HydroFluxAB
Blåsgränd 23
907 35 Umeå

hydrofluxab@gmail.com

HydroFlux AB

An independent analysis of the shunt system PYS

An independent analysis of the shunt system PYS

A defect has been detected in HydroFlux AB patented system for regulation of shunts. Find cause and suggest modification in design.

The shunt system PYS (Piezo-electric Y-switch System)

PYS is a patented system for regulation of shunts. The system controls shunts very precisely by applying an electrical potential over a piezo-electric material which therefore expands and regulate the given shunt. In PYS an Y-switch is used (see figure 1and 2) in order to force two shunts shut/open in phase when a given electric potential is applied. In the situations where this system is used it is of extreme importance that the two shunts shut/open in phase. This means that it is very important that each leg in the Y-switch carries the same amount of current, otherwise the two shunts opens differently and the system gets out of phase.

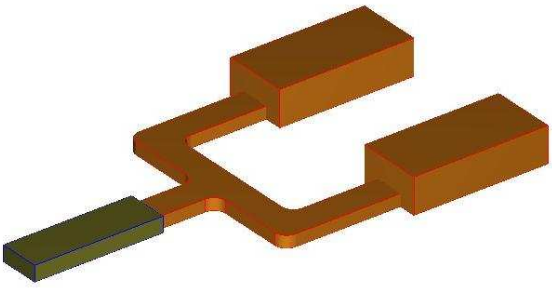

Figure 1. Schematic sketch of PYS. The two boxes to the right in the figure contain the piezo-electric elements, the shunts and some classified electrical components.

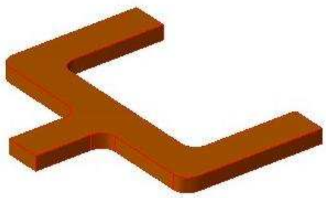

Figure 2. Schematic sketch of the Y-switch.

Background

Recent tests done by HydroFlux AB indicate that PYS is unexpectedly sensitive to temperature differences. Since it is of great importance that we correct this problem, the board of HydroFlux AB has decided to let some independent expert groups to do the analysis of the problem.

Problem specification

The tests have shown that the two legs in the Y-switch, under certain conditions, carries different currents. This means that the shunts gets out of phase and has to be corrected. The piezo-electrical elements has a built in robustness against small changes in currents, but the measured values are far above the tolerance levels and thus means a severe problem. At the moment when a current difference has been measured, a temperature difference has also been registered. Is this temperature difference the cause of the problem with the currents, or is there another cause?

Construction details

The Y-switch (see figure 3) is made of steel in order to work properly in environments with high humidity without oxidize. In addition there is a thin layer of a thermal isolator applied on the surface of the Y-switch shown in figure 3, and all heat flow through this surface can thus be neglected (i.e. the heat flow in the direction perpendicular to the paper). Correct dimensions of the Y-switch are listed in appendix B.

The thin sides of the Y-switch (not visible in figure 3) have no thermal isolation. The reason for this is that the switch is mass produced by applying the thermal isolator as a thin layer on large plates of steel from which the switch is cut out.

Temperature regulation

The two parallel legs in the Y-switch is hold by the surroundings at the temperatures T_1 (lower part of lower leg) and T_2 (upper part of upper leg), see figure 3. The other parts of the switch are cooled/heated by air at temperature T_0 blowing across the metal.

Electrical currents

The currents regulating the extension/contraction of the piezo-electrical elements are driven by an electrical potential V_0 applied at the ingoing leg in the Y-switch (see figure 3). At the short ends of lower and upper leg the potential V_1 and V_2 are applied.

