# Measurement Method for Dynamic Flow Characteristics of Hydraulic Bushing Features

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# Measurement Method for Dynamic Flow Characteristics of Hydraulic Bushing Features

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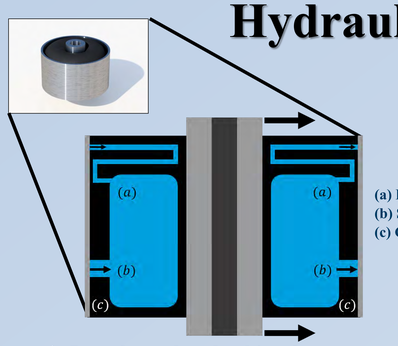
## Abstract

Hydraulic bushings are soft mechanical joint components which provide excellent vibration damping for a low-frequency band. These properties emerge from a tuned dynamic interaction between several features which either store or dissipate energy when the joint is flexed. In order to design and predict the dynamic properties of a hydraulic bushing, an understanding of the underlying physics governing each feature is needed. Typical feature models are based on many assumptions which are unlikely to be physically realistic under in situ loadings, so this study seeks to investigate the dynamic properties of hydraulic bushings' flow passages under unsteady flow conditions.

In this project, a new measurement method is developed to subject flow passages to dynamic flow conditions, such as sinusoidal or transient flows, and measure the resulting characteristics. The apparatus is configured to test both controlled flow restrictions and isolated passages from production bushings. Analysis of the experimental results should facilitate improved modeling of hydraulic mounts and bushings. Some sample results are given, and future work is proposed.

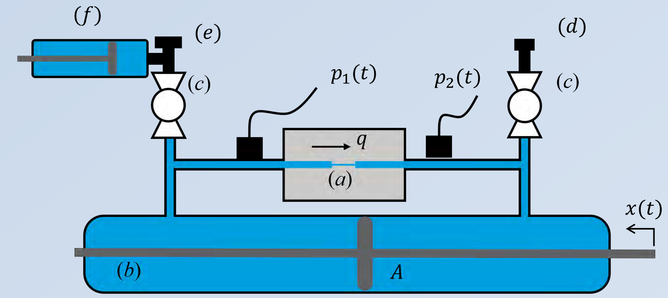
## The Problem: Hydraulic Bushings




(a) Long flow passage
(b) Short flow passage
(c) Compliant structure

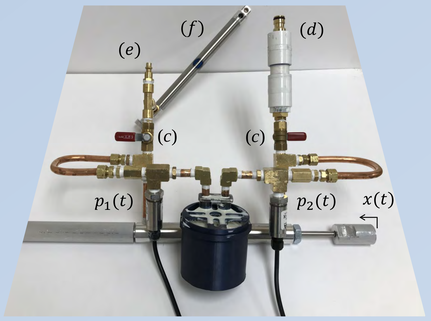
- Interdependent bushing features influencing total response
  - Elastomeric and rigid structure
  - Complex flow passages and geometry
  - Compliant fluid chambers
- Feature isolation for individual analysis
  - Interface specific features / bushing geometry with controlled external flow
  - Eliminate compliance via rigid encasement

## Flow Testing Apparatus Breakdown




(a) Flow restriction
(b) Main cylinder fluid cavity
(c) Quick access ball valve
(d) Quick fill hose attachment
(e) Pressure charge port
(f) Manual pressurization cylinder

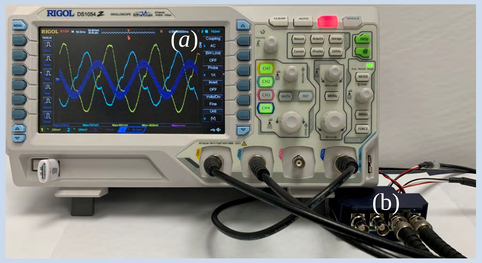
## Experimental Approach




Experimental Apparatus with Test Bushing Impedance

- System features
  - Symmetrical about impedance
  - Interchangeable impedance
  - Adjustable mean pressure to reduce cavitation at high pressure differentials, thus increasing test range
- Flexible flow conditions
  - Comprehensive flow testing with single test setup to reduce experimental uncertainty
  - Adjustable mean pressure

