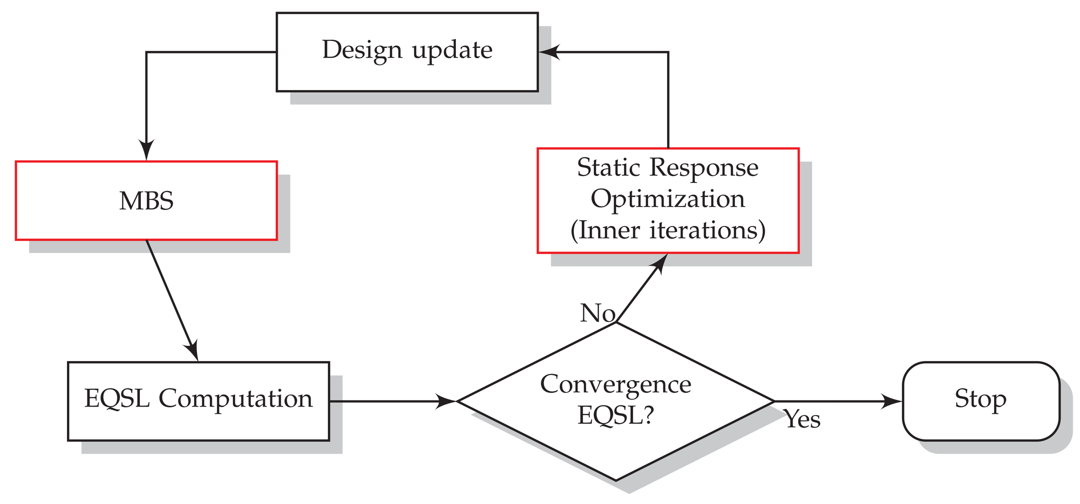




Ongoing Work: The preliminary results with the Level Set approach are promising. The ongoing work is to develop a semi-analytical method for the sensitivity analysis.

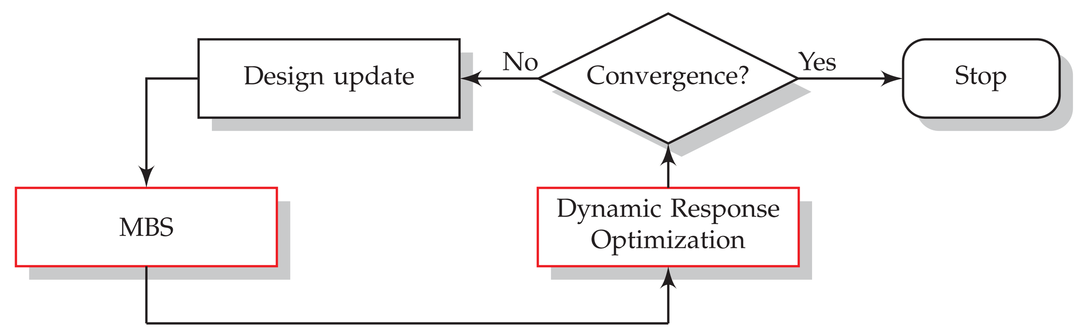
Methods

- **The Equivalent Static Load Method** [2] aims at removing the time component from the problem.



- + Take advantage of the well-established and robust methods of static response optimization;
- – Weak coupling between the MBS and the optimization;
- – The formulation of the design problem is limited to static or vibration design criteria;
- – Design dependent loading may lead to non-convergence.

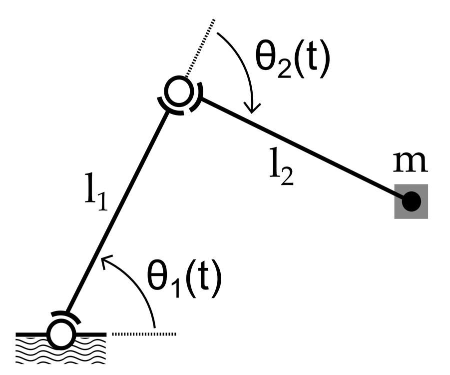
- **The Fully Integrated Method** aims at considering as precisely as possible the effects of dynamic loading under service conditions.

