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Modeling of Combined Phenomena Affecting an AUV Stealth Vehicle

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ABSTRACT: In the paper some results of research connected with modeling the basic stealth characteristics of an AUV vehicle are presented. First of all a general approach to design of the stealth AUV autonomous underwater vehicles under consideration is introduced. Then the AUV stealth vehicle concept is briefly described. Next a method of modeling of the stealth characteristics is briefly described. As an example of the stealth characteristics investigations some results of modeling the boundary layer and wake are presented. Some remarks regarding the behavior of the AUV stealth vehicle in the submerged conditions are given. The final conclusions are presented.

1 INTRODUCTION

Despite of the number and types of navy ships each of EU key navies should have a set of unmanned surface (USV - Unmanned Surface Vehicle) and underwater (UUV - Unmanned Underwater Vehicle) vehicles for the different missions to perform. Some of the vehicles should be partially or fully autonomous (AUV - Autonomous Underwater Vehicle).

The last decade it was the time when the research investigations towards implementing a new generation of the multi-task small navy ships and unmanned USV and UUV vehicles has been conducted. The small multi-task navy ships despite the patrol and typical combat missions may be the platforms for the unmanned air and maritime vehicles.

The discussion how many small multi-task navy ships and unmanned maritime vehicles of which type a navy needs seems to be over. The research teams are ready to implement the chosen solutions concerning both the small multi-task navy ships and USV, UUV and ASV vehicles.

Concerning the USV, UUV and ASV vehicles they may perform the typical patrol, reconnaissance or combat missions. Depending on the mission the vehicles may be equipped with either the sophisticated reconnaissance electromagnetic, hydro acoustic and IT-based equipment or conventional arms. The most advanced vehicles may be equipped with the small fast underwater missiles (Gerigk, 2014).

2 A STEALTH AUV VEHICLE CONCEPT

The primary aim of the research is to work out a functional model of the stealth AUV vehicle moving in the data operational conditions.

The novel solutions have been applied regarding so far the hull form, arrangement of internal spaces, materials and propulsion system. The final hull form is a combined stealth hull form. The arrangement of internal spaces has been designed according to the functional requirements and is very much affected by the sub-systems to be installed onboard.

The major sub-systems of the stealth AUV vehicle are as follows (Gerigk, 2015; Gerigk, 2016):
- ballast sub-system,
- energy supply sub-system (batteries),
- water-jet propulsion sub-system,
- T-foil stabilizing sub-system,
- steering sub-system,
- communication and navigation sub-system.
- dedicated sub-system.

The main parameters of the stealth AUV vehicle are as follows (Gerigk, 2015; Gerigk, 2016):
- overall length L - is equal to 2.2 meters (4.4 meters for the larger stealth AUV vehicle (LS-AUV)),
- operational breadth B - is equal to 1.1 meters (2.2 meters for LS-AUV) without the additional equipment and appendages,
- height H - is equal to 0.35 meters (0.70 meters for LS-AUV) without the additional equipment and appendages,
- mass is equal to from 0.38 tons to 0.65 tons, depending on the mass of equipment installed onboard,
- averaged speed during the underwater mission for the submerged conditions (3 meters) v_{uw} - is equal to 1.0-2.0 meters per second.

The general visualizations of the hull form and arrangement of internal spaces of the stealth AUV vehicle are presented in Figure 1.

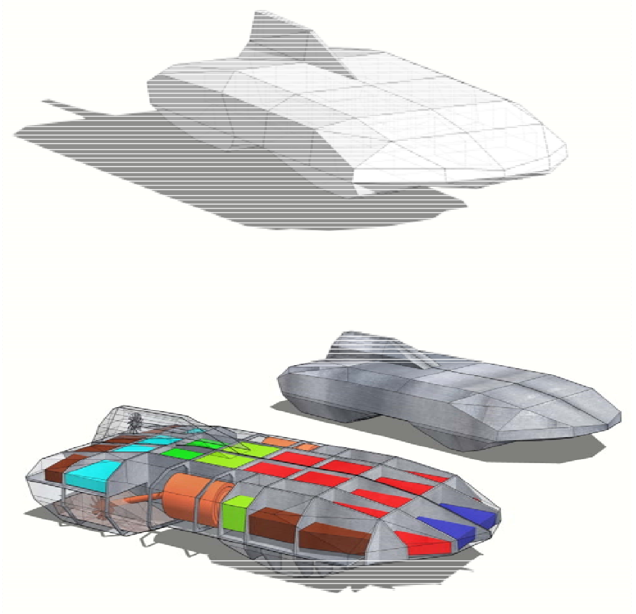

Figure 1. The general visualizations of the hull form and arrangement of internal spaces of the stealth AUV vehicle (Gerigk, 2014-2016).

