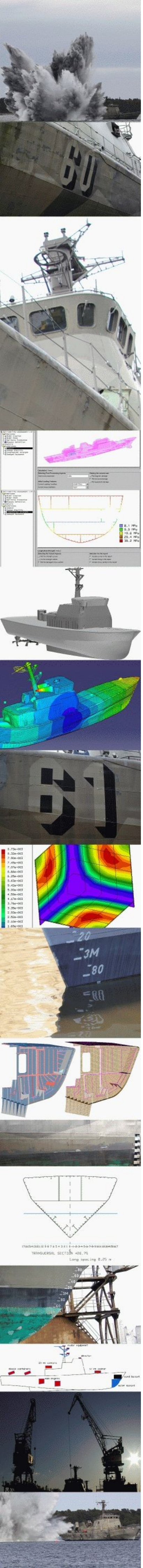

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Signature Assessment as an Integral Part of Navy Ship Design Process

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Abstract

Different signature aspects are considered to be important features when new navy combatants are designed and procured. The traditional methods to assess different signature related phenomena are very time consuming and the manual work required to build up the computer models exposes the process to errors. Separate assessment of each different signature type is also frustrating when the design changes during the ship design process.

With examples of above surface radar signatures and underwater electromagnetic signatures, this paper is an introduction to how ship designers can get information related to signature levels. This also ensures that the designers can be aware of the effects the design modifications have on the signature levels. This integration is achieved utilizing a common ship design product model which serves as an information source to all signature assessments.

Now all the assessments related to different signature phenomena can be rather quickly assessed and the certainty that they represent the same design is guaranteed. Avoiding unnecessary modeling work the signature experts can concentrate on the real issues.

Background

As a natural continuation to the series of papers presented in MAST conferences by members of Surma personnel this paper widens the scope of utilization of the one model concept introduced before. Previously the main focus has been in the vulnerability assessment. Now another crucial aspect of comprehensive survivability assessment, namely susceptibility, can also be evaluated using information derived from the design model.

As an introduction to our one model concept it is recommended to go through the paper presented in MAST Americas 2010 "COTS Ship Product Model as a Backbone of Modern Naval Design Process" and "A Modern Product Model as a Simulation Integration Platform".

Traditional Methods

Currently most of the assessments related to susceptibility or signatures in general require a lot of labor when each of the different phenomena, RCS, IR, EM or acoustics, just to name a few, are analyzed using separate computer models. These processes lead to two main obstacles that inhibit the information from being efficiently usable in modern ship design process -

1. The results from these analyzes come usually in months rather than days. This kind of time span is too long for a normal iterative ship design process.
2. Due to the complexity of these phenomena the interpretation of the results requires an expert of each field and the designers cannot really benefit or learn that much from the assessment data.

Integration into Design Process

To enable a successful and efficient integration of signature assessment into design process it is necessary to eliminate the above mentioned problems of the traditional methods. In other words it is mandatory to reduce the turn-around time of the analyzes and also to receive the results in such a form that a designer working on the ship project can effectively use them to improve the design. Both of these goals can be achieved by tuning the working methods towards the one model concept.

The time consumed for analyzes can be reduced enormously by automatizing the model creation for the analysis software. Currently a noticeable amount of the working time in analysis process is taken by the building and maintaining these computer models. Depending on the signature phenomena at hand, this can take up to more than half of the actual working hours per assessment. Automation can be achieved by creating interfaces from the design software to the analysis software. In many cases this is quite an easy task to complete keeping in mind that most of the design software have various output formats and usually the analysis software support some ascii formatted input.

An alternative method to make the assessment process faster for the designers is to simplify the assessment calculations. In many cases, the analysis tools have been created to support a scientific approach and the detailed research of the phenomena. This approach is good in cases when exact results are needed. However, the requirements from ship designers' perspective are more or less different. Quite often just a sophisticated indication of whether one solution is better than another is sufficient, and usually the exact level of signatures sensed from all directions is not necessary. This means that if the results are accurate enough with a faster analysis code, this serves the design purposes better.

To make sure that the designers can improve their design after getting the results, the produced analysis reports must be short and easy to comprehend. If the designer can get just a few values - for example, the maximum level of a certain signature or the level of a signature detected from a specified sector - then it is much easier to aim at lowering these values and improving the overall design signature-wise.

Radar Cross Section Calculation

As an example of the above surface signatures, RCS is selected for introducing the solutions aiming to integrate the signature assessments into the design process.

Besides eyesight, the usage of radar is one of the most traditional methods to gain information on the marine traffic. Even nowadays it still is the most common method to control the traffic at seas. In almost all the coastal area the traffic is observed with land, air and sea based radar stations. As remaining undetected is the main purpose of signature reduction the minimization of radar cross section has also been one of the most utilized methods when controlling the signature levels. The design variables aiming towards lower radar cross section levels are usually the outer geometric shape and selection of absorbent surface materials.