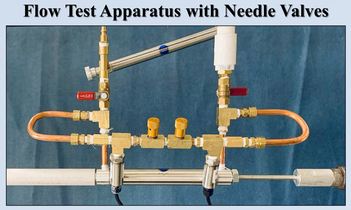
## Data Collection and Verification




RIGOL Oscilloscope

- Data acquisition system
  - Multi-channel oscilloscope (*a*) for acquisition and monitoring
  - Pressure, force, and displacement sensors
  - Data exported for analysis
  - Custom interface board (*b*) provides sensor power and signal flow to scope through BNC connectors
- Interchangeable restriction allows for variety of flow restriction specimens
  - Needle valves provide well-known restrictions for validation of apparatus
  - Hydraulic bushing features
  - Controlled laboratory specimens for R&D

Flow Test Apparatus with Needle Valves

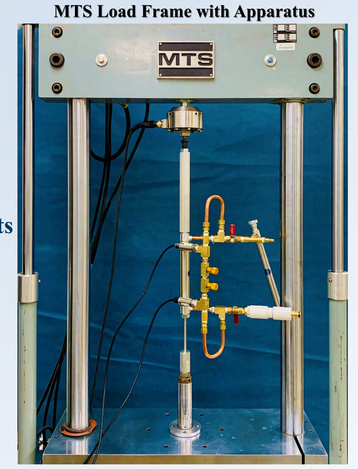


## Testing Method

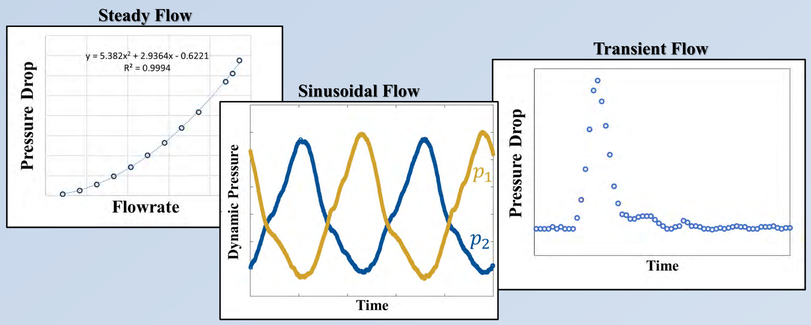
- MTS machine capabilities
  - Well-controlled motion
  - Convenient fixturing
  - Steady, dynamic, and transient excitations
- Systematic testing approach
  - Time and frequency domains
  - Speed, frequency, and amplitude effects


MTS 407 Controller

MTS Load Frame with Apparatus

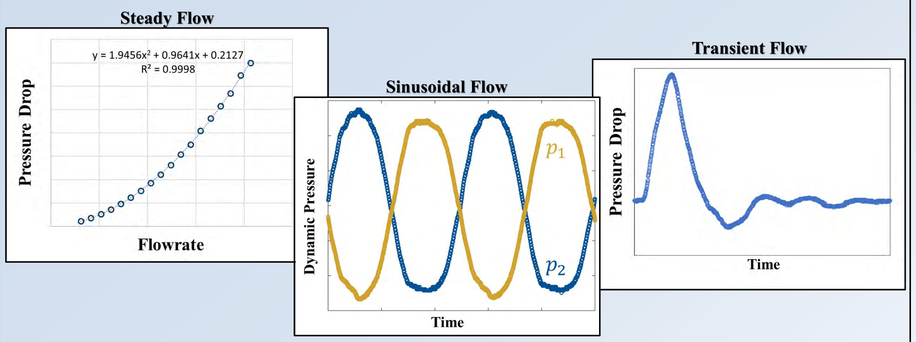



## Results for Controlled Restriction




- Steady flow test exhibited expected quadratic trend
- Physical insights from dynamic flows:
  - Same trend as steady flow?
  - Relationship between major and minor losses?

## Results for Production Hydrobushing




- Steady flow differs from simple restriction
- Inertial effects visible in dynamic data
- Strong and diverse nonlinearity measured from dynamic results

## Conclusions and Future Work

- Verification of experimental method
  - Component isolation method
  - Steady flow verification
  - Dynamic data
- Mathematical model enhancement and validation
  - New data can validate existing models
  - Improvements to state-of-the-art with new, physics-based model features
  - Customizable configuration enables future design work and laboratory tests:
- Applications
  - Fluid-filled mounts and bushings
  - Other vibration reduction devices
  - Biomedical applications