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DESIGN AND MECHANICAL ENGINEERING: HOW GOOD IS THE LINK?

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1. Introduction

Unfortunately a large gap between designers and mechanical engineers still exists. Designers are concentrated on design aspects, while mechanical engineers are responsible for their professional duties only. This reduces the quality of final products. Designers pay a lot of attention to the appearance of product and innovations in its design, while the mechanical part suffers lack of consideration. The simplest examples of this are the mechanical failure as well as the use of too much material in the product, making it more expensive and less environmentally friendly. At the same time from the point of view of mechanical engineer the product should be as simple as possible to achieve a necessary reliability and strength. And this is often in contradiction with the design requirements and commercial attractiveness of product. In other words more attention should be paid to bring designers and mechanical engineers together. In order to achieve this more effort should be paid during the educational process. All aspects of product development should be mentioned to the students. While making nice sketches they should remember not only about a good appearance but also what is inside, what kind of problems can be expected when a detailed design will be in development.

It is evident that there are a lot of people working on improving of educational process professionally with a great effort. But in spite of this effort design mistakes still take place. More attention should be given to multidisciplinary and teamwork aspects. Absence of a good link between designers and mechanical engineers is just one of examples, which the author experiences by himself. But before starting discussions in this paper it is necessary to give some explanations why this paper appears and who the author is. The professional background of the author is mechanical engineering, or to be more precise, he is a mechanical engineer with marine specialization. The author believes that his fresh view on this problem as an outsider can generate new ideas and discussions. This paper reflects experience of a person, who often faces the lack of understanding between people of different specializations. The author hopes that this paper will find response of ordinary teachers, designers, and engineers.

2. Examples of fatal errors

Before going into details of the chosen subject it would be wise to see some examples of wrong design solutions, which potentially can cause disasters. The first example is from a ship design office. Once a person responsible for internal equipment suggested to cut through a web frame in order to place a pipe line (Figure 1). The whole web frame would be cut into two pieces loosing capacity to carry any load.

Another example is from one of students studying industrial design engineering. The subject was a design of windmill blade. The good performance of a windmill can be achieved if the windmill has long narrow blades. But at the same time it is very difficult to transport such long blade from the factory to the place of installation. So the student suggested a folding blade having a hinge in the middle (Figure 2). It should be mentioned that the structure of typical windmill blade is highly loaded.

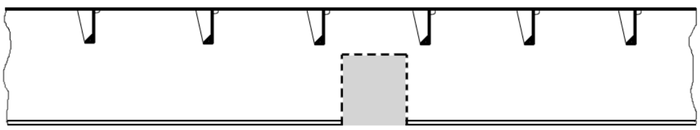


Figure 1. Cutting through a web frame

The design of blade should be highly optimized in order to make the blade light and strong enough at the same time. Of course in case of application of a hinge in the middle of the blade it would not be possible to deal with strength requirements. When the student was asked what the design solution is going to be to provide enough structural strength, he had no idea about this.

