FEM Based Studies of a Mg/Al Hybrid Component Joint Regarding Corrosion Prediction

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Abstract

Galvanic corrosion of magnesium alloy based components coupled to more noble materials is a known problem in multi material design. Even, the joining of aluminium based components (having a relatively low potential difference to magnesium) with magnesium parts results in serious corrosion problems. This work will give an insight into the challenge of combining fundamentals of corrosion with an engineering problem like self-pierce punch riveting in COMSOL Multiphysics® FEM simulations like shown in the 3d extruded model geometry of Figure 1. The long term goal is to develop a model being able to optimised and to simplify construction processes by minimizing experimental effort and reducing secondary processing steps (coatings etc.) Therefore, the analysis of corrosion processes via computer is a powerful possibility to study corrosion interface kinetics, the arising loss of material and the surface appearance with respect to the long term performance and functionality.

For that purpose the ALE free surface modelling approach has been coupled to electrochemical computations in the Battery and Fuel Cell module on different rivet geometries including chemical reactions in the electrolyte and further ODE's to compute the surface coverage and the self induced porous corrosion layer thickness. The interface velocity was calculated by first: solving the Nernst equation inside the electrolyte for every time step and secondly: by the computation of interface kinetics applying the Butler-Volmer equation on Mg, a diffusion limited version on Al (under model assumptions validated by experiments shown in Figure 2) and by considering Mg(OH)2 layer formation at varying conditions. Latter, is presented in Figure 3 for the hybrid model system Mg/Al after 2h exposure to a 0.5% NaCl electrolyte film of 0.8 mm thickness.

Extensions of the model will include the development of mathematical descriptions of test environments (e.g. liquid film/convection), describe the full chemical reaction chain (e.g. Cl-), reveal time dependent "corrosion" boundary conditions and cross-link materials design and engineering to corrosion science. The model can be utilized for a virtual design of a hybrid joint. Structures can be optimized by the simulations by tailoring the parameters to get the most suitable result towards a Computer-Aided Engineering CAE regarding corrosion protection. This kind of computer based studies is a very useful method to accelerate developments in light weight structural design.

The outlook and concluding remarks will give advice on possible applications within other

research topics and on other activities in progress.

Figures used in the abstract

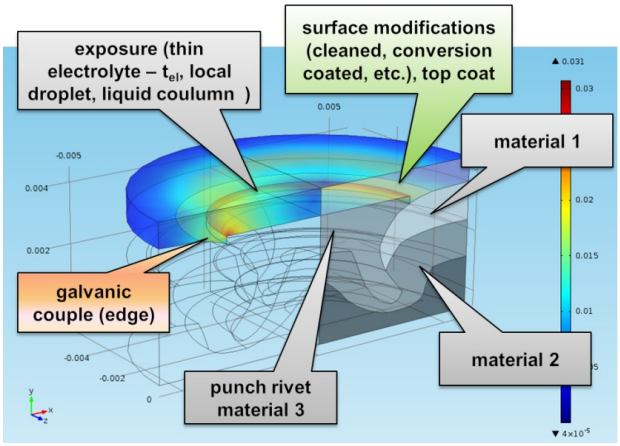

Figure 1: Model geometry of a self-pierce punch rivet joint (Al alloy) of two sheets (Mg/Al).

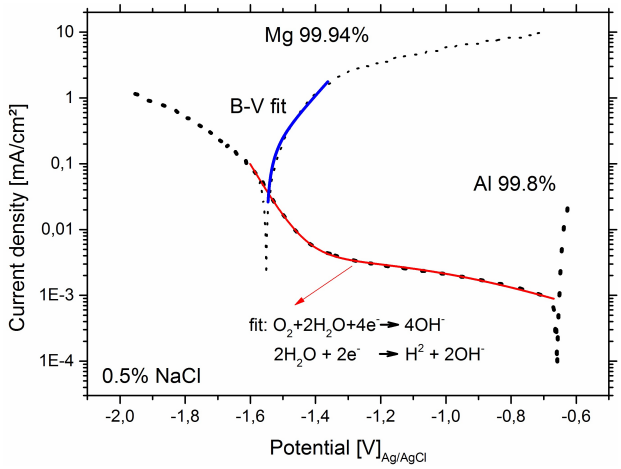

Figure 2: Potentiodynamic polarization curves and its evaluation by fitting.

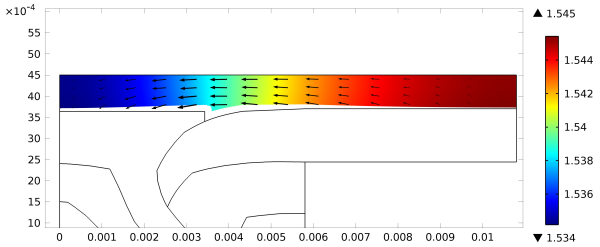

Figure 3: Mixed potential Umix in the electrolyte (color) with arrows (corrosion current) and deformed shape due to degradation and precipitation.