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DESIGN OF EFFICIENT STRUCTURES CONSIDERING FLOW-INDUCED EFFECTS

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ABSTRACT

With increasing lightness and slenderness in modern optimized structures, loads from surrounding fluid flows gain more and more importance and are decisive design factors. Typical applications in the civil engineering context are cable, membrane, or shell structures subject to wind. Common to all these structures is a thoroughly specified shape so that the resulting structure is able to carry loads mainly by membrane action. Therefore, finding the most suited geometry for a certain type of loading is the core task in the design process of highly optimized structures.

The aim of this research is to develop a framework for the analysis and improvement of light, thin-walled structures, such as membranes, towards flow induced effects. To capture the decisive effects of this coupled system, a multi-physics computation is necessary. As the flow induces loads on the structure's surface, the appropriate modelling is done in a surface-coupled Fluid-Structure Interaction (FSI) analysis.

In order to conceive a powerful as well as flexible simulation environment, a partitioned coupling scheme is chosen. As a first step, the physical models for the two different fields, the structural and the fluid field are derived. These models are based on the initial geometry of the structure. Together with material parameters and completive data, a numerical structural model is derived for the initial geometry. This numerical structural model has to represent the structural behaviour of the system, e.g. be able to show the correct deformation for a certain load case. Also based on the initial geometry, a numerical fluid model is created. The two requirements for the numerical fluid model are firstly, the appropriate modelling of the flow in, trough, or around the construction and secondly, to derive the correct surface loads imposed on the structure. Therefore, the fluid model has to feature a three-dimensional representation of the construction. In the case of a complex flow condition, like wind flow, special attention has to be turned to the correct inflow and other boundary conditions of the fluid simulation.

In order to perform a coupled simulation, the fluid and the structural simulation need to exchange their boundary conditions, mostly loads and displacements. This is not a trivial task, since in a general case, data between a one, two, or three dimensional

structural model and a three dimensional fluid model with non-matching interface discretisations have to be exchanged. Therefore, a coupling management tool (CMT) is employed. Based on the geometry, the structural model, and the fluid model, a third, surface based model is derived by this CMT, the interface model. This interface model establishes a relation between the structural and the fluid model and thus realizes the exchange of data between the two non-consisting models.

After creating the three models, the coupled multiphysics computation can be started. For the representation of strong physical coupling and to ensure stability for the coupled simulations, an iterative staggered coupling scheme is realized: several iterations, in which the fluid and the structural problem are sequentially solved, are conducted until an equilibrium between flow induced load and structural deformation is reached. In order to stabilize and accelerate the coupled computation, adaptive under-relaxation of coupling quantities is applied. To keep the simulation time reasonable, the fluid simulation is performed in parallel on multiple processors.

The results of the coupled simulation are subject to an evaluation according to the initial design requirements and constraints. In case the requirements and constraints are not met, the structure has to be improved. This can be done by changing the material parameters (e.g. by choosing a material with higher strength), adapting the sizes of structural elements (e.g. increase the diameter of a tension cable), or modifying the geometry. If the aim is to derive a structure with an optimal utilization of the material, the modification of the initial geometry with respect to the specific load case is clearly the most interesting choice.

As the structural and the fluid model are directly derived from the geometry, a change in the geometry results in changes within these models. With the help of automatic or semi-automatic pre-processing, a possibility exists to reuse and readjust the existing models to the changed geometry.

This contribution suggests an environment for the analysis and improvement of structures subject to fluid flow. With the usage of one consistent geometrical model and a semi-automatic pre-processing, it is possible to adapt the simulation setup easily to a modified geometry. Besides an efficient way to perform parameter studies, this environment opens the perspective for multi-physics optimization.

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