Investigation of Cup - Cup Extrusion Process and Study of Friction in this Process

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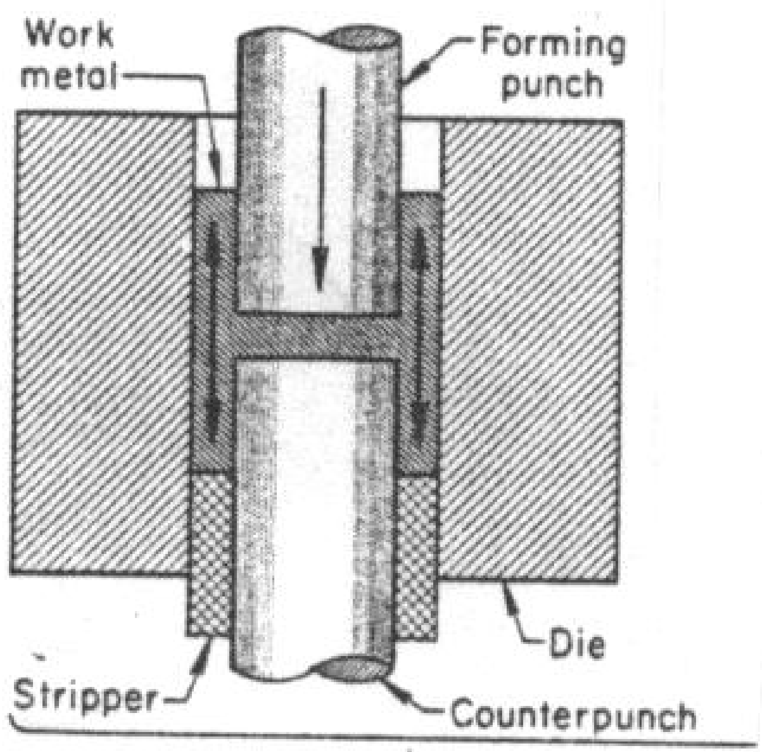
Contents :

Introduction

Cup - Cup Extrusion



Literature review

- Iran , Egypt
- Leonardo da vinci (1500)
- Amontons (1699)
- Coulomb (1750)
- Bowden and Tabor (1964)
- Geiger (1976)
- Frederiksen and Wanheim (1985)
- Schichun (1989)
- Buschhausen and et al. (1992)
- Arentoft and et al. (1996)

Theory and Experimental Procedure

Friction in metal forming

Maximum possible frictional shear stress is: $\tau_{friction}^{maximum} = \tau_{yield} = k$

