Galvanic corrosion simulation of ball intake valve

Task Force Tips is a manufacturer of firefighting equipment in USA. The reliability of the equipment is very crucial especially in those applications where the equipment is not frequently used. In any case, corrosion is not allowed.

The model studied here is the Ball Intake Valve commonly used on fire engines to control the flow of water into the pump. The valve's lightweight aluminum design has proven ideal for use on mobile equipment. The valve consists of 3 different metals. A patented waterway system drains off the water in the assembly after operation to minimize the corrosion risk.

Fig 1- ball intake valve (courtesy of TFT)

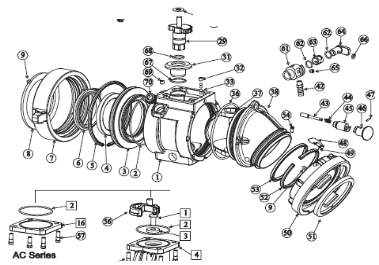


Fig2- material composition of the assembly

In practice, however, the Ball Intake Valve can be connected to iron or brass couplings and can remain completely filled with salt water. Put it all together and galvanic corrosion can be a problem!

GalvanicMaster Technology

The risk of galvanic corrosion is predicted by Elsyca's GalvanicMaster software. An FEA (Finite Element Analysis) method is employed to solve the fundamental electrochemical equations that govern the corrosion phenomena. GalvanicMaster consists of following components:

- Pre-processor
  - Generic and flexible CAD-import tool (STL-based)
  - Automatic high quality surface mesh
  - Automated polarization curve selection
- Solver
  - Robust and fast
  - Supports multi-body configurations and external current sources
- Post-processing
  - Fully automated and configurable reporting
  - Powerful visualization tool available throughout the organization

The software uses a new and unique thin film approach comprising an analysis based on a constant film thickness and constant conductivity and a potential method approach that models the gradient of the electrolyte potential in relation to the distance to the surface. The software calculates the overlap between thin films on different bodies to ensure ion transfer between neighbouring bodies with overlapping films.

The aim of this study is to predict the galvanic corrosion behaviour of the ball intake valve in respectively tap water and seawater.

Step-by-step modeling

CAD-import

In a first step a 3D-CAD model is loaded in GalvanicMaster. The user selects the different components and defines the materials to it. Each material group has its own colour attributed to keep a clear overview. The total surface area for each group is listed as a reference. In this case the assembly contains 5 different metals (iron and brass included) and several insulating gaskets.

