Experimental analysis of using cavitation to treat ballast water

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Why ballast water?

- Target - to obtain similar nautical conditions for vessel during its voyage.
- Answer – ballast water - cheap, easy to load and unload, no storage areas - water can be taken directly from harbor .

Ballast water – unexpected problems

- Pollution which can be transported by ballast water can have significant impact on environmental and all aspects of human life.
- By transportation ballast water during long trips of vessels, an unwanted spieces can be easily transported to new areas. It can lead to destroy natural balance in environments.

Ballast water – treatment methods

- Changing ballast water during voyage;
- Heating ballast water;
- Screens and filter;
- Electromagnetic radiation;
- Chemicals.

The cavitation phenomenon

- Cavitation is a very complex process of changing stadium by water – from liquid to vapor.
- This process can occur in temperature 273 – 300 K when the pressure of water decreases significantly.
- During this phenomenon, a volume of water goes from liquid to gas in short time.

The cavitation phenomenon

- There is a big difference between pressure in gas bubbles and water, in addition values of pressure can changes rapidly.
- Gas bubbles are unsteady – time of their duration is short, pressure changes rapidly and process of collapsing can lead to destroy elements of networks, propellers and pumps.

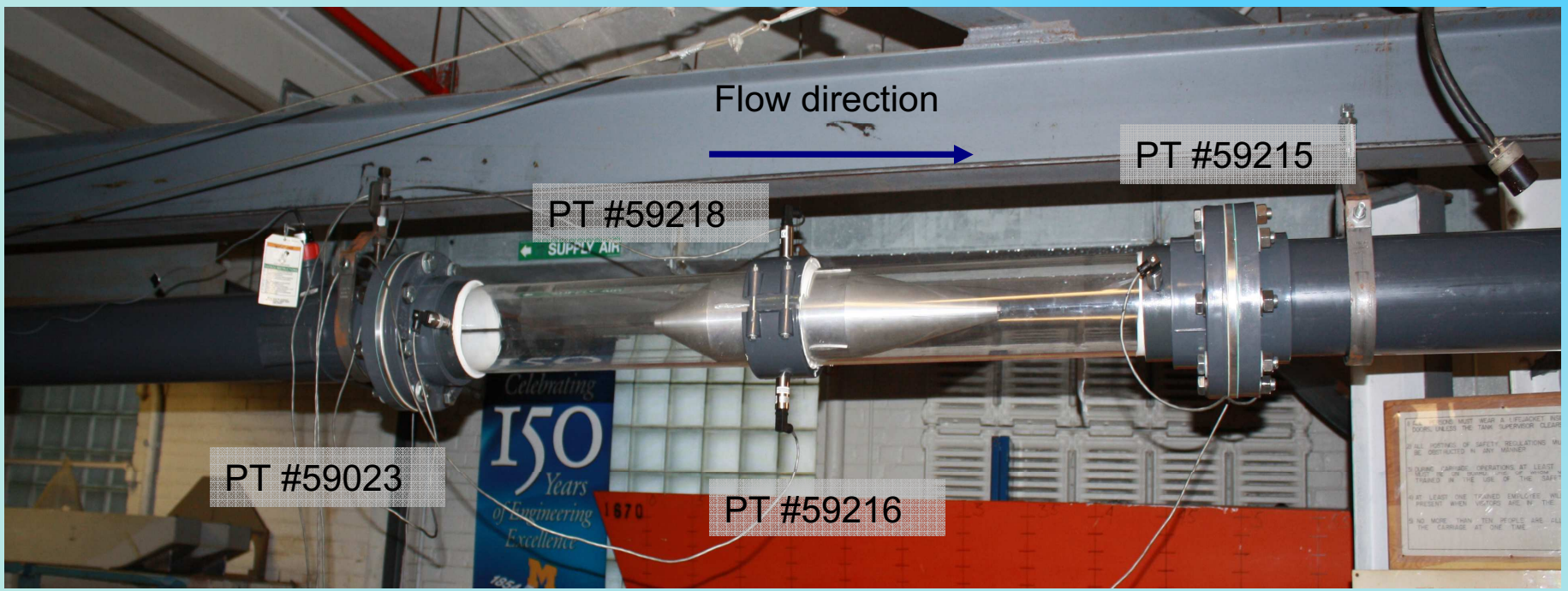
Idea

- The rapidly changes of pressure can be dangerous for organisms in water – the main aim of research is to answer how significant is impact of cavitation on organisms.

