A SysML Based Conceptual Framework for System Level Design in Micromechanical Electrical System

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ABSTRACT

The design of a microelectromechanical systems (MEMS) is a hard task due to the complexity of the systems. Model driven engineering approaches, like model-based systems engineering (MBSE) and SysML provide a way for the systematic design of MEMS. However, the conceptual design of MEMS is an iterative and multidisciplinary issue, which makes a long time for design space exploration. In this study, a SysML based method is proposed to implement the system design and simulation models of MEMS product. The design process reaches from requirements specification to the detailed modeling and simulation of the system. This proposed method was illustrated by designing a high-resistivity silicon based patch antenna which is used as RF front in a Beidou receiver. The results showed that the SysML based information from the different diagrams of Beidou receiver and the multidisciplinary design phases can be connected and used during the development of new MEMS product, resulting in shortened development cycles.1

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1. INTRODUCTION

The development of microelectromechanical systems (MEMS) is a complex task [1]. It require the background knowledge of multiple disciplines, such as mechanical, electronic, electromagnetic to fulfil the functional requirements. Thus there is a great need of modeling and simulation of MEMS product in the conceptual design phase.

Model-based systems engineering (MBSE) was introduced to integrated the different knowledge of each domain [2]. As in mechanical engineering, systematic approaches to design and develop products are used to improve efficiency of the design process [3]. Paper-based methods and documents centric methods are adopted to transform function, behavior and structure in concept design [4]. Now MBSE is the mainstream method for complex system design, and SysML, which has been established based on unified modeling language (UML) to support the MBSE by the International Council of Systems Engineering (INCOSE), is used to consider engineering system in general.

Research works have been carried out on the model based design of products. Shea et al. [5] proposed a multi-domain computational synthesis method in MEMS design. This method combined a generate test algorithm with an object-oriented, systems-based representation called Connected-Node System. Cao and Paredis[6] put forward a meta-model based method is proposed to integrate the system design and simulation models of mechatronic system. Simulation information was formalized in SysML to support an analysis of the system dynamic behavior with the aid of simulations.

Our objective is to introduce a conceptual design framework for MEMS using SysML. In this unified framework and modeling environment, the information of MEMS product can be utilized efficiently to evaluate design schemes in early stage.

This paper is organized as follows: ASysML based conceptual design method for MEMS is presented in Section 2. The implementation and simulation results of a high-resistivity silicon based patch antenna which is used as the RF front in a Beidou receiver are given in Section 3. Section 4 summarizes this method and describes the future works.

2. SYSML BASED CONCEPTUAL DESIGN FRAMEWORK FOR MEMS DESIGN

In this section, the SysML based conceptual design framework for MEMS is described in Figure 1. All the information illustrated below, is applied to elements of every level of abstraction. SysML has nine diagram types, each representing aspects of a system. These diagrams provide an efficient knowledge to engineering system and information intensive systems. With the SysML based information interaction, a MEMS product model is constructed by diagrams under this framework. According to product requirements, multidisciplinary views of
specifications about the MEMS product are figured out. The information transferred from computer aided design (CAD) tools to computer aided engineering (CAE) tools. This process helps to build a virtual prototyping in the stage of conceptual design. As supported by SysML based information interaction, virtual design guidelines abstracted from product requirement diagram are used to evaluate the initial design schemes.

2.1 Requirement Diagram

The package of requirement diagram is designed for creating hierarchy independent requirement groups. Figure 2 is the requirement diagram of a high-resistivity silicon based patch antenna which is used as the RF front in a Beidou receiver. It provides requirements, test standards, design and verify modeling objects. Requirement object contains a unique id, attribute values, unit et al. this diagram is flexible according to the MEMS product description. The antenna here should meet both mechanical and electrical properties.
2.2 Parametric Diagram

Parametric diagram is a detailed item derived from working structure block, so the design variables properties, constrain properties and potential object properties which will build the future optimization model are derived from part blocks and constrain blocks. In Figure 3 the parameters of the patch antenna are displayed as small rectangles on the blocks. Binding paths connected indicates that the parameters are the same. The constraint blocks are networked. In this diagram, the conceptual schemes computation results can be numeric simulated within a multidisciplinary optimization (MDO) framework.

Figure 3. Parametric diagram of patch antenna. Figure 4. Electrical performance of patch antenna.

Parametric diagram is an important factor because once the parameters in it have been configured, they need to be checked for the latter design process. The SysML based conceptual design modeling method in this paper is better than the previous paper based or documents centered methods, a preliminary check for consistency can be done in the early design stage. That is the parameters in patch antenna meet the needs of mechanical and electrical targets in the real working environment.

3. Results

The current proposed SysML based conceptual design framework provides general diagrams from MEMS product development. It represents the necessary factors in early stage of MEMS design which concerned both mechanical and electrical properties. This multidisciplinary design process is concerned with modeling, simulation and integration of different CAD and CAE tools, trading off design objective when search feasible region in design space. Here we adopt the finite element tools HFSS and ANSYS respectively to analyze the electrical
performance, thermal performance and mechanical performance. The design parameters of the patch antenna obtained after design iterations showed the results (Figure 4, Figure 5 and Figure 6) meet the initial requirement in Figure 2.

4. CONCLUSIONS

The work has shown SysML is suitable for MEMS concept design. Combined with capabilities for design methodology and system engineering, it provides a general base for integrated multidisciplinary product models. In this MEMS concept design framework, the SysML based design process for system level development of MEMS products illustrated benefit of model driven engineering through the information seamless transferred within SysML diagrams. For modeling the MEMS products, the integrated views of the system including detailed SysML based specification and analysis of multidisciplinary design have been constructed in MEMS.

Figure 5. Thermal performance of patch antenna. Figure 6. Mechanical performance of patch antenna.

Our method has also shown a case study of a high-resistivity silicon based patch antenna which is used as the RF front in a Beidou receiver, the mechanical and electrical performances have been achieved with less design iterations under this conceptual design framework. Additionally, this framework will help the designers to focus on key design functions according to requirements diagram during the system lifecycle. All relevant information of patch antenna in the presented modeling architecture can be conducted to the new design stages, even to a new project.

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REFERENCES