where $k = 0.5 \cdot Y \; (Tresca)$ or $k = 0.577 \cdot Y \; (v.\,Mises)$

Coulomb Model

$$F_{friction} = \mu \cdot F_{normal}$$

$$\tau_{friction} = \mu \cdot \sigma_{normal}$$

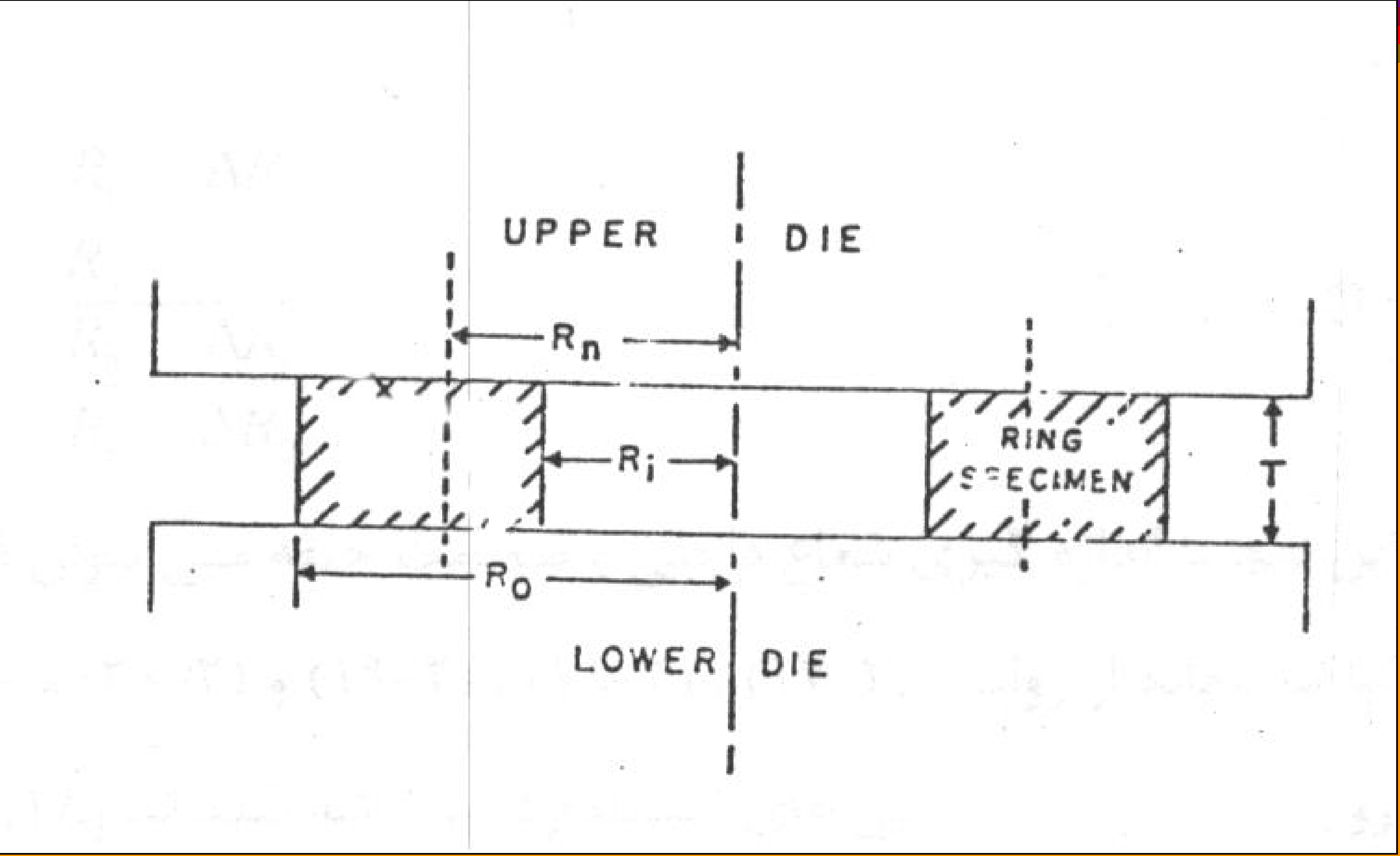
Friction coefficient μ:
$0 \le \mu \le 0.5 (0.577)$

Shear Model

$$\tau_{friction} = m \cdot k$$

Friction factor m: $0 \le m \le 1$

Ring test



Ring test

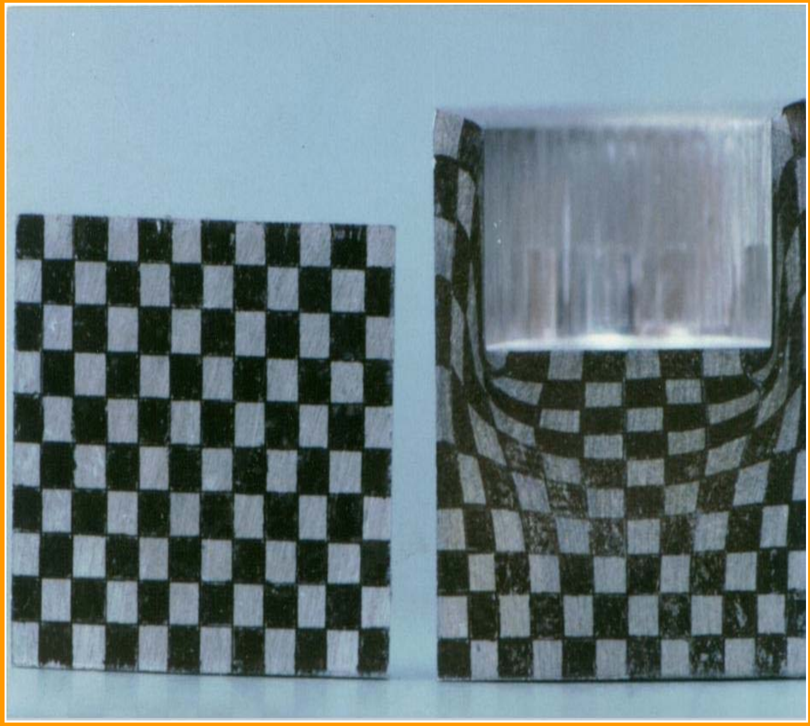
$$\frac{R_n}{R_o} = \frac{2\sqrt{3}m\frac{R_o}{T}}{\left(\frac{R_o}{R_i}\right)^2 - 1}\left\{\sqrt{1 + \frac{\left(1+\frac{R_i}{R_o}\right)\left[\left(\frac{R_o}{R_i}\right)^2 - 1\right]}{2\sqrt{3}m\frac{R_o}{T}}} - 1\right\}$$