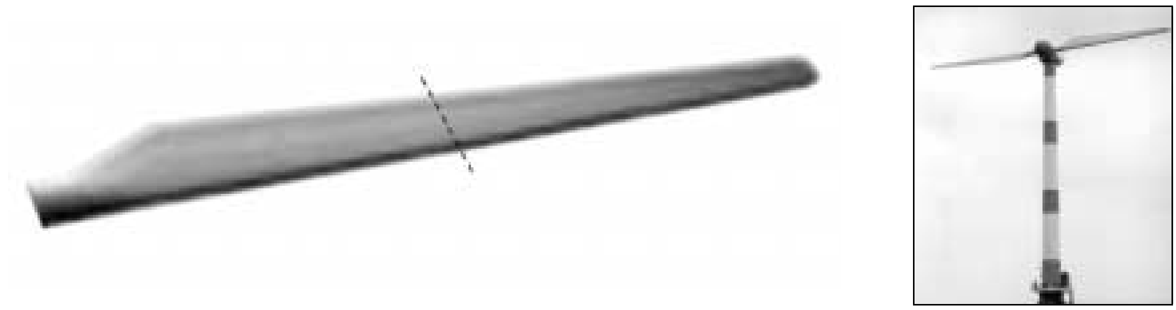


Figure 2. Blade of windmill

There is one more example from a ship design office. An engineer responsible for the structural design received drawings of a yacht. He had to design the structure of the yacht’s hull choosing proper stiffeners. When he saw the drawings he found that there was not enough space left for the stiffeners (Figure 3). The yacht was perfectly designed with respect to the living space and furniture but nobody thought about the primary structure. As soon as the internal arrangements could not be changed much there was only one solution left. The structural engineer had to put very wide heavy beams instead of for instance standard “T”- profiles. It was a considerable waste of material causing increase of the structural weight and hence the costs.

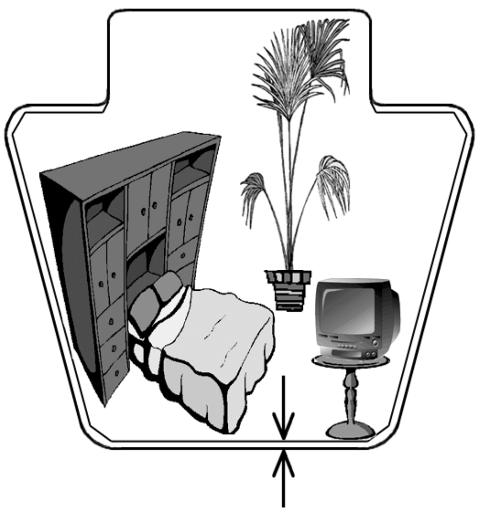


Figure 3. Cross-section of yacht (not enough space left for stiffeners)

It is clear from these examples that design mistakes can be catastrophic. On the other hand without innovative solutions and crazy ideas there would not be any progress. New design ideas require new mechanical solutions. It is always a lot of contradictions in the design process. A compromise has to be found. In order to do that it is necessary to bring people working on different parts of project together. It is extremely important to give all of them more global knowledge about this project in general. Each person involved, whoever he is: designer, mechanical engineer, electrician, etc, should be aware of business of others. He should not be concentrated on his professional duty only. And this is the goal, which should be achieved in the educational process, when a basic knowledge of a new specialist is formed. Certainly this is a very broad area for research and work to be done. So the next chapter of this paper will deal with just one of possible components of the design process. Mechanical analysis is chosen as a subject of discussion. The author has quite advanced experience in this area and he hopes that his remarks and recommendations will be useful.

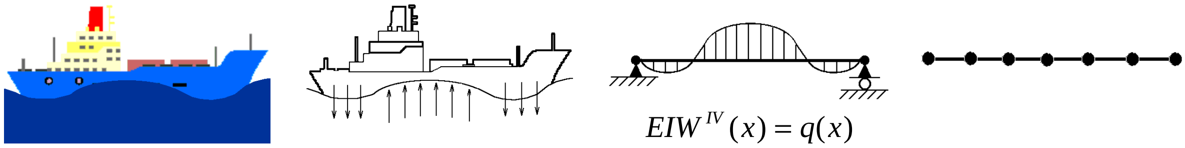
3. Analysis

One of the most important parts of design process is to predict how the new product is going to work when it is manufactured. Here we often use analysis. It helps us to investigate if this design is properly done and what is its performance. Analysis can answer a lot of questions. It can help to optimize and improve the product. It can prevent mistakes in design. But all this can be done only if the analysis is properly performed.

A simple problem from applied mechanics is considered here. Analysis of a ship hull is discussed. The overall ship girder strength is the subject of consideration. The primary goal is to make a correct design of the ship girder. Ship must be strong enough and light at the same time.

It is a long distance between a real object and its final model. Four most important parts can be marked (Figure 4):

1. Real object: Ship in waves is subjected to the gravity force and the varying buoyancy, which causes the bending moment.
2. Physical model: Ship is considered as a rigid body under the gravity force and the distributed supporting force.
3. Mathematical model: Ship is considered as a beam under distributed force, differential equation describes bending of the beam.
4. Numerical model Finite element analysis is applied in order to find the beam response.