Model

- A model consists of pump (Goulds i9136), pipes (5.625” internal diameter), valves, pressures transducers and speed meter was build in Marine HydroLab, NA&ME, The University of Michigan

Model

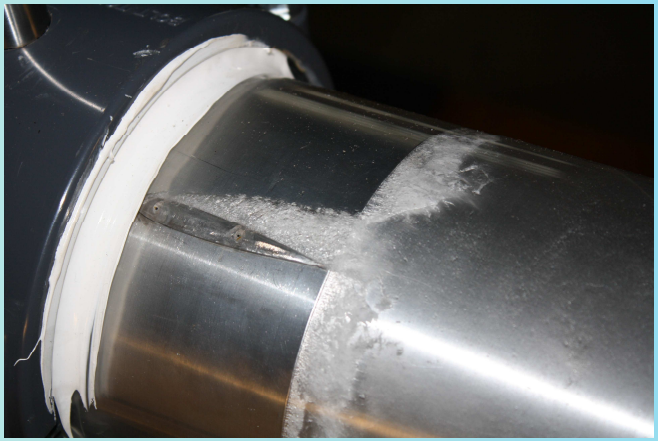


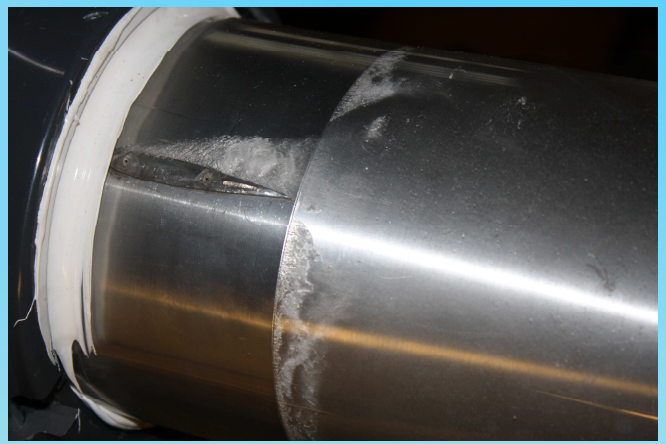
- Cavitation set

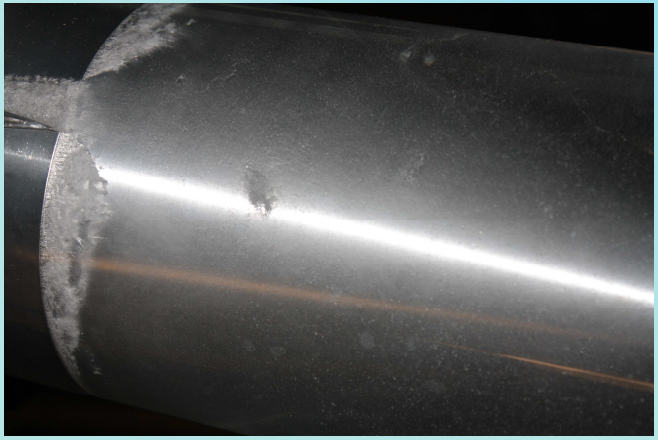
Experiments

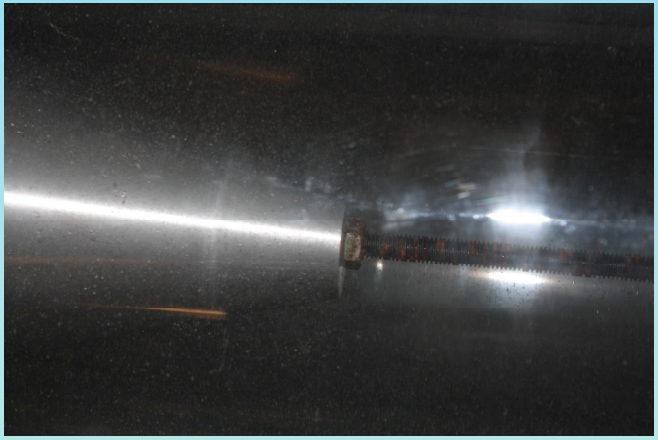
- Experiments were made in two steps
  - First step – analysis of conditions of cavitation in horizontal and vertical pipeline
  - Second step – analysis of cavitation's influence on microorganisms in water