3 THE STEALTH CHARACTERISTICS

The new Polish solutions concerning the unmanned maritime vehicles (USV, UUV, ASV) have been worked out at the Gdańsk University of Technology by the team conducted by the author. The team work is devoted to the interdisciplinary research and application of advanced technologies. Some implementations concern development of innovative small multi-task navy ships and unmanned maritime vehicles (mainly UUV and ASV) (Gerigk, 2015; Gerigk, 2016).

The most innovative concept of the unmanned maritime vehicle work worked out by the author is the concept of the stealth triple-state FIST-RP vehicle. According to the opinion of the experts this vehicle seems to be between the most advanced and innovative special task unmanned maritime vehicles. The concept is still under development form the research and design point of view. The visualization of the stealth triple-state FIST-RP vehicle is presented in Figure 2.

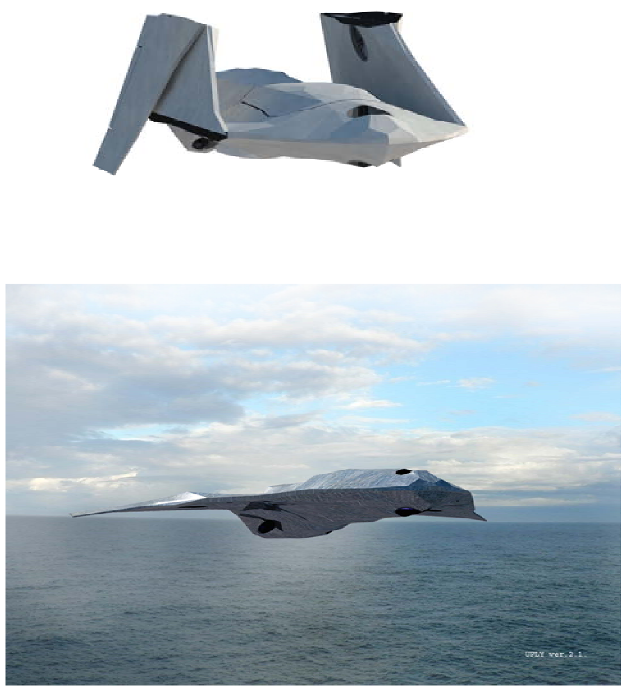

Figure 2. The visualization of the stealth triple-state FIST-RP vehicle (Gerigk, 2012-2016).

The latest research and design concerns the stealth AUV vehicle. The research is sponsored by the National Centre for Research and Development (NCBiR) (Gerigk, 2015; Gerigk, 2016) .

Intelligent and autonomous stealth AUV. Despite of the mission the stealth AUV vehicles should be applied with the coded communication and navigation subsystems to operate the vehicles above the water surface, on the water surface and under the water surface. The vehicles should be equipped with the energy supply subsystem (batteries) to perform up to several hours missions with the possibility to upload the batters using the submerged energy loading stands. According to the performed tasks some vehicles should be equipped with the autonomous intelligent (AI - Artificial Intelligence) steering and vehicle positioning subsystems enabling to use the data obtained from the vehicle sensor subsystems. The most advanced stealth AUV vehicles would be those which could independently communicate with the other vehicles (USV, UUV, ASV) and make decisions on their own .

Silent and invisible stealth AUV. Despite the above mentioned features the most important for the AUV vehicles is to design and manufactured using the most advanced STEALT technologies. Nowadays, "stealth" does not only mean to avoid and/or absorb the radar radiation by the unique hull form and/or hull skin cover. "Stealth" concerns the propulsion system. The stealth AUV vehicles should be equipped with the silent both the electric engines and jet propellers. The noise and vibrations generated by a vehicle should on the lowest possible level. The subsystems and construction of the stealth AUV vehicle should protect the emission of heat. Moving under the water surface the stealth AUV vehicle should generate a small value boundary layer and wake to limit its own acoustic signal. This is why the innovative hull skin covers are of great importance.

A research is conduced to find a cover to make the hull skin invisible.

"Stealth" means to limit the probability to detect the AUV vehicle as much as possible using the well known and hardly known methods and means of reconnaissance.