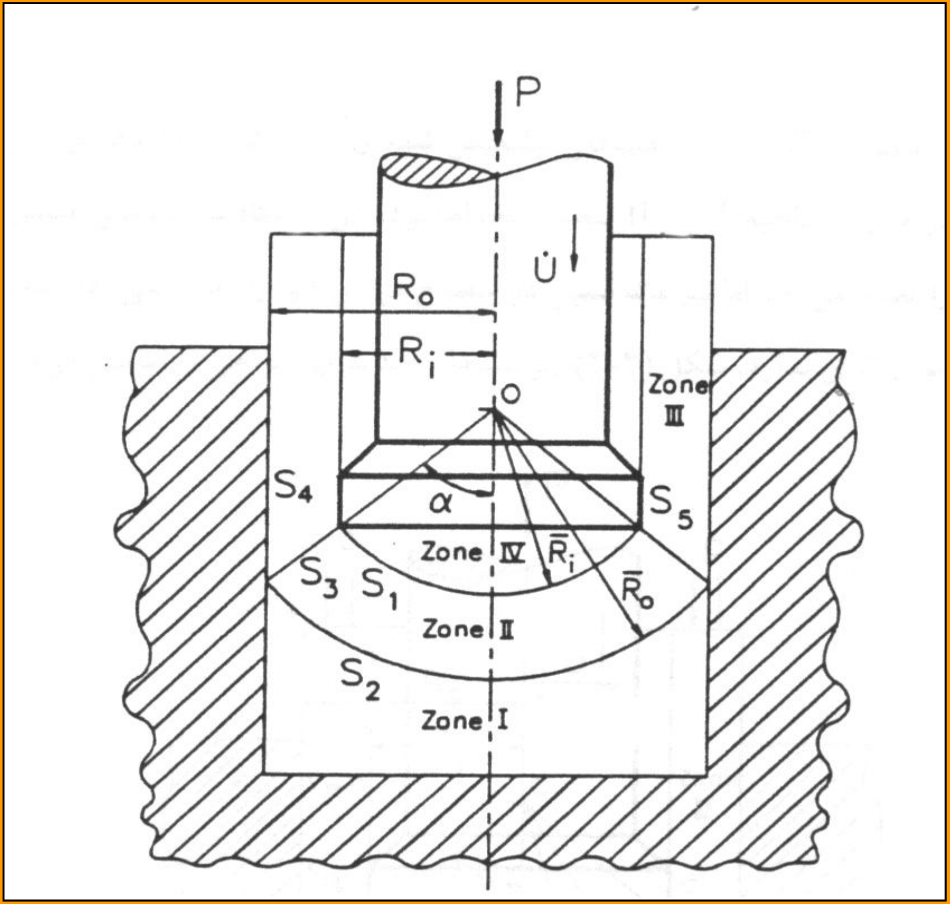
$$\left(\frac{R_n}{R_o}\right)^2 = \frac{\frac{R_i}{R_o} - \frac{\Delta R_i}{\Delta R_o}}{\frac{R_o}{R_i} - \frac{\Delta R_i}{\Delta R_o}}$$

Friction factor obtained from ring test

$R_\circ + \Delta R_\circ$ (mm)	$R_i + \Delta R_i$ (mm)	T (mm)	m
۱۲	۶	۴	
۱۲/۰۵	۵/۹۸۶	۳/۹۵	۰/۲۹
۱۲/۰۶	۶/۰۰۶	۳/۹۵	۰/۰۶
۱۲/۱	۵/۹۷۴	۳/۹	۰/۰۷
۱۲/۱۱	۶/۰۰۵	۳/۹	۰/۰۷
۱۲/۱۶	۶/۰۰۷	۳/۸۵	۰/۰۸
۱۲/۱۵	۵/۹۹	۳/۸۵	۰/۳۴
۱۲/۲۱	۵/۹۸۹	۳/۸	۰/۱۴
۱۲/۲۶	۵/۹۵	۳/۷۵	۰/۴۳
۱۲/۳۱	۵/۹۳	۳/۷	۰/۴۷