Experiments –cavitation zone

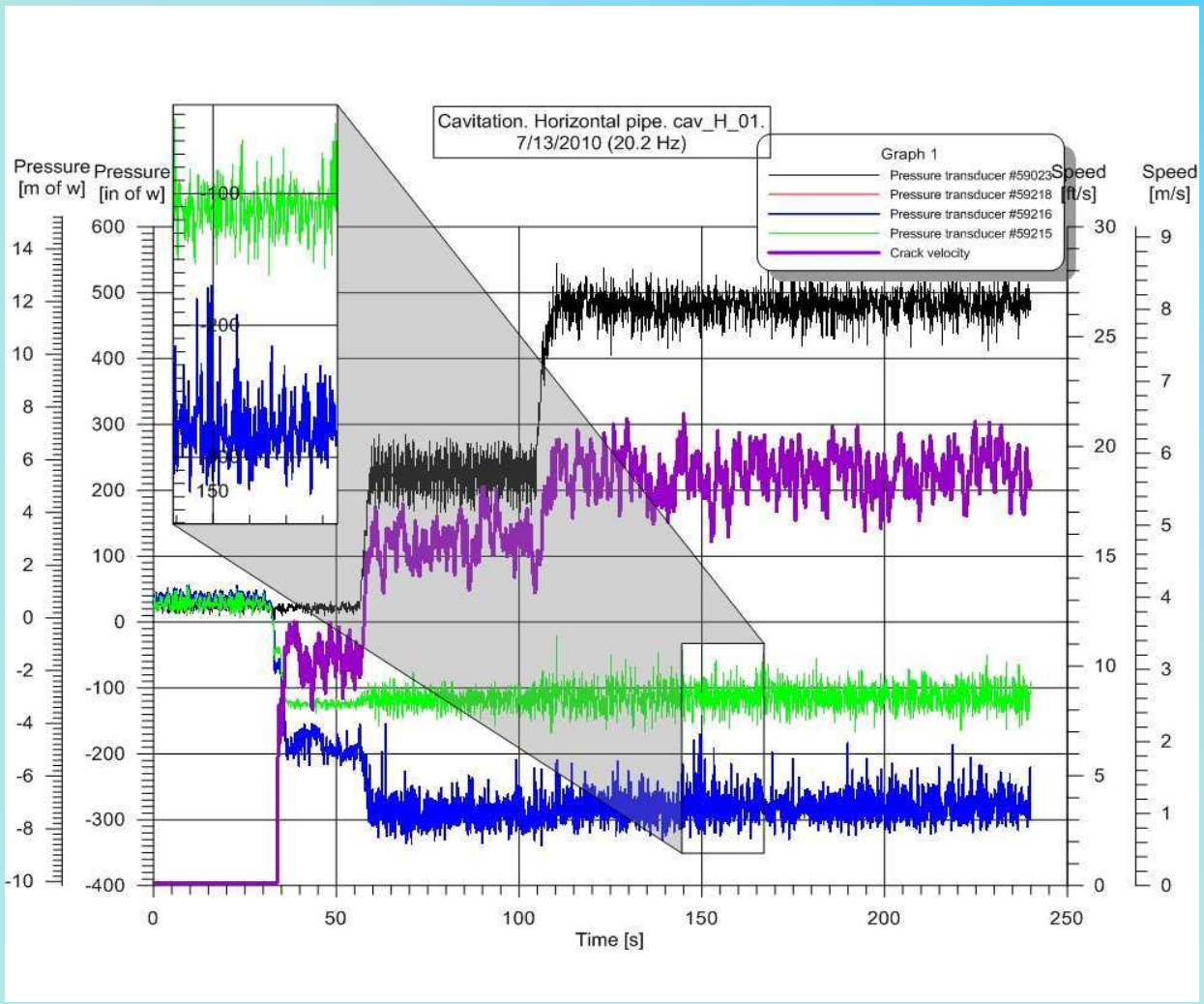








Experiments – pressure transducers in cavitation zone



Field's tests

Field's tests were made in Muskegon from 8/03/2010 to 8/05/2010.