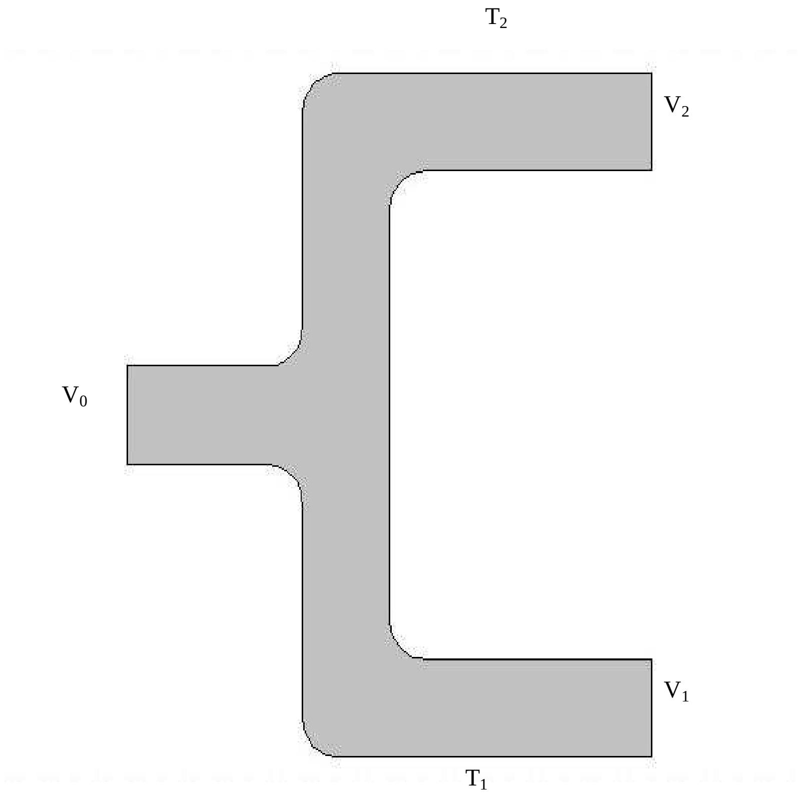

Figure 3. Detailed sketch of the Y-switch used in PYS (top view). Definition of variables can be found in table 1.

Table 1. Relevant parameters and their values in PYS

V_0	0.01 V	Electric potential at Y-switch in-leg
V_1	0.001 V	Electric potential at Y-switch lower leg
V_2	0.001 V	Electric potential at Y-switch upper leg
T_0	293 K	Initial temperature
T_1	300 K	Temperature at lower leg
T_2	300-310 K	Temperature at upper leg
λ	200 $W/m^2/K$	Heat transfer coefficient for air cooling
I_{tol}	2 mA	Tolerance level of current fluctuations in piezo-electrical element

Table 2. Relevant material parameters in PYS

k	45 $Wm^{-1}K^{-1}$	Thermal conductivity
ρ	7800 kg/m^3	density
C_p	460 $Jkg^{-1}K^{-1}$	Heat capacity
r_0	$16 \cdot 10^{-8}\ \Omega m$	Resistivity
TC	$3.3 \cdot 10^{-3}\ K^{-1}$	Temperature coefficient
Rcorner	0.001 m	Radius of corner

Instructions from HydroFlux AB

In order to correct and develop PYS it is valuable to have a computer model of the system where different situations and ideas can be tested directly. HydroFlux AB thus wants you to construct a 2D FEM-model that simulates PYS, and then use the model to answer some questions of great importance for the company.

A. The numerical model

The model should satisfy the following requirements:

- It should reproduce the experimental data obtained by Hydroflux AB (see appendix A)
- Your numerical solutions should not depend seriously on the choice of mesh

B. Analysis

According to your numerical model:

- What temperature on T_2 can we at most accept?
- How long does it takes, at a typical T_2, for the electrical currents to stabilize?
- What effects would we expect by altering the material properties of the Y-switch?
- What effects would we expect if we change the cooling of the Y-switch?
- What effects would we expect by changing the electrical potentials?

C. Actions

The problem for HydroFlux AB is that T_2 has a tendency to be so much larger than T_1 that the current differences in the Y-switch exceed the tolerance level I_{tol}.

What can be done to decrease the current differences?

- What are the advantages and disadvantages with those actions?
- Which of the actions do you recommend HydroFlux AB, and what are your arguments for those recommendations?

