**Background and Objective**

**Objective:** Develop 3D model for ultrasonic lubrication under speed and stress conditions found in metal forming processes

- **Ultrasonic lubrication:** coefficient of dynamic friction between two surfaces decreases when ultrasonic vibrations are superimposed to the macroscopic sliding velocity
- This form of friction reduction is "solid state" and requires no greases or oils
- We use a piezoelectric actuator to create ultrasonic vibrations.
- Modulate the friction coefficient between "high friction" (off state) and "low friction" (on state) by driving the actuator at different voltages

**Literature Review**

- **Superposition effect**
- **Swaging effect**
  - Hayashi et al. and Hung et al., 2003
- **Metallurgical properties**
  - Hung et al., 2007; Siddiqi and Ghassemieh (2008)
- **Change of friction coefficient**
  - Olievirt et al., 1997
- **Reverting friction vector**
  - Ullmann et al., 2001; Siegert & Ulmer 2001, Tsai and Tseng 2006

**Experiments**

Ultrasoic lubrication was tested between stainless steel pin and stainless steel disc under stress (31-35 MPa) and speed (266 mm/s) conditions found in metal forming

<table>
<thead>
<tr>
<th>US Welder</th>
<th>Laser sensor</th>
<th>Waveguide</th>
<th>Acorn nut</th>
<th>Disc</th>
<th>Chuck</th>
<th>Turntable</th>
<th>Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction without US</td>
<td>22.88 - 27.52 N</td>
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<tr>
<td>Friction with US</td>
<td>9.93 - 10.71 N</td>
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<tr>
<td>Friction reduction</td>
<td>56.8 - 61.1%</td>
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</table>

**Examples of Ultrasonic Metal Forming**

- **Sheet rolling**
  - Severdenko et al. (1974)
- **Wire drawing**
  - Murakawa et al. (2001)
- **Compressing**
  - Siddiq and Ghassemieh (2008)

"Ultrasonic lubrication" was tested between stainless steel pin and stainless steel disc under stress (31-35 MPa) and speed (266 mm/s) conditions found in metal forming processes.