INTEGRATING FINITE ELEMENT ANALYSIS WITH SYSTEMS ENGINEERING MODELS

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ABSTRACT

In order to promote traceability, consistency, interoperability and better collaboration between systems engineering and Finite Element Analysis (FEA)-based simulation activities, we propose a tool-independent description of FEA models that integrates with the Systems Modeling Language (SysML), for future standardization. As technical systems become more complex, it is important to support traceability between systems engineering artifacts such as requirements and test cases and corresponding FEA artifacts such as FEA models, simulation conditions, and results. SysML is the standard for model-based systems engineering. It supports the description of system requirements, use cases, functions, structure, behavior and cross-cutting aspects. SysML can be formally extended through mechanisms for capturing additional domain-specific information.

While there is a standard for model-based systems engineering in the form of SysML, there is no standard description of FEA models. Existing model descriptions are incomplete, tool-specific, or informal, or a combination of these. As a result, interoperability between FEA software applications is compromised, and communication between engineers is inefficient. It is difficult for simulation engineers to understand FEA models of others, and even more so for systems engineers. Without a standard description of these models, no relationships between systems engineering and FEA can be established such that they can be understood by a wide range of engineers.

A standard for the description of FEA models is difficult to develop, as the geometry, mathematics and physics of finite elements can vary greatly. New standardized descriptions of the mathematics of finite elements, including information to describe the number, type and location of finite element degrees of freedom, have been proposed recently, such as a periodic table of finite elements and the Unified Form Language developed within the FEniCS project. These recent descriptions use mathematical constructs which are accessible to mathematicians but considered too complicated for most engineers.

We propose a description of finite element mathematics based on the topological characteristics of finite element that is formal, precise, and understandable to engineers. It can describe a large variety of finite element degrees of freedom, a larger

variety than the FEniCS periodic table of finite elements can, and does not use complex mathematical constructs. We think that such a description is suitable for broad adoption among both FEA and systems engineers. We validate the new description of finite element mathematics by solving FEA problems using our own developed Python code. We demonstrate how FEA models can be described in SysML in order to facilitate the definition of relationships between systems engineering and finite element analysis information in a common SysML model.