Current methods

There are numerous approaches and methods in use world wide. Most of the navies use their in-house tools, or ones developed with other governmental institutes, which they rely on. Generally these tools have also gone through a thorough validation process. Unfortunately most of these applications, as well as many other software assessing any of the signature related features, require their own computer models, which are created only for this specific purpose. This means that as such, they can hardly serve the rapidly evolving design process. Fortunately however, most of these tools can read in some sort of ascii or some other format geometry file and more than this, most of the software also can read the definitions of surface materials from these import files.

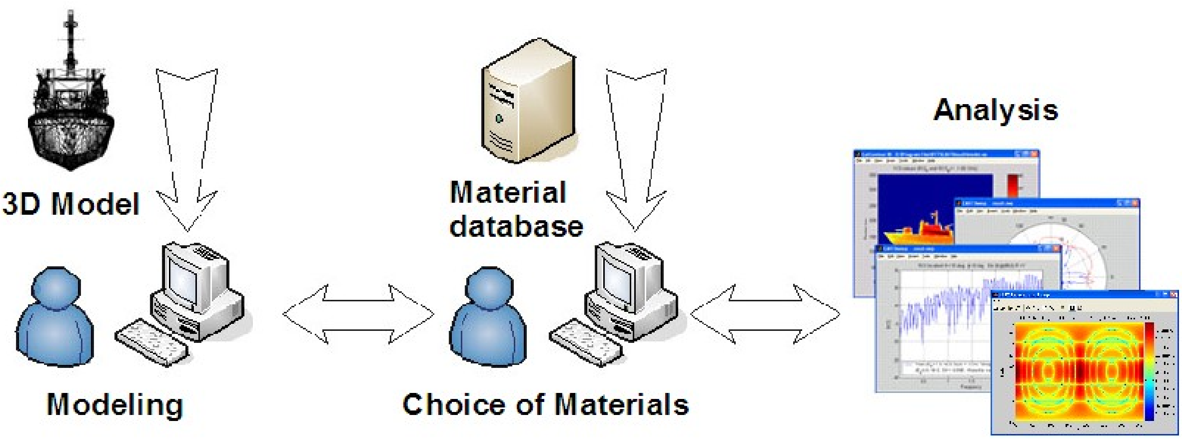

Figure 1: RCS analysis process

One model approach

For the RCS calculations, the Finnish Navy is using a software tool called CAST. The algorithms this software use are developed at VTT, The Technical Research Centre of Finland. These algorithms utilize Antenna Theory applied to Physical Optics (APO) in combination with the Physical Theory of Diffraction (PTD) to predict the radar cross section. The method takes into account multiple reflections and material properties. Like many other similar applications, it can also import models from triangulated geometry files containing the material properties as well.

There is an existing interface from a well known ship design software to this analysis tool. By using this interface in the design process it is really easy to get an analysis of the influence of any change to the outer geometry of the ship. Also the usage of absorbing materials in the outer surfaces can be optimized – yielding trade offs like added weight versus the amount of gained radar camouflage.

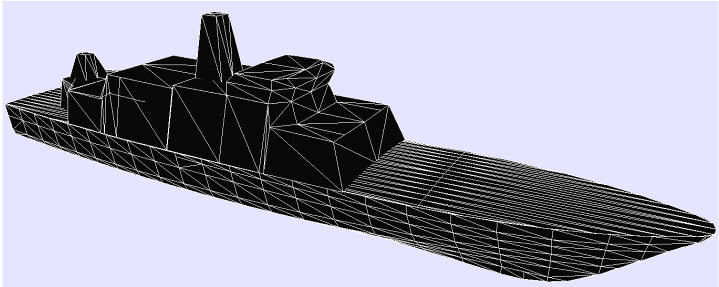

Figure 2: FAC Hamina-class triangulated model imported to CAST

Advantages

To support the designers in fast evolving iterative design project, the analysis results can be made short and clear by stripping the non-relevant detailed information out of the report. For example, to keep some desired stealth level it can be agreed for example that an index presenting the total radar signature level is calculated by the analysis software by weighting different angles and wavelengths and summing up the results to form a single value. This way the designer is able to check that any change made to the outer geometry stays below the required acceptance criteria.

Electromagnetic Signatures

In this paper, ferromagnetic signatures are selected as an example of under water signatures.

When a ship constructed of steel or other ferromagnetic material is moving on the surface or under water, by its very nature, it develops a detectable local disturbance in the earth’s magnetic field. This disturbance can be sensed with underwater sensors attached to a surveillance or mine warfare system. The initial magnetic signature of a ship can be reduced by means of degaussing; for example, by generating a counteracting magnetic field of suitable strength and direction based on measured data of the magnetic properties of the vessel.

Preliminary Analysis

A good estimation of the magnetic signature levels caused by the ship in design can be calculated with a rather simple method where the main source for the ship's magnetic signature, the hull, is treated as a longitudinal series of magnetic dipoles. The results can be made more accurate by adding the effect of larger system main components, such as main and auxiliary engines, gears, axles and armament to the hull dipoles.