Ship in waves Physical model Mathematical model Numerical model

Figure 4. Analysis: from a real object to a simplified model

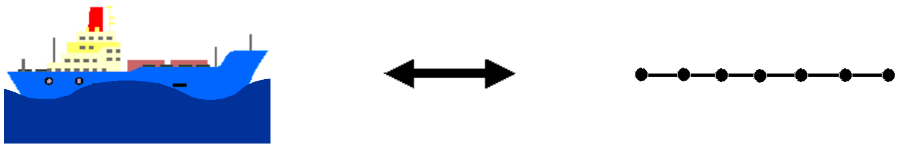
In order to perform analysis three steps are required:

Step 1: From a real object to a physical model.
This is the most difficult step. Most of mistakes are made here. Creating the physical model of real phenomenon requires philosophical thinking, good experience and intuition.

Step 2: From the physical model to a mathematical model.
As soon as the physical model is completed a mathematic approach has to be found. Usually there are a lot of mathematical models, which are already available. So it is very important to make a correct choice of the most suitable one. But sometimes the mathematical model does not exist yet. Then a new model has to be created.

Step 3: From the mathematical model to a numerical model.
In practice only very simple mathematical problems can be solved directly and analytical solutions can be found. More often the problem is quite complicated. And the only one way to solve it is a numerical approach.

Figure 5 shows that the distance between the real object and the final model is really big. A lot of mistakes can be made on this long way. Only careful treatment of each of the steps can give reliable results.



Ship in waves Numerical model

Figure 5. The distance is big

4. Finite element analysis

Fast increase of computing power today makes numerical tools very attractive in the design process. Many students choose finite element analysis (FEA) at the latest stage of the design process in order to perform the verification analysis or to improve the product design. This choice becomes more and more popular nowadays. Designers take FEA software and try to apply it to their products. What happens then? Majority of FEA software packages are becoming quite user-friendly. Sometimes FEA is just a part of an advanced design software package. And this is a very good development today. But a complicated theory is hidden behind. Often FEA software does not give any warning if the model is incorrect. Wrong results can be obtained. In order to make a proper FEA model an advanced knowledge is still required. To show this let us consider a very simple example.
One of the students was trying to find an error in his FEA model without any success for a month. It was a 2D problem of heat transfer. The results showed a rough change of temperature in the area where it should not be expected. Later on it was found that the refined mesh was not connected with the mesh, which was less dense (Figure 6). Mistake of this type could possibly appear because of one reason only: the student had no idea about the finite element analysis. This trivial mistake is as old as the finite element analysis. But what is important that this kind of mistakes still takes place and something should be done to prevent this.

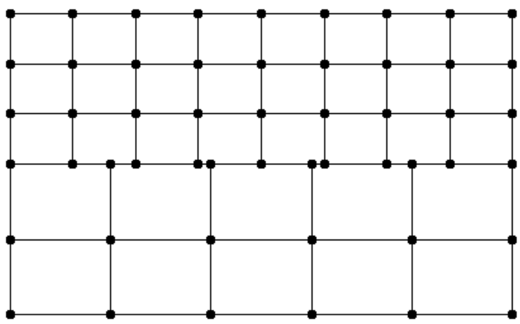
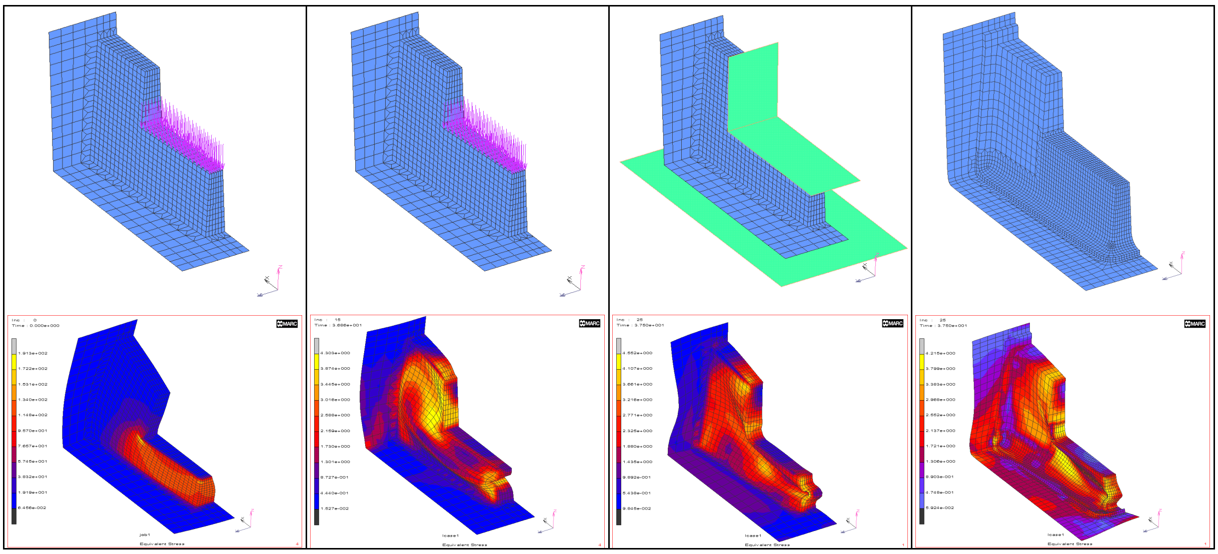