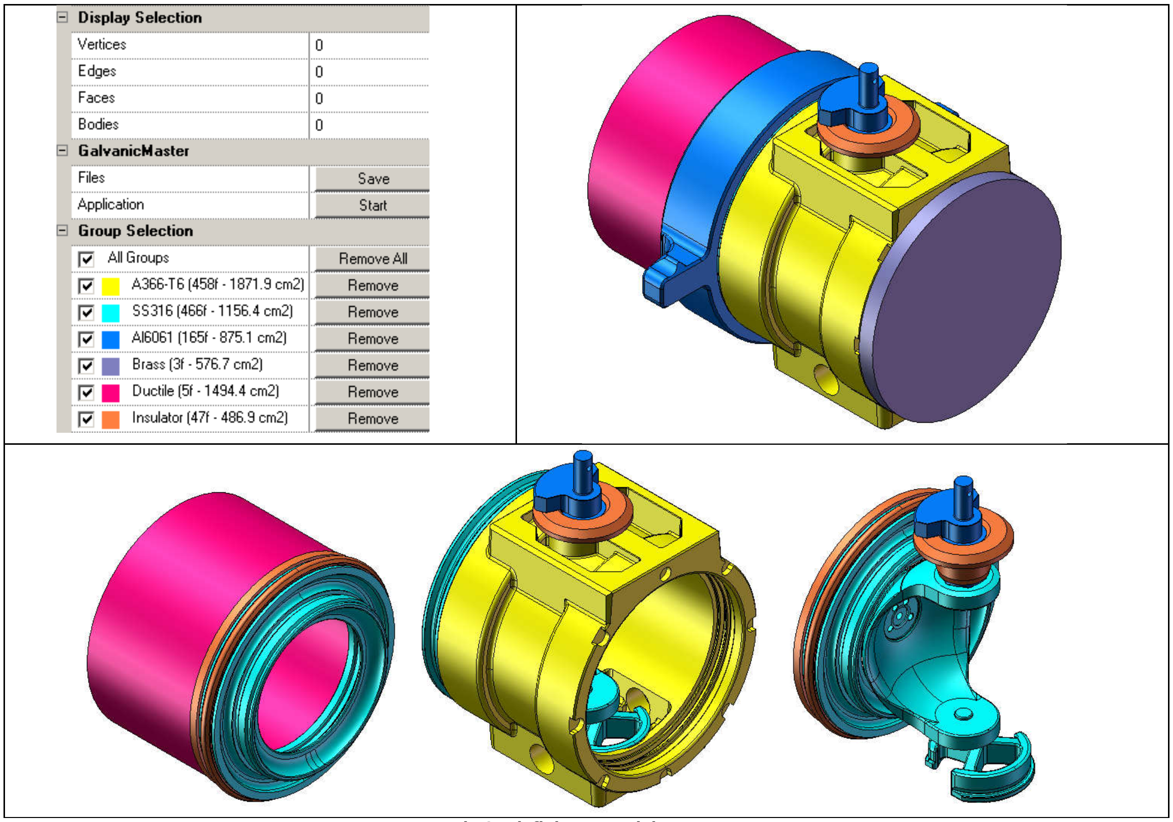


Fig 3 - defining material groups

Defining boundary conditions

In a second step the boundary conditions need to be entered. A simple input wizard guides the user through the different steps. In a first tap the environmental characteristics and electrolyte properties are defined. For this specific test case a film conductivity of 0.12 and 4.36 S/m was measured in respectively tap and seawater. The thin film thickness is taken to be 1 mm (1000 microns) for both electrolytes.

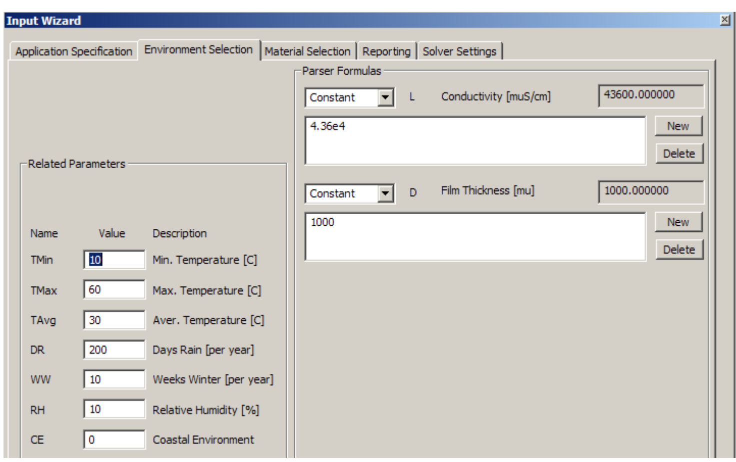


Fig 4 – electrolyte characteristics and environmental conditions

Each metal has specific polarization behaviour in the electrolyte of concern. The polarization behaviour is measured by conventional electrochemical techniques like linear sweep voltammetry or stepwise potentiostatic method. In a second tap of the input wizard the polarization behaviour for each metal is selected from a database of polarization curves. For this study the polarization data were measured in Elsyca's electrochemical laboratory in respectively tap water and artificial seawater at 30°C.

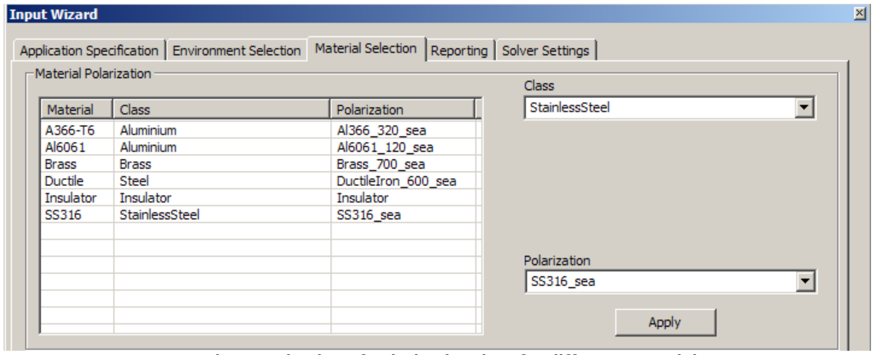


Fig 5 – selection of polarization data for different materials

Launching the solver

Before the calculation starts, a high quality mesh is automatically generated based on the input STL files. This allows increasing the accuracy of results significantly, even in confined areas. The user can adapt

GalvanicMaster solves the electrochemical equations subjected to the boundary conditions established by the materials, the model and the environment. Simulation takes only a few minutes.