Experiments were made on shore of Muskegon Channel that connects Muskegon Lake and Michigan Lake.

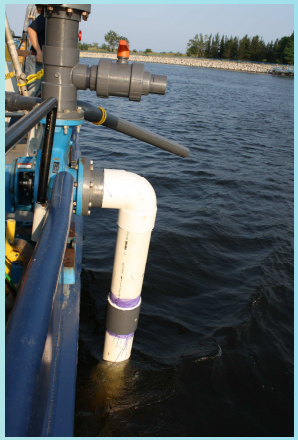
The model was installed on board of a vessel, and experiments were made on ship.

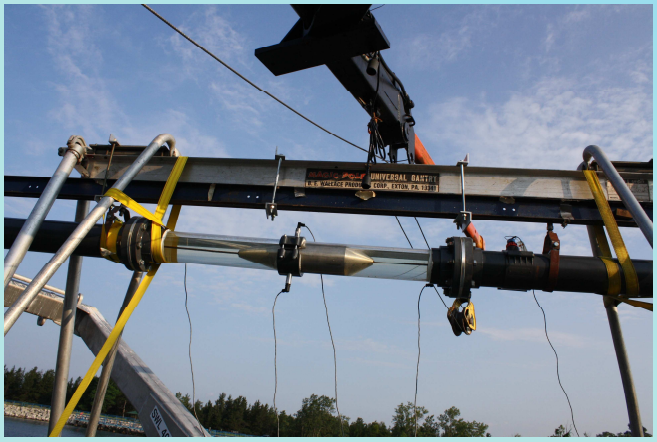
Field's tests – first stage

Field's tests – on the ship

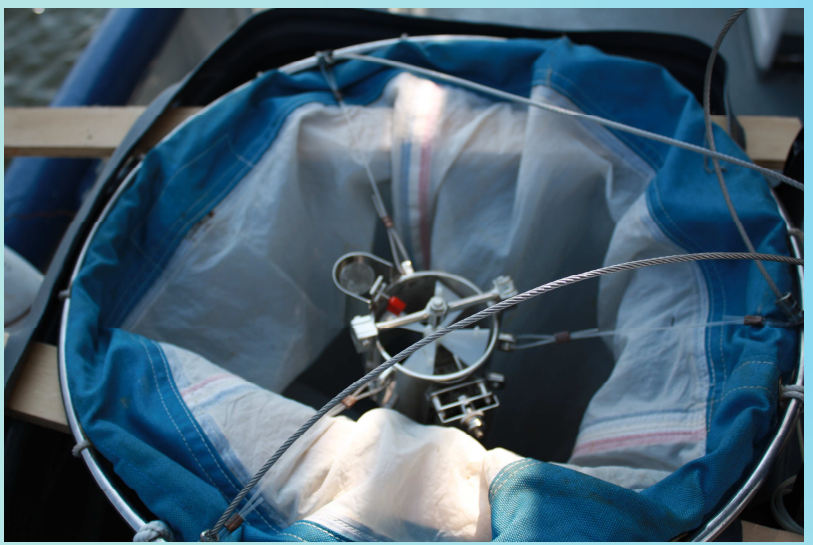
- Cavitation model on the ship

Field's tests – on the ship





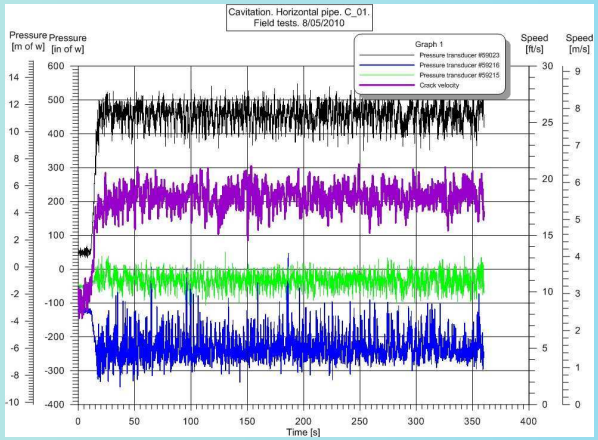
Field's tests - experiments

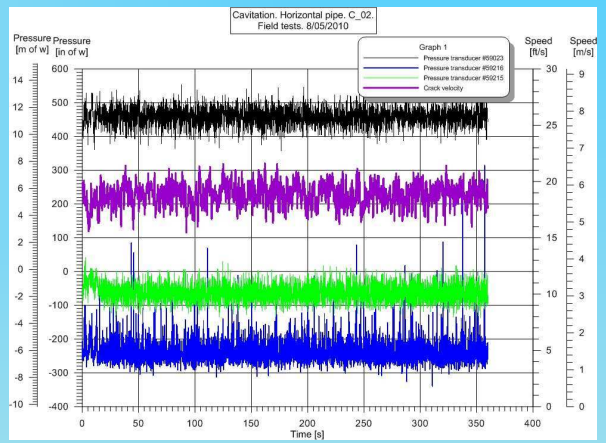


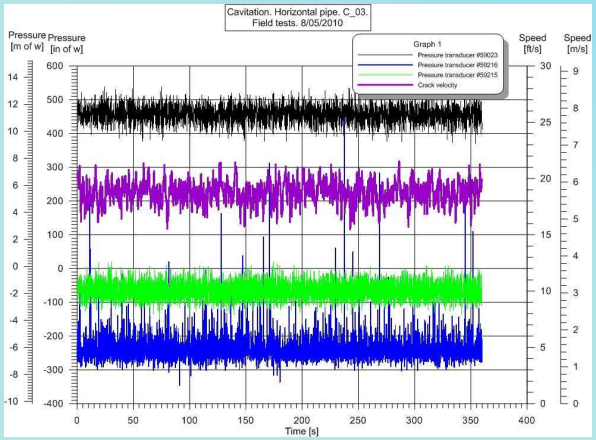
- Biological investigation – zooplankton screen and filter