Figure 6. Wrong FEA mesh (elements are not connected)

The primary rule in FEA (probably analysis in general) is to make the model step by step starting from a very simple one and then adding more details in it. It can be easily demonstrated by the following example. Mechanical properties of a packaging system made of paper for transportation of video tape recorder are the subject of consideration [Bereznitski 1998a and 1998b]. A simplified analysis of one of the stiffeners of this packaging system was performed. The shock absorption performance was studied. The work started with a series of tests, where the stiffener was slowly loaded and the compression force was recorded (Figure 7). Then a numerical verification took place (Figure 8).
First, a very simple static model was built. Then a quasi-static problem was solved taking into account non-linear geometrical behaviour of the stiffener (large displacements) as well as non-linear material properties (elastic-plastic curve with work hardening instead of ideal-elastic material for the static model). The third model included a contact option since a contact boundary condition took place in the tests.

Figure 7. Packaging system and test setup

These models had a quite coarse mesh. It reduced the computing time, which was very helpful at these first stages of model development, when many runs were necessary. As soon as the model gave stable results the mesh was refined giving more accurate results. The goal was achieved. Results of numerical analysis showed a good agreement with the experimental data. The numerical tools were verified. Further improvement of the product became possible through numerical analysis.



Static Quasi-static Quasi-static & contact Precise geometry

Figure 8. FEA: from a simple model to a more complicated one

This example shows how simple it is to make a complicated model if the analysis starts with a simple model. Unfortunately this approach is not very common. The modern FEA software has so many possibilities and options that it is very difficult to resist including everything at once in the first model or a very heavy mesh is generated at the first stage of analysis taking a lot of computing resources. What happens then? Very often the analysis just crashes. And this is not so bad since it makes us think that there is something wrong with the model. But if the analysis is completed, what results we obtain? It is very important to explain in the educational process how to make simple models and how to verify the results. A complicated model can not be built at once. It is long process of trials and errors, checks and double checks. And our task is to deliver this to the students.

5. Design engineering and mechanical engineering together

Design of modern products, which have to be competitive in the market, is a great challenge. The time period between the market demands a new product and this product should appear in the shop is very short today. Only the united effort of people carrying extensive knowledge and skills in multiple disciplines will lead to design of high quality products. This united effort can be achieved through further improvement of the educational process. And the first priority here is to give students the global overview of different subjects involved in their design. These subjects put together form the final product. Besides the students have to become aware of the interaction between these subjects. A person responsible for one part of the design process should realize what kind of difficulties the others can face. It is clear that nobody can be an expert in everything. But the interaction and the healthy exchange of information between the people are the only solution. Establishment of good communication between designers and mechanical engineers is one of the key necessities. And this paper considers this particular case just as an example.

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