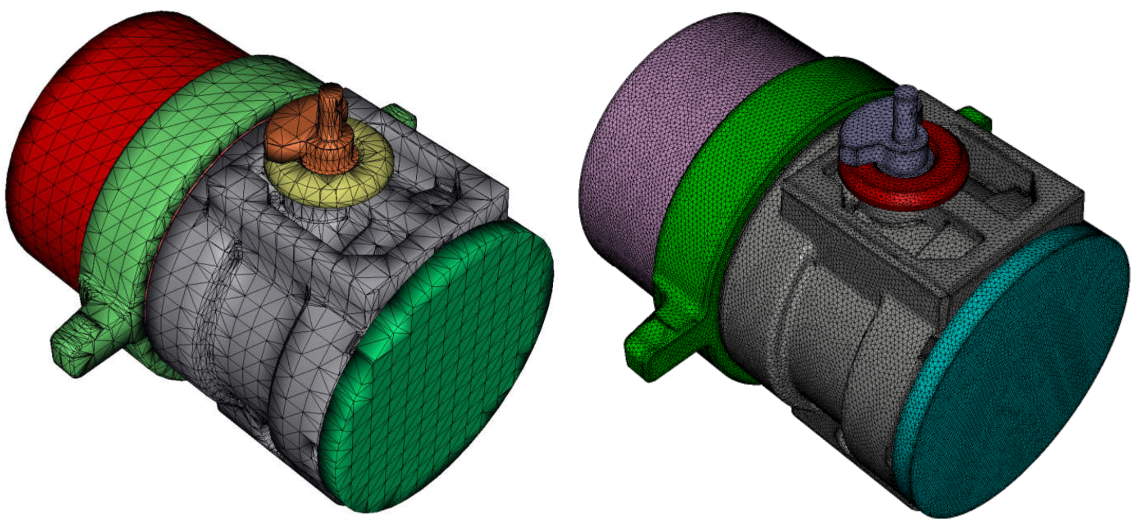
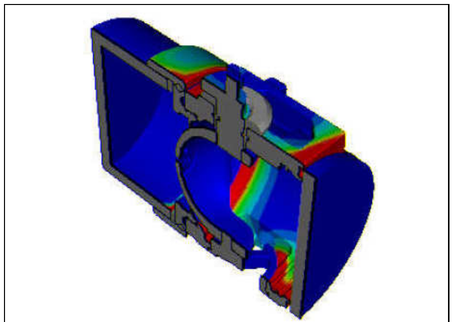


Fig 6 – re-meshing of STL files to high quality surface mesh

Analyzing results

GalvanicMaster generates a report for each simulation run. The report contains many colour plots and tables that illustrate the corrosion behaviour of each component. The major parameters like e.g. current density and corrosion rate are given for the different components in the assembly. The galvanic corrosion behaviour in tap and seawater are easily compared and the results can be shared within the organization.



Material	Maximum [um/year]	Average [um/year]	Maximum Allowed [um/year]	Exeeds Limit?
AL1	461.09	181.99	200.00	Yes
AL2	672.43	173.93	200.00	Yes
AL3	653.13	164.39	200.00	Yes
Brass	0.00	0.00	200.00	No
Stainless Steel1	0.00	0.00	200.00	No
Stainless Steel2	0.00	0.00	200.00	No
Stainless Steel3	0.00	0.00	200.00	No
Steel	2861.43	43.46	200.00	Yes

Fig 7 – reporting corrosion rates

Moreover, the simulation results can be analysed with Elsyca's XPlorer 3D visualization software. This dynamic tool allows exploring the assembly into detail. In Figure 8 the brass cap has been removed to look "inside" the model. The largest corrosion rates can be found on the valve body where the aluminum is in contact with the brass and on the tip of the upper trunnion where aluminum is close to stainless steel of the valve ball.

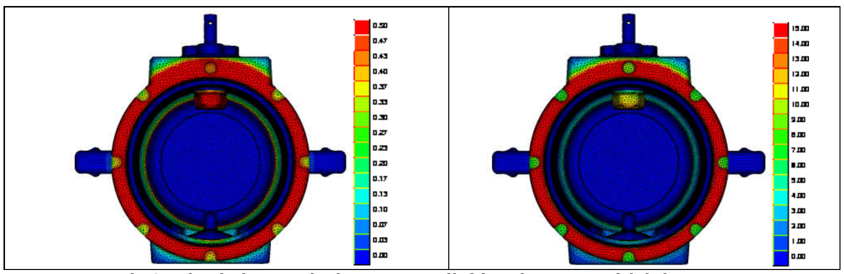


Fig 8 - simulation results in tap water (left) and seawater (right)

The simulation results have been compared with corroding equipment from the field. The galvanic corrosion on the aluminum trunnion and the valve body was identified and was perfectly in line with customer's real-life experience.

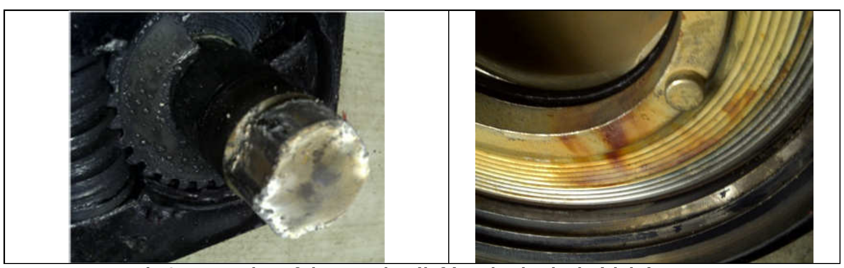


Fig 9 – corrosion of the trunnion (left) and valve body (right)

Conclusion

The galvanic corrosion risk of a ball intake valve of a fire extinguish equipment was investigated by Elsyca's GalvanicMaster technology.

The software is simple to use and allows determining different material combinations in a fast and effective way. In this simulation the ball intake valve contains 3 different metals and is capped with an iron and a brass piping component. The electrochemical behaviour of the metals was measured in laboratory and the environmental conditions were defined.

GalvanicMaster was able to predict galvanic corrosion on the trunnion and valve body. The simulations can be seen as the starting point for material selection optimization. This can be done by calculating the effect of finishes, coatings and alternative materials.