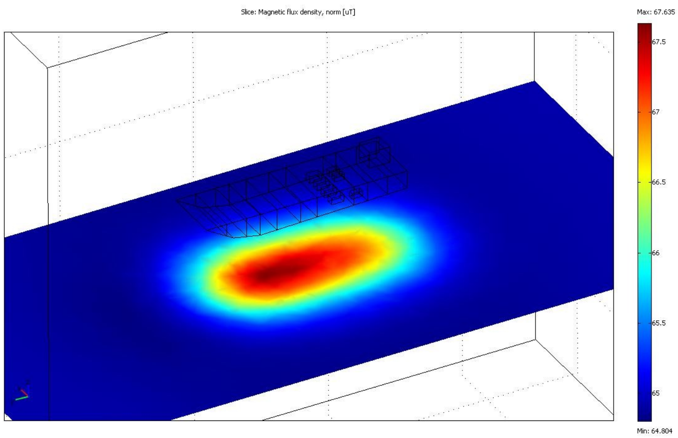

Figure 3: Magnetic signature of a simplified model

The estimation process for the magnetic signature is based on the magnetostatic scattering theory. In case of a steel hull vessel, the hull itself is treated as the scatterer, enclosing and partially shielding the shipboard magnetic units and components inside it. In case of a non-magnetic hull, each of the individual ferromagnetic component is modeled separately as a dipole source, located in their exact positions in the ship geometry.

For this assessment all the geometric and material parameter values can be fetched easily from a modern design product model the design being in such a phase that some kind of structural model has been already created. For example, the hull can be divided into a number of longitudinal blocks or sections and the parameters for each of the dipoles can be calculated from the model. After this the calculation of the signature levels caused by this "set of dipoles" model is rather a straightforward process. When using this kind of approach one has to keep in mind that the results are not good when the assessment is done too close below the keel.

For preliminary analysis and for comparing design alternatives, the relatively simple method described above has proven to be efficient. The acceptance criteria can be boiled down to a single number, the maximum scalar value of the predicted signature below keel in some predefined depth.

Detailed Analysis

For further analysis, to assess the ship in detail or construction design phases, it is often necessary to get a more detailed calculation, for example, to determine the exact positions and sizes of required degaussing loops. This can be done using a more advanced analysis tools available in the scientific software market. These tools typically have a finite element method (FEM) approach for solving physical problems. Defining and solving a physics problem with the FEM tools require the following steps:

- defining the problem with partial differential equation(s)
- defining the boundary values, both internal and external boundaries
- defining the problem geometry
- creating the finite element mesh (discretization)
- solving the problem iteratively in the mesh node points

In the FE analysis of the magnetostatic scattering problem for the ship, the scalar and vector potentials defining the magnetic field can be solved from the FE model, The ship's magnetic signature or more precisely, the magnetic flux density outside the ship hull, can be derived from these potentials. The external boundary values are used to define the primary earth magnetic field, and the distribution of ferromagnetic material is defined in the mesh geometry.

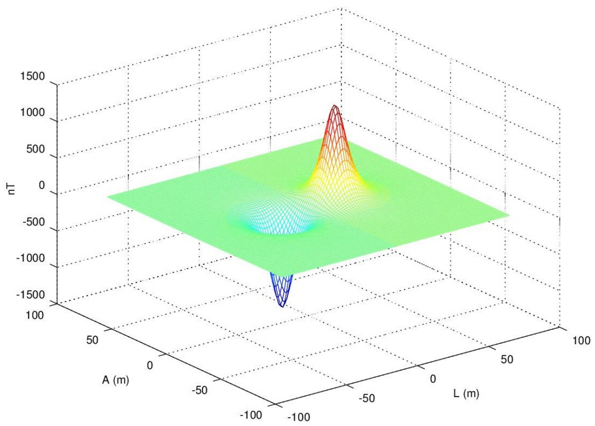

Figure 4: Magnetic signature level at a given depth

For this the information can also be fetched from the design model. For example the hull structure, with geometry and material parameters, is outputted as a face mesh and the system components are outputted as volume mesh. In the calculation the surrounding medium, the sea, is also modeled as volume. An example of this kind of link between the ship design model and a commercially available multiphysics FEM solver is created in Finnish defense industry's common research project Smulan.

Conclusions

As emphasized with the presented examples, the utilization of the described one model concept in navy ship design process gives many benefits, such as reduced design hours, decreased risk of errors in the analysis, but also the possibility to get all the aspects related to comprehensive combat survivability assessment integrated into actual ship design process. When this becomes a natural and truly integrated part of the process, it really is easier and more practical to end up with better design yielding increased safety level and enhanced mission performance capability.

There are several benefits an organization working with novel naval ship designs can get by the use of the design model they anyway need to create during the ship project. As shown, this model can also aid when aiming for a comprehensive survivability assessment - signature evaluation included. The one model concept can be realized in practice and this philosophy is already in use in SURMA software. For further information regarding SURMA, please visit our website survivability.fi.