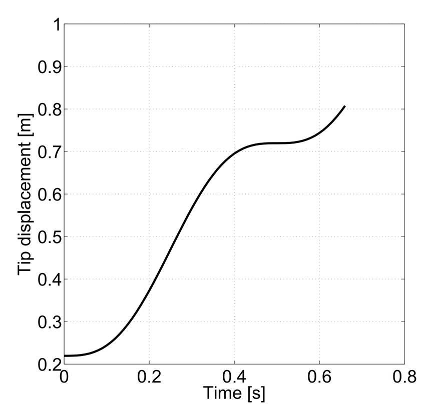


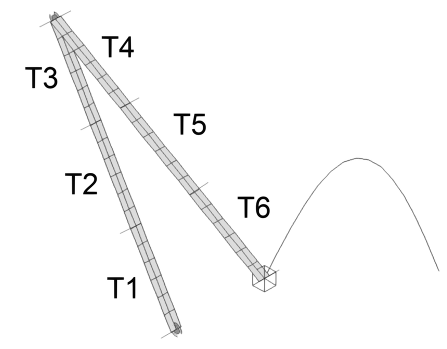
- + Strong coupling between the MBS and the optimization;
- + The problem can deal with dynamic design criteria;
- + Dynamic effects are naturally taken into account;
- – More complex optimization problem.

Optimization Problem Formulation

The numerical application is based on the mass minimization of a two-arm robot subject to a tracking trajectory constraint. By reducing the robot mass, deformations and vibrations appear and introduce trajectory errors that have to be kept under a given tolerance.

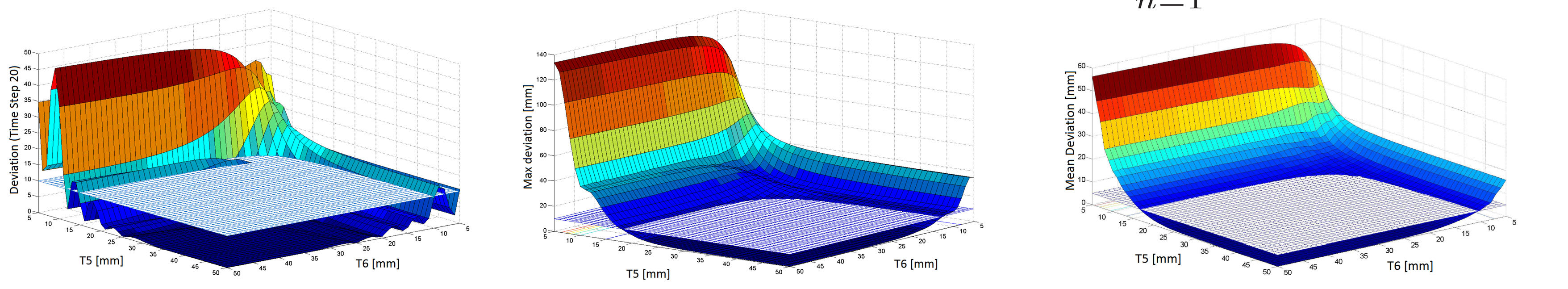






The formulation of the optimization problem modifies drastically the design space.

$$\Delta l\left(\mathbf{x}, t_n\right) \leq \Delta l_{max} \qquad \max_{n} \Delta l\left(\mathbf{x}, t_n\right) \leq \Delta l_{max} \qquad \frac{1}{t_{end}} \sum_{n=1}^{t_{end}} \Delta l\left(\mathbf{x}, t_n\right) \leq \Delta l_{max}$$



- + Tight control;
- – Complex design space.

- + Simplified design space;
- – Non-smooth characteristics.

- + Smooth design space;
- – Impose only a trend.

References

[1] Bendsøe M, Sigmund O (2003) Topology optimization: Theory, Methods, and Applications. Springer Verlag, Berlin.

[2] Kang B, Park G, Arora J (2005) Optimization of flexible multibody dynamic systems using the equivalent static load method. AIAA Journal 43(4):846-852.

Acknowledgment

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