The deformation model in backward extrusion

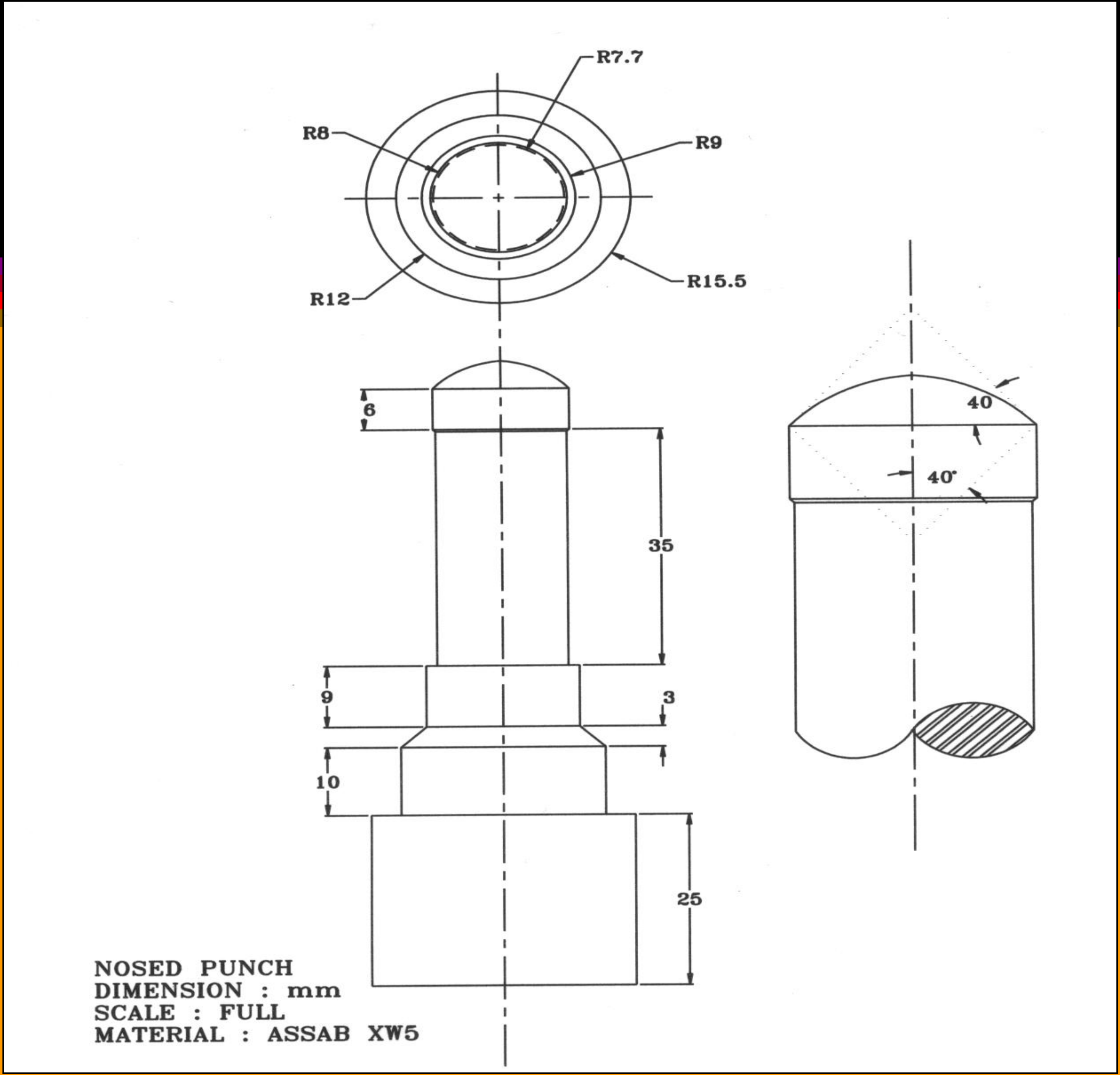




A new friction test

$$m = 1 - \frac{2\tan\beta}{f_1(\alpha,\beta)}\left(1 - R_{io}{}^2\right)\frac{P - P_{nosed}}{\sigma_o}$$

$$f_1(\alpha,\beta) = \frac{\csc^2\alpha}{32\sqrt{3}}\{\ln[\tan\left(\frac{\pi}{4}+\frac{\beta}{2}\right)](44\alpha + \sin 4\alpha - 24\sin 2\alpha) +$$
$$\sin\beta\sec^2\beta(20\alpha - \sin 4\alpha - 8\sin 2\alpha)\}$$


R7.7
R8
R9
R12
R15.5
6
35
9
3
10
25
40
40°
NOSED PUNCH
DIMENSION : mm
SCALE : FULL
MATERIAL : ASSAB XW5

Nosed Punch

Nosed Punch and Flat Punch

lubricant	force difference (Newtons)	m
Castor Oil	18600	0.1
Paraffin	14500	0.29
Glycerine	7000	0.65
Foam	20000	0.04
Graphite	18000	0.13
Stearic Acid	19100	0.08
Soap Paste	19350	0.07
Motor Oil	17600	0.15
MoS_2	17350	0.16
Vaseline	18900	0.09