The current investigations on the stealth technologies towards their application onboard the AUV vehicles are associated with the following problems:
– size and vehicle hull form,
– hull skin covers,
– minimizing the noise, vibrations and heat factors and impacts,
– minimizing own electromagnetic and acoustic signals,
– avoiding and absorbing the outside electromagnetic and acoustic signals,
– maximizing the invisibility.

4 A PERFORMANCE-ORIENTED RISK-BASED METHOD OF MODELING THE STEALTH CHARACTERISTICS

The research method for modeling the stealth characteristics, assessment of the stealth AUV vehicle performance and risk assessment is a kind of performance-oriented risk-based method which enables to assess the above mentioned at the design stage and in operation (Gerigk, 2010). The method takes into account the influence of design and operational factors on the performance and safety of the stealth AUV vehicle including many factors following from different sources. The holistic approach and system approach to safety have been applied.

For assessment of the stealth AUV vehicle performance the investigations using the physical models and computer simulation techniques have been applied. The performance assessment of the stealth AUV vehicle enables to identify the operational sequence of events for the conditions very close to reality (Gerigk, 2015; Gerigk, 2016: Gerigk, Wójtowicz, Zawistowski, 2015; Gerigk, Wójtowicz, 2015).

The risk assessment is based on application of the matrix type risk model which is prepared in such a way that it enables to consider almost all the scenarios of events. The criteria is to achieve an adequate level of risk using the risk acceptance criteria, risk matrix, (Gerigk, 2010). Providing a sufficient level of safety based on the risk assessment is the main objective. It is either the design, operational or organizational objective. Safety is the design objective between the other objectives. The measure of safety of the stealth AUV vehicle is the risk (level of risk).

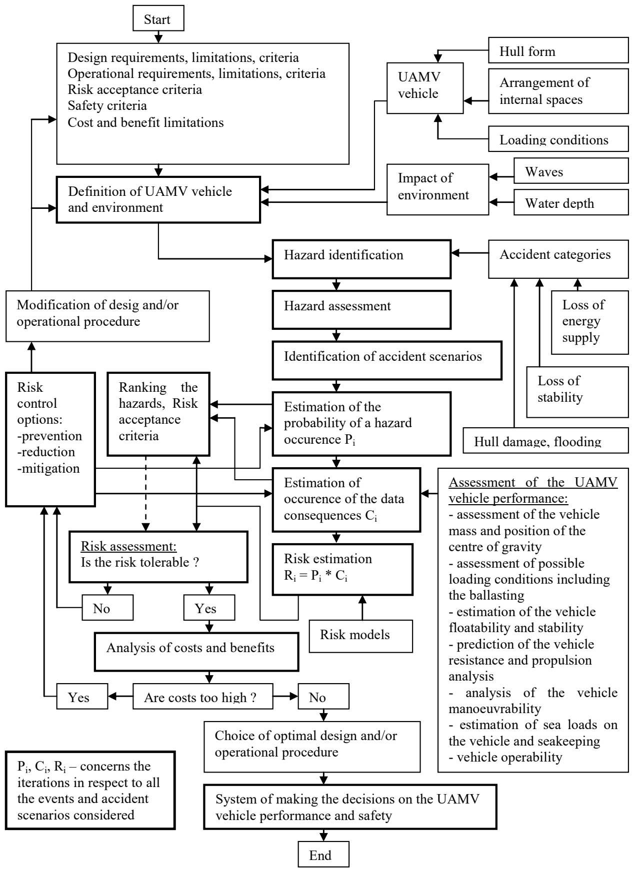

Figure 3. A Structure of the method for assessment of the UAMV vehicle performance and risk assessment (Gerigk, 2014-2016).

The method itself is based on the following main steps:
– setting the requirements, criteria, limitations, safety objectives;
– defining the stealth AUV vehicle and operational environment;
– identifying the hazards and identifying the sequences of events (scenarios);
– assessing the stealth AUV vehicle performance;
– estimating the risk according to the event tree analysis ETA and matrix type risk model (risk is estimated separately for each scenario development);
– assessing the risk according to the risk acceptance criteria (risk matrix) and safety objectives;
– managing the risk according to the risk control options;
– selecting the design (or operational procedure) that meet the requirements, criteria, limitations, safety objectives;
– optimizing the design (or operational procedure);
– making the decisions on safety.

