A HIGH PRECISION MULTI-DOF ACTIVE VIBRATION ISOLATION SETUP FOR A CORIOLIS MASS FLOW RATE METER

K. Staman, L. van de Ridder, D. M. Brouwer, J. van Dijk, W.B.J. Hakvoort
Laboratory of Mechanical Automation and Mechatronics
University of Twente, Enschede, Netherlands

INTRODUCTION
A Coriolis mass flow meter (CMFM) for small mass flows, as presented by Mehendale [1], is limited from measuring smaller flows accurately by vibration disturbances introduced through the device's frame [2]. Considerable improvements are expected from the application of passive and active vibration isolation strategies [3]. The component of the CMFM that needs to be isolated from disturbances is the tube window (see figure 1). This fluid-conveying tube is actuated in oscillation around the actuation-axis, which at the sensing locations causes tube motion in the order of tenths of millimeters. A fluid flow results in a Coriolis-force induced motion around the Coriolis-axis in the order of sub nanometers for the lowest flows.

This paper describes the design and modeling of an active vibration isolation setup that serves as a proof of principle for multiple vibration isolation strategies. The design of the setup is discussed, followed by the results obtained from a dynamic model. An attenuation of the main source of disturbance larger than 50 dB is expected to be achievable.

CONCEPT DESIGN
Foremost, the setup is required to actively isolate the tube window from disturbances that cause out of plane motion around the Coriolis-axis at the actuation and measurement frequency of 170 Hz. These disturbances are indistinguishable from flow induced motion and thus result in a measurement error. The two main contributors to this error are a translation in the z-direction and a rotation around the x-axis. Furthermore the setup will be used to test if the tube window can be actuated through the suspension by means of a rotation about the y-axis, requiring the three voice coil actuators as seen in figure 2.

The designed vibration isolation setup as shown in figure 2 will consist of the tube window, including actuation and sensing components (both omitted in figure 2) on a measurement frame. This will be mounted on a suspension with voice coil actuators that provide the active degrees of freedom (the minimum number of independent coordinates required to describe relevant system motion (DOF)). The other degrees of freedom are either constraint or left passively suspended, the optimum solution being a research objective. The optional constraints will be discussed below.

 MODELING
The entire setup has been modeled using the non-linear finite element flexible multibody software package SPACAR [4].
RESULTS
From the finite element model the influence of frame disturbances in x-, y- and z-directions and rotations around these axes on the Coriolis induced motion (a motion of the tube window at the sensing locations) is derived and it is concluded that the aforementioned (z-translation and x-axis rotation) two disturbance directions are still of primary concern in the suspended setup. A large attenuation of the sensitivity to disturbance is already obtained by passively suspending the measurement device in these two directions as can be seen in figure 3. In the region of interest (purple) an attenuation of about 30 dB is obtained. This passive solution is limited by the static behavior of its suspension stiffness, which is designed to produce a suspension frequency around 30 Hz. In previous work [3] feedback control is applied to the suspended system in the form of a PI controller, adding virtual mass (lowering the suspension frequency to 13 Hz) and skyhook damping, attenuation of frame disturbances by about 60 dB is obtained for translational and about 40 dB for rotational disturbances.

DISCUSSION
With this setup it should also be possible to investigate if the effect of vibrations is sufficiently reduced by suspending and actively isolating only one DOF, resulting in a more efficient solution. By attaching one of two or both optional constraints at the sides of the setup (see figure 2), the measurement frame is constraint in its rotation about either or both the x- and y-axis, leaving only the z-translation as a active DOF. Research into the influence of disturbances has also shown that in addition to the two already mentioned disturbance directions, a third disturbance, a translation in y-direction, can cause unwanted motion in the tube window. Therefore an interchangeable four DOF suspension is created to convert the setup into a three DOF active isolation setup with one passively suspended DOF. The alternative four DOF suspension is shown next to the three DOF suspension in figure 4.

CONCLUSION
The influence of the two dominant disturbances (z-translation and x-axis rotation) on the measurement is expected to be attenuated by about 60 dB and 40 dB respectively, when the device is suspended and actively isolated using the presented setup. The setup can also be used to find the optimal suspension solution for significant vibration isolation in all directions. See the full version of this paper for the validation of the model and the vibration isolation strategies, using a physical setup.

REFERENCES