Bench-Top Screening of Wet Clutch Materials

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Outline

• Motivation and Background for Clutch Testing and Material Screening
  • Past and Current Test Methods
• Developing the Bench-top Test Conditions
  • Identifying the Key Variables for friction testing
  • Sample & Rig Configuration
• Examples
  • Clutch Materials
  • ATF Chemistry
  • Run-in Effect
Motivation and Background
Motivation – Why test clutch Material?

- Smooth wet clutch performance is directly tied to friction behavior\(^{(1,2)}\)
- Harshness, vibration and noise (HVN) is strongly correlated with the Velocity Dependence of the coefficient of friction (COF)
- Increasing COF with decreasing velocity ("negative slope") promotes stick-slip\(^{(1,2)}\)


Motivation – Why test clutch Material?

• Recently, increasing interest and demand for higher torque capacities at reduced sizes of automatic transmissions
  • Lower weight = better fuel economy
• Modeling of clutch behavior is an important development tool in reduced weight new clutch designs
  • COF data are critical for modeling efforts
Motivation – Why test clutch Material?

• Many possible new materials combinations and processing parameters exist to obtain desired torque capacity and durability
  • Fibers, friction modifiers, abrasives, fillers, binder, counter-surface

• COF data are typically obtained from tests on full scale clutch test machines
  • Time and resource consuming, costly

• Desire to get accurate COF data economically for modeling efforts
Past and Current Test Methods
Historical Clutch Material Testing

- “Early Days”
  - Design changes were evolutionary and empirical
  - Build and test clutches on vehicles
- In the lab, prior to 1967 – Test fully assembled clutches using SAE #1 Friction Test Machine
  - Friction test conducted under steady state conditions
- In 1967, SAE #2 Friction Test Machine was introduced\(^3\)
  - Varying conditions designed to simulate in-service clutch conditions

SAE No.2 Friction test machine and Samples

Typical sample size 133mm/99mm

Clutch disc photo courtesy of Par Marklund, Doctoral Thesis, ”Wet Clutch Tribological performance optimization methods” Lulea Univ of Technology 2008
Individual Effect Studies

- Pin-on-Disk and comparison studies\(^{4-6}\)
- Specific properties of oils and paper\(^{7,8}\)
- Modeling studies - dynamic effects, judder, shudder and chatter\(^{9-11}\)

So why a bench-top screening test?

- The answer is multifold, but simple:
  - Friction data are used in modeling
  - Many things affect friction behavior
    - Materials, porosity, cure parameters, counterface material and roughness
  - Easy and economical to make a small batch (single sheets) of new clutch materials
  - Fast and easy down-selection process for full-scale SAE #2 tests and in-service vehicle tests*

- Bottom line: Cost effective, less material intensive, less time consuming,

* - Not trying to replace full scale, component level test machine, just make those tests more efficient.
Developing the Bench-top Test Conditions
Defining the Tribotest

Turning the Tribosystem into a Tribotest...

What are the important parameters?

- Materials
- Contact Geometry
- Loading
- Motion
- Environment
Materials and Contact Geometry

- Bench-top Test Sample to be of same material of interest: Prototype wet clutch papers.
- Contact Geometry: Flat ring on flat counterface, scaled down
  - Focus on influence of the materials

145 mm Dia.

29 mm Dia.
Size Effect Concerns
(Macro geometry excluded)

Minimum Contact Size
- Non-Homogenous Nature (Material and Geometry Features)

$R_a = 9.09 \mu m$

$R_a = 12.88 \mu m$

$R_a = 3.11 \mu m$
• Test calls for **3 Pressures** of 0.8 MPa, 2 MPa and 3 MPa
  - 3 MPa on Bench-top Sample = 750N Load

• Test calls for **14 Speed Slip Steps** from 0.007 m/sec to 1.7 m/sec
  - Equivalent Linear Velocity on Bench-top Sample for 1.7 m/sec
    = 1,237 RPM

• Test calls for **3 Temperatures** of 40°C, 90°C and 120°C.
  - Higher Temperatures can be achieved on Bench-top system
    (limit depends only on lubricant)

• “Flooded” Lubrication Condition
  - Only 15-18 ml of fluid are required for each Bench-top test
Test Sequences
(to mimic OEM-specific test)

• Additional Sequences:
  • Up-and-Down Velocity Ramp Tests at Constant Pressure
  • Breakaway Friction
  • Reverse loading direction (high to low pressure)

• Total of over 300 test “conditions”!
Loading and Motion Example: Speed-Slip Test

Apply fixed load at given velocity, hold for 3-seconds.

Unload after each step.

(COF data point captured at 2.9 seconds)

Achieve and hold each successive velocity.