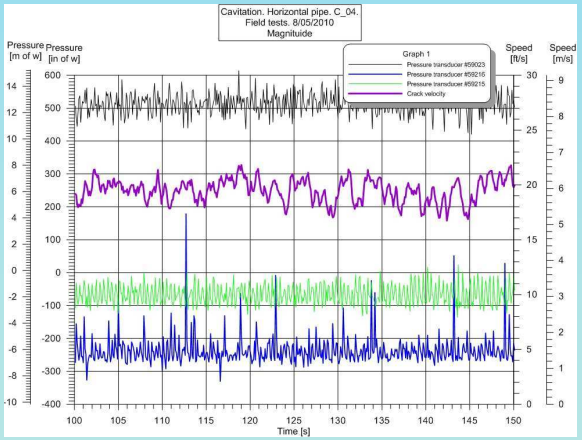
Field's tests - cavitation

Field's tests - cavitation

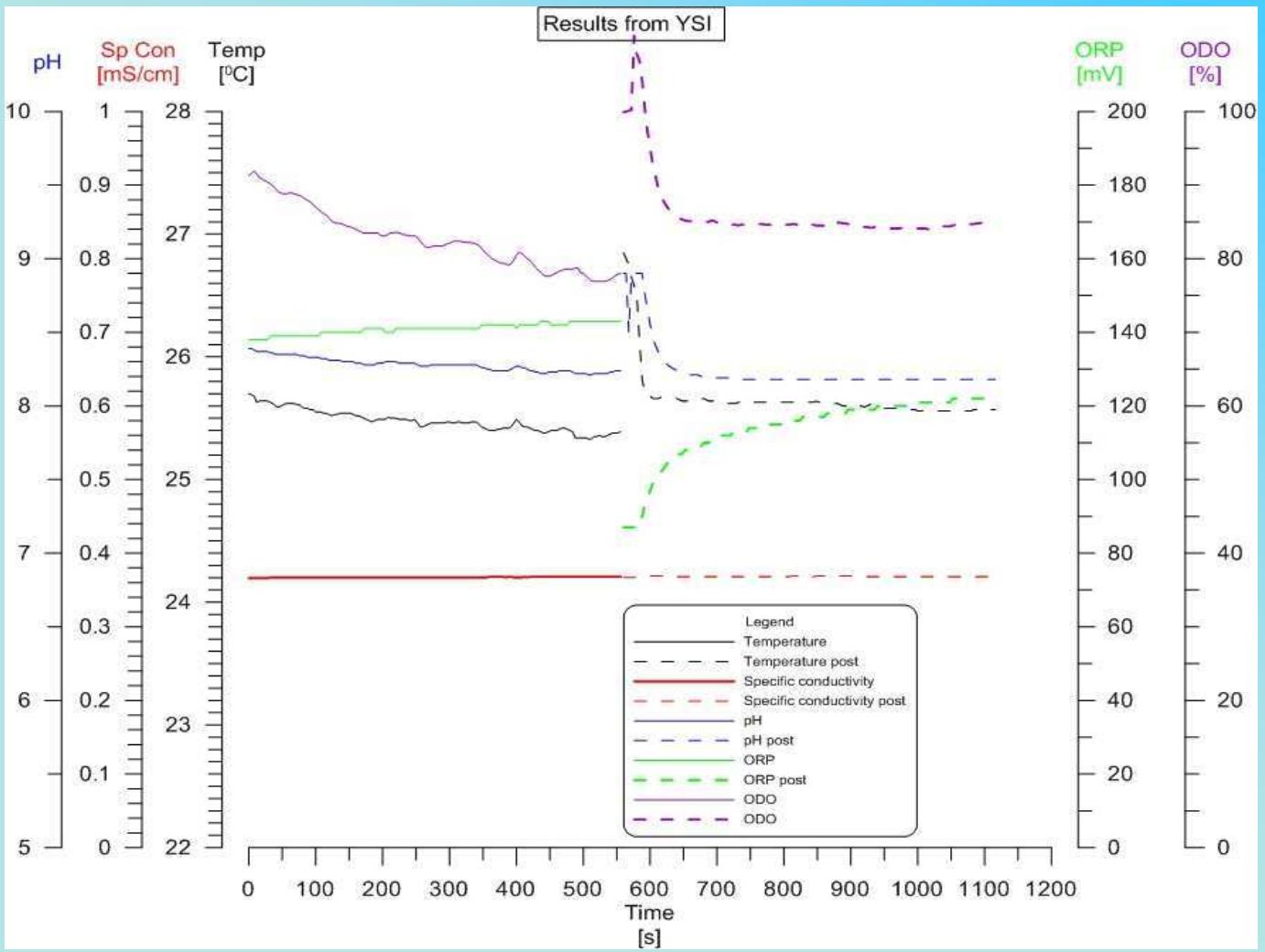








Field's tests – YSI data



Field's tests – YSI data

- Temperature
  - there is a small increase of temperature (initially 1.2^0C, then approx 0.2^0C)
- Specific Conductivity
  - There is no influence a cavitation phenomenon on specific conductivity
- pH
  - In the first phase there is an increase of pH, however there is a time of equipment stabilization, then the value of pH is similar like before the cavitation phenomenon

Field's tests – YSI data

- ORP
  - There is a significant decrease of value – from approx 140 mV before cavitation to initially 90 mV, then value of ORP increases during time to level approx 120 mV.
  - Oxidation reduction potential – there is a measure of tendency of a chemical species to acquire electrons and thereby be reduced.
- ODO
  - There is increase of ODO – from 75% before cavitation to approx 85% after cavitation.
  - Oxygen saturation – relative measure of the amount of oxygen dissolved in the water.

Conclusions

- After analyzing samples collected during the field tests, high efficiency of using cavitation to eliminate microorganism was confirmed. The result of 80% destroyed species after one stage of cavitation is very promising. Next experiments and analysis are necessary to improve the method and to design a prototype of ballast water treatment system by using cavitation.
- In addition, a very interesting phenomenon of changing values of ORP and ODO was observed, which is a proof of efficient mixing water during cavitation process and should be tested in next steps.

Thank you for your attention