Appendix A

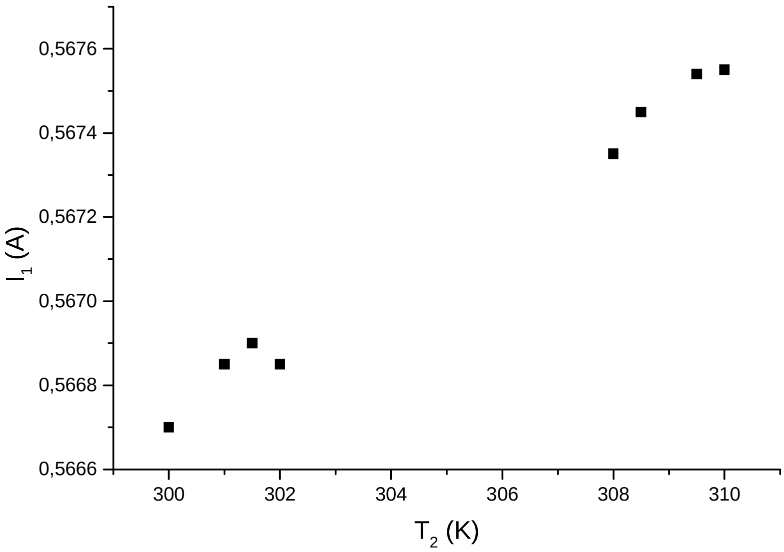

Figure A1. Experimental data obtained by HydroFlux AB (material properties: steel with resistivity $16 \cdot 10^{-8}\,\Omega m$ and a temperature coefficient $3.3 \cdot 10^{-3}\,K^{-1}$).

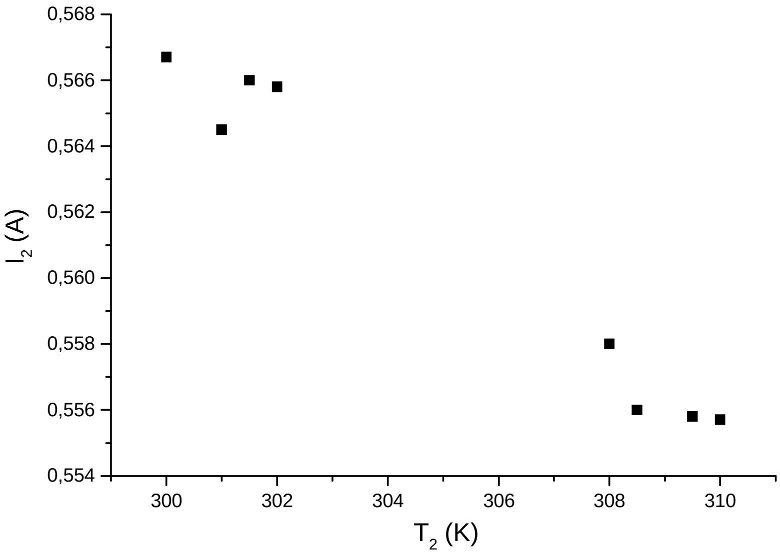

Figure A2. Experimental data obtained by HydroFlux AB (material properties: steel with resistivity $16 \cdot 10^{-8}\,\Omega m$ and a temperature coefficient $3.3 \cdot 10^{-3}\,K^{-1}$).

Appendix B

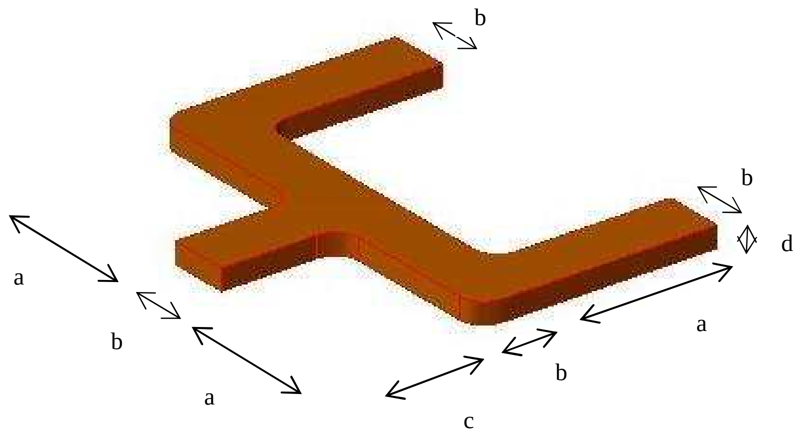

Figure B1. Detailed sketch of the Y-switch used in PYS where $a = 7.5 \cdot 10^{-3}\, m, b = 2.5 \cdot 10^{-3}\, m$, $c = 5 \cdot 10^{-3}\, m$ *and* $d = 0.1 \cdot 10^{-3}\, m$.