Return to zero velocity after each step.
Loading and Motion Example: Velocity Ramp

Ramp Test

- **5-Sec hold**
- **20-Sec ramp up**
- **20-Sec ramp down**
- **Constant Load**
Sample & Rig Configuration
Upper & Lower Clutch Sample Pair

Upper Sample
- CLUTCH MATERIAL
  - 29 mm diameter
  - x 5 mm width

Lower Sample
- BACKING PLATE
- 40 mm diameter
Bench-Top System - Samples

Upper Sample Holder (Self-Aligning)

Clutch Material

ATF Supply Port

Clutch Material Sample

Reaction Plate Material Samples
Bench Top System - Overview
UMT-TL (TriboLab)

UMT-TL Base Unit

775 mm
Bench Top System – Details 1

- Load Cell: (0-2 kN)
- 4-Spring Suspension
- Torque Sensor: (0-11.3 N·m)
- Insulating Lid
- Heater Chamber: (RT-400°C)
- Rotary Stage: (0-5000 rpm)
Bench Top System – Details 2

- Fluid Thermocouple
- Heating Chamber/Rotary Drive
- Upper Sample Holder, Self-Aligning Gimbal, ATF supply channel
- ATF Supply
- ATF Return
- Liquid bowl, holds lower Sample
Bench Top System
Lubricant-Reflow Between Steps (Video)
Bench Top System
ATF Feed (Video)
Examples
14 Speed Step Test

4 Materials
Standard ATF
120°C
Results: Slip-Speed Step Tests:
Clutch Materials A & B

UMT Bench-top Data

Material A - UMT 120° C

Material B - UMT 120° C

Full Scale SAE Rig Data

Material A - SAE2 120° C

Material B - SAE2 120° C
Results: Slip-Speed Step Tests: Clutch Materials C & D
Speed Ramp Test

Material C
Standard ATF
40°C
Results: Speed-Ramp Test

Full-Scale SAE #2 Tests – Velocity Ramp

Sub-Scale Bench-Top Tests – Velocity Ramp
Results: Speed-Ramp Test

Full-Scale SAE #2 Tests – Velocity Ramp

Note dynamic effects in both full-scale and bench-top tests

Sub-Scale Bench-Top Tests – Velocity Ramp
Results: Speed-Ramp Test

Full-Scale SAE #2 Tests – Velocity Ramp

Sub-Scale Bench-Top Tests – Velocity Ramp

Note breakaway friction in both full-scale and bench-top tests
Fluid Chemistry Effect
Neat vs. Fully Formulated
Results: Slip-Speed Step Tests: Effect of ATF Chemistry

UMT Bench-top Data

Fully Formulated ATF

Neat ATF Base Fluid

Full Scale SAE Rig Data
Run-in Effect
Results:
Run-in at low contact pressure, 20°C

Sample No. 2 – 0.775 MPa – 20°C

Run-in effect
Results:
Run-in at medium contact pressure, 20°C

Sample No. 2 – 1.94 MPa – 20°C

Graph: Coefficient of Friction (COF-T) vs. Speed (rpm)

- Run-in effect

Legend:
- File 1 Run 0
- File 2 Run 1
- File 3 Run 2
- File 4 Run 4
- File 5 Run 3
Results:
Run-in at high contact pressure, 20°C

Sample No. 2 – 2.96 MPa – 20°C

Run-in effect

<table>
<thead>
<tr>
<th>File 1 Run 0</th>
<th>File 2 Run 3</th>
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Results:
Run-in at high contact pressure, 20°C

Sample No. 2 – 2.96 MPa – 20°C

Run-in effect

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Results:
Run-in at high contact pressure, 20°C

Sample No. 2 – 2.96 MPa – 20°C

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Results:
After Run-in, all contact pressures, 20°C

Sample No. 2 – 3 Loads – 20°C

![Graph showing friction coefficients after run-in](image)
Bench-top screening of wet clutch materials:

Wrap-up
Concluding Remarks for Wet-Clutch Material Screening

• Agreement with full scale tests were very good in:
  • Relative rankings
  • Curve shape
  • Magnitude of COF for each material
  • Effect of chemistry

• Observation of Phenomena was possible:
  • Dynamic effects
  • Breakaway friction
  • Run-in

• Test cycle time is reduced and resources are minimized in bench-top test
  • Changing of clutch materials and fluids is simplified
  • Minimal disposal of Fluid (only 15-18 ml used)
• Please complete the survey questions which will be sent subsequently

• Please write to Productinfo@bruker.com with additional questions or requests for information
  • Please put “UMT Clutch-Material Screening” in the Subject Line