**DIPLOMA THESIS:**
*Optimizing a three-stage servo-valve*

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**Introduction**

Customers of high dynamic flight motion simulators typically require very high dynamic, large signal performance to simulate the motion of a missile during the terminal phase of flight. However, there is also an increased demand for high pointing accuracy and good low rate performance. This demand for higher dynamics is compounded by the need for stable and accurate small signal characteristics. To accurately and smoothly drive a hydraulic actuator, a precise servo-valve is needed. High simulation rates need high flow into the actuator. In order to achieve the necessary flow either multiple valves running in parallel or one multiple stage servo-valve can be used. However, test-results of three-stage servo-valves did not give acceptable stable, small signal performance.

**The Problem**

The assignment of this diploma thesis was to obtain more knowledge about the servo-valve, determine the problem areas and develop a solution if possible.

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**Servo-valve**

With a power consumption of 100-200mW, the analyzed three-stage servo-valve controls an actuator of several 100kW. To get a better understanding of how this high amplification can be achieved, a block diagram based on physical principal was developed. This resulted in a system 7th order. The main piston (3rd stage) is being controlled by a two-stage servo-valve. After analysis of the pre-control stage, a functional Simulink® simulation model could be derived. The physical model of the pre-control stage had to be reduced significantly. Development of a Model, which represents the static as well as the dynamic characteristic, was difficult. As the frequency response comparison shows, the non linear behavior of the servo-valve made the modeling task a challenge.

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**Small signal characteristic**

Initial small signal measurements of the main stage showed good small signal behavior of the servo-valve. But with increase of the oil temperature the behavior got worse. As a result, the focus shifted from optimizing the servo-valve to finding the reason of the negative effect of the oil temperature on the small signal characteristic.

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**Summary of the small signal characteristic. Control 0.1%.**

Top trace control, bottom trace feedback

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Unfortunately it was not possible to find the reason for this flaw with the existing information and within the scope of the Diploma Thesis. Nevertheless, it could be narrowed down to the main stage. Possible causes were identified and the results were forwarded to the manufacturer.

**Primary solution**

A primary solution to improve the performance of a three-stage servo-valve is to have adequate oil tank cooling or the use of a heat exchanger which accurately regulates the oil in the feed line.

**Conclusion**

After modification of the servo-valve by the manufacturer, it will again be placed on the test bed to see if improvements have been made. ACUTRONIC will continue to develop the thesis work and endeavor to improve the performance of three-stage servo-valves for hardware-in-the-loop applications.