EVALUATION OF FRICTION CONDITIONS AT COMBINED BACKWARD CAN – FORWARD ROD COLD EXTRUSION

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1. Introduction
2. Methods for friction determination
3. Combined backward can – forward rod extrusion
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1. Introduction

HISTORY OF DETERMINATION OF FRICTION COEFFICIENTS

- M. Burgdorfi: 1967: Ring compression test, also calibration curves
- J. Danckert, T. Wanheim: 1988: Frictional ring test and stresses at bulk metal forming
- Buschhausen, A., Lee, J.Y., Weinmann, K. and Altan: 1992: Double can extrusion test
- K. Kuzman, E. Pfeifer, N. Bay, J. Hunding: 1996: Forward rod – backward can extrusion
- T. Nakamura, N.Bay: 1998: Forward conical can - backward straight can extrusion
The Coulomb friction model:

\[ \tau = \mu p \]

Constant shear model:

\[ \tau = m^* k \]

General friction model developed by Wanheim et al.:

\[ \tau = f^* \alpha^* k \]
DETERMINATION OF FRICTION COEFFICIENTS – BURGDORF RING COMPRESSION TEST

\[ d'_i = \frac{d'_{i,0} + d'_{i,90}}{2} \]

\[ d''_i = \frac{d''_{i,0} + d''_{i,90}}{2} \]

\[ d_i = \frac{d'_i + 2d''_i}{3} \]

DRAWBACK: Appropriate for lower pressures only.
BURGDORF RING COMPRESSION TEST – FACTORS m

Methods for friction determination

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Methods for friction determination

- Backward can – forward rod extrusion (various authors – different geometries)
- Backward can – forward can extrusion (various authors – different geometries)

AIM: Free material flow in two directions can be a measure of friction during the bulk forming process.
• Free divided material flow – friction factor $m$ can be obtained from geometrical changes of the specimen. Force measurements are not necessary.

• Diagram of material-lubricant ratios $h_p/d_2$ versus $h_c/h_r$ is created.

• Calibration curves were determined for various friction factors $m$ based on the constant friction law.

• Analyses were performed for combinations of two materials and two lubricants.
• Determination of calibration curves is performed with FEM program DEFORM.

• Fixed values of friction factor $m$ are used for each simulation -> calibration curves could be extracted from various extrusions.
CALIBRATION CURVES OF BCFRE TEST FOR QSt 32-3 MATERIAL

Combined backward can – forward rod extrusion

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CALIBRATION CURVES OF BCFRE TEST FOR 16MnCr5 MATERIAL

Combined backward can – forward rod extrusion

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TOOL FOR BCFRE TEST

QSt32-3 extruded with MoS2

QSt32-3 extruded with Na-soap

Combined backward can – forward rod extrusion
The statistical model

\[ m = f \left( \frac{h_p}{d_2}, \frac{h_c}{h_r} \right) + \epsilon \]

The equation was fit to data using a linear regression routine with cubic B-splines on both independent variables A (1-\(\alpha\))%.

Confidence interval for the fitted value

\[ \hat{m} \]

is constructed from the standard deviation of the prediction \( \hat{\sigma}_p \)

and is given by

\[ \left( \hat{m} - t(\frac{\alpha}{2}, \nu) \cdot \hat{\sigma}_p, \hat{m} + t(\frac{\alpha}{2}, \nu) \cdot \hat{\sigma}_p \right) \]

where \( t(q, \nu) \) represents the qth quantile of the t distribution with \( \nu \) degrees of freedom.
Material: QSt32-3

Calibration curves

Experimental values for lubricants MoS2 and Na-soap
Material: QSt32-3

Predicted values for $m$:

for MoS$_2$ lubricant: **0.1440**, min=0.1260, max=0.1669, $\sigma_d=0.010701$

for Na-soap lubricant: **0.1801**, min=0.1241, max=0.2432, $\sigma_d=0.039973$
Material: 16MnCr5

Calibration curves

Experimental values for lubricants MoS$_2$ and Na-soap
Material: 16MnCr5

Predicted values for $m$:
- for MoS$_2$ lubricant: $0.10090$, min=0.06234, max=0.11770, $\sigma_d=0.013068$
- for Na-soap lubricant: $0.15300$, min=0.07056, max=0.22810, $\sigma_d=0.060274$
AVERAGE FRICTION FACTORS $m$ OBTAINED FROM BCFRE TEST

<table>
<thead>
<tr>
<th></th>
<th>QSt32-3</th>
<th>16MnCr5</th>
</tr>
</thead>
<tbody>
<tr>
<td>MoS2</td>
<td>Current results</td>
<td>0.13 – 0.17</td>
</tr>
<tr>
<td></td>
<td>Source [17]</td>
<td>0.10 – 0.14</td>
</tr>
<tr>
<td></td>
<td>Source [19]</td>
<td>0.11 – 0.18</td>
</tr>
<tr>
<td>Na - soap</td>
<td>Current results</td>
<td>0.12 – 0.24</td>
</tr>
<tr>
<td></td>
<td>Source [17]</td>
<td>0.14 – 0.18</td>
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<tr>
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<td>Source [19]</td>
<td>0.12 – 0.20</td>
</tr>
</tbody>
</table>

Source [17]: Krušič, V. et. all.: The impact of the forming system parameters on tool service life and product accuracy in cold forging, ICIT 2007, Celje 2007, 63-70.

Predicted lines:

QSt32-3 + MoS$_2$:

\[ m = 0.16814 - 0.02515 \cdot \frac{h_p}{d^2} \]

QSt32-3 + soap:

\[ m = 0.02171 + 0.15983 \cdot \frac{h_p}{d^2} \]

16MnCr5 + MoS$_2$:

\[ m = 0.10474 - 0.00415 \cdot \frac{h_p}{d^2} \]

16MnCr5 + soap:

\[ m = -0.10254 + 0.27626 \cdot \frac{h_p}{d^2} \]
- Backward can forward rod extrusion test was selected for the determination of friction factors $m$ in bulk metal forming.
- DEFORM simulation was implemented as a tool for determination of calibration curves for two materials and two lubricants.
- Based on the obtained calibration curves the statistical model for the friction factor $m$ was created.
- Measurements of BCFRE test with combinations of QSt32-3 and 16MnCr5 material lubricated with MoS$_2$ and Na-soap have shown better and more stable lubrication with MoS$_2$ in particular at higher pressures.
- Experimental evaluation of numerically obtained calibration curves showed good agreements, differences were only at high deformations therefore in the future the increase of contact surface extension and its influence on factor $m$ should be considered as well.
- In the future the increase of surface extension and heat generation and their influence on factor $m$ should also be considered.