The structure of the method which combines the typical design/operational procedures with the risk assessment techniques is presented in Figure 3 (AUVSI/ONR, 2007; Abramowicz-Gerigk, Burciu, 2014; Cwojdziński, Gerigk, 2014; Dudziak, 2008; Faltinsen, 1990; Faltinsen, 2005; Gerigk, 2010; Gerigk, 2015; Lamb, 2003; Szulist, Gerigk, 2015).

5 AN EXAMPLE OF INVESTIGATIONS OF THE STEALTH CHARACTERISTICS

As an example of investigations concerning predicting the influence of a stealth characteristic on the stealth AUV vehicle performance the impact of different hull skin covers (generated during the computer simulation) on the flow (boundary layer and wake) around the stealth AUV vehicle has been modeled.

During the computer simulation the mesh consisted of 3 275 000 elements. The numerical domain had the size (Kardaś, Tiutiurski, Gerigk, 2016):

5 meters x 1.5 meters x 1.2 meters (1)

and it is presented in Figure 4.

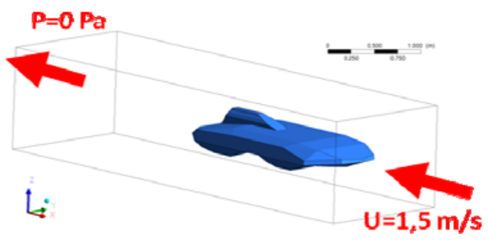

Figure 4. A visualization of the numerical domain for simulating the impact of different hull skin covers on the flow around the stealth AUV vehicle.

The water flow velocity was anticipated to be from 0.5 meters per second to 2.5 meters per second with the step 0.5 meters per second.

During the computer simulation the hull skin cover was generated by the skin roughness as follows:
– Ra 80 - as a normal steel plate surface,
– Ra 1.25 - as a slightly polished steel plate surface,
– Ra 0.01 - as a polished steel plate surface,
– Ra 0.0025 - extremely polished steel plate surface (nano-surface).

The flow was estimated for example 0.5 meters, 1.0 meters, 1.5 meters and 2.0 meters behind the stealth AUV vehicle. Some results of the flow estimation for the data skin roughness and velocity are presented in Figure 5 (Kardaś, Tiutiurski, Gerigk, 2016).

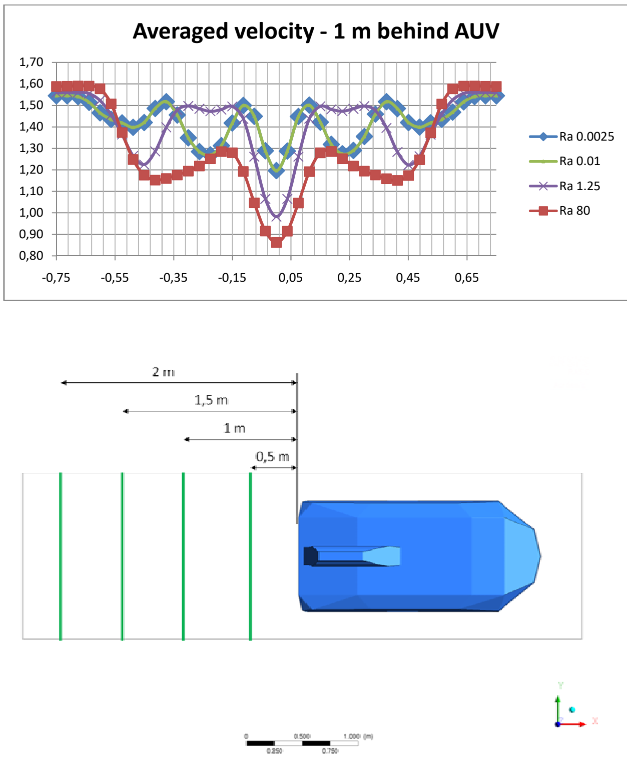

Figure 5. Some results of the impact of different hull skin covers on the flow behind the stealth AUV vehicle for the data skin roughness and flow velocity.

6 CONCLUSIONS

In the paper some results connected with development of a functional model of the stealth AUV vehicle are presented.

Some data on the stealth AUV vehicle concept, major stealth characteristics, performance-oriented risk-based method of modelling the stealth characteristics are described in the paper.

As an example some results concerning predicting the influence of the different hull skin covers (generated during the computer simulation) on the boundary layer and wake are presented in the paper.

At the current stage of research an influence of combined stealth characteristics on the stealth AUV vehicle performance is investigated.

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