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New Computational Mechanics for Ships and Offshore Engineering From Construction Stage to Structural Collapse Stage

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To assure the safety of large structures such as ships and offshore structures, it is important to clarify the entire process leading to the overall collapsing state of the structures. For this purpose, several computational methods are developed in the 2 main fields of mechanics with the aid of the finite element method (FEM): Computational Welding Mechanics for Construction Stage, and Computational Structural Mechanics for Ultimate Strength Analysis—ISUM (Idealized Structural Unit Method). These new computational methods form an essential basis for the idea of design by analysis and production planning based on computational simulation.

INTRODUCTION

This paper was prepared for the J. S. Chung Award Lecture for 2007. Since the award is presented for an outstanding creative and innovative contribution to the offshore, ocean and polar engineering fields, I would like to shine a light on these aspects of my research. Before I retired from research activities several years ago, I was engaged in research for more than 35 years, mainly on the development of computational mechanics based on the finite element method (FEM). The main purpose of my research was to clarify the mechanism for how steel structures sustain external loads until collapsing, and to provide proper information for rational structural design.

I initiated most of my original work with the aid of the computer in the late 1960s. At that time, computational science was far behind that of the present. During the time when I was engaged with research under those circumstances, its outputs had been completely new developments. As time passed, some of these have become standard theories and methods, but others need updating. This trend should be observed in every field of science, since the advance of the computer is so rapid. However, I believe that our research outputs have contributed to the development of the present-day computational mechanics with originality, creativity and innovative ideas. Then, for the title of the lecture, I dare to name it New Computational Mechanics.

As the pages allotted for the lecture are limited, I would like to use the pages not so much for explaining details of our achievement, but to give some inside stories relevant to our individual research work. We suggest that those readers who are interested in academic aspects refer to the original papers.

My experiences as expressed in the inside stories may evoke similar feelings among the seniors and/or may present some hints on future research activities for the younger people.

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BACKGROUND OF RESEARCH

My research interest has been the strength of steel structures such as ships and offshore structures, since I majored in naval architecture at Osaka University. For many years, ship structures were designed according to elastic analysis-oriented codes. A few decades ago, a trend arose toward more economical ships and offshore structures, and this demanded the application of higher allowable stresses together with lighter-gage structural components of high-strength materials. This trend made us pay serious attention to the issue of safety.

In order to guarantee the safety of ships and offshore structures, an important task in the design stage is how to define a structure's necessary strengths and the rigidities of the individual components. When a structure is subjected to increasing loads, local failures—such as local buckling, local yielding or even collapse of some component members, etc.—may take place. Such local failures cause reduction of stiffness of the concerned members. Changes in the relative stiffness of the members in the structure induce the redistribution of the internal forces. Progressively passing through such highly nonlinear processes, the structure finally attains its ultimate strength.

Regarding ship hull girders as a typical large steel structure, the first approximate solution to design limit strength may be the limit of the linear elastic response against the external loads, which may be local yielding or buckling. This may correspond to the yield bending moment or buckling moment, and it should be a lower bound of the actual capability of the ship. Next, the fully plastic moment may be evaluated by the plastic theory. This should be an upper bound of the capability. Before the actual ship reaches the fully plastic moment, local failures such as buckling and yielding of some members should have started. Then, in order to define the design limit strength, more realistic analysis should be performed, including the effects of local failures and collapse as closely as possible.

Although 40 years ago the elastic analysis-oriented design was still popular, I started to develop my design concept that the scantlings of individual structural members should be determined, ideally after their functions had been clarified, observing the entire process through to the overall collapsing state. In order to realize this concept, we needed new computational mechanics, which enable us to conduct ultimate strength analysis, taking into consideration local failures and influential factors such as welding the