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Author: Ms. Saskia Sütterlin
KSat e.V., Germany, suetterlin@ksat-stuttgart.de

Mr. Manfred Ehresmann
Institute of Space Systems, University of Stuttgart, Germany, ehresmann@irs.uni-stuttgart.de
Mr. Felix Schäfer
Institute of Space Systems, University of Stuttgart, Germany, fschaefer@irs.uni-stuttgart.de
Prof.Dr. Georg Herdrich
Institute of Space Systems, University of Stuttgart, Germany, herdrich@irs.uni-stuttgart.de

DESIGN AND EVALUATION OF ELECTRICAL AND THERMAL FERROFLUID SWITCHES

Abstract

A novel switch type is presented, utilising ferrofluid to enable a switching operation. Conventional mechanical switches consist of moving components and are, therefore, susceptible to wear and tear, resulting in a limited lifetime. As a result, the advantage of these switches is the absence of moving parts and their inhibited mechanical stress. These novel switches can be a promising solution, especially for complex systems where replacement, access, and maintenance are challenging – such as space systems.

These innovative switches are based on distinct concepts of fluid actuation. All concepts consist of an insulating and conductive fluid (either thermally or electrically) with suitable housing materials, contact materials, and magnetic field sources. Electro-permanent magnets (EPMs) are particularly interesting as magnetic field generators to allow effective actuation of ferrofluid. Due to the combination of different material properties, they offer the possibility to switch on-demand strong magnetic fields ON and OFF, whereby high electric power is only required for a short period during magnetic state changing. In addition to the conventional oil-based ferrofluids, a newly developed ferrofluid is being tested with Galinstan as carrier fluid - a liquid metal similar to mercury, offering the advantageous properties of conducting electric current and heat, but with a lower environmental impact and safety concerns. Using Galinstan-ferrofluid as the thermal and electrically conductive liquid, selecting a respective insulating fluid is possible. High purity silicone oils or mineral oils are particularly suitable for electrical switches, as their breakdown voltage is usually higher than that of gases. However, Gases are particularly suitable for a thermal switch due to their low thermal conductivity. Nevertheless, this utilisation is limited, as Galinstan oxidises above a particular oxygen concentration, potentially hindering free liquid movement. The feasibility of different concepts is tested and successfully shown with a selection of materials and fluid combinations.

The developed electrical switch is capable of switching the tested electric loads properly. Optically, no arcs and no fluid alteration occurred even at high voltages. Furthermore, long-term stability with switching times in the range of a few milliseconds is demonstrated. A layout with Galinstan-ferrofluid and an insulation gas is presented for the thermal switch, and a respective switching ratio is defined.

This study was performed as part of a Bachelor thesis at the Institute of Space Systems at the University of Stuttgart (IRS) and further developed as an ISS experiment in the FARGO project to be operated in 2023.