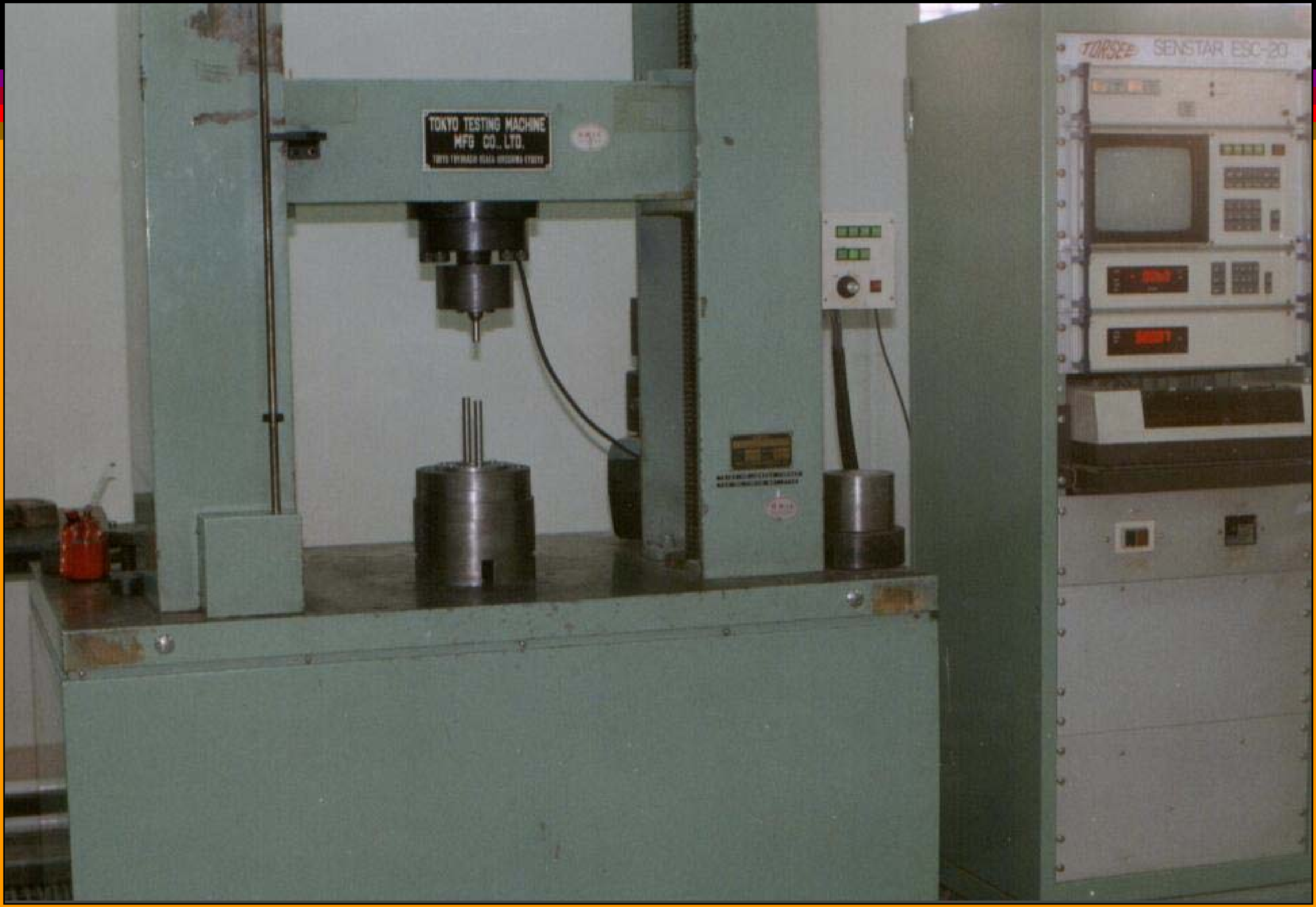
Reduction in area in the cup - cup extrusion process

$$r = \frac{A_o - A}{A_o} = \frac{\pi/_4 d_b^{\,2} - (\pi/_4 d_b^{\,2} - \pi/_4 d_p^{\,2})}{\pi/_4 d_b^{\,2}} = \frac{d_p^{\,2}}{d_b^{\,2}} = \left(\frac{d_p}{d_b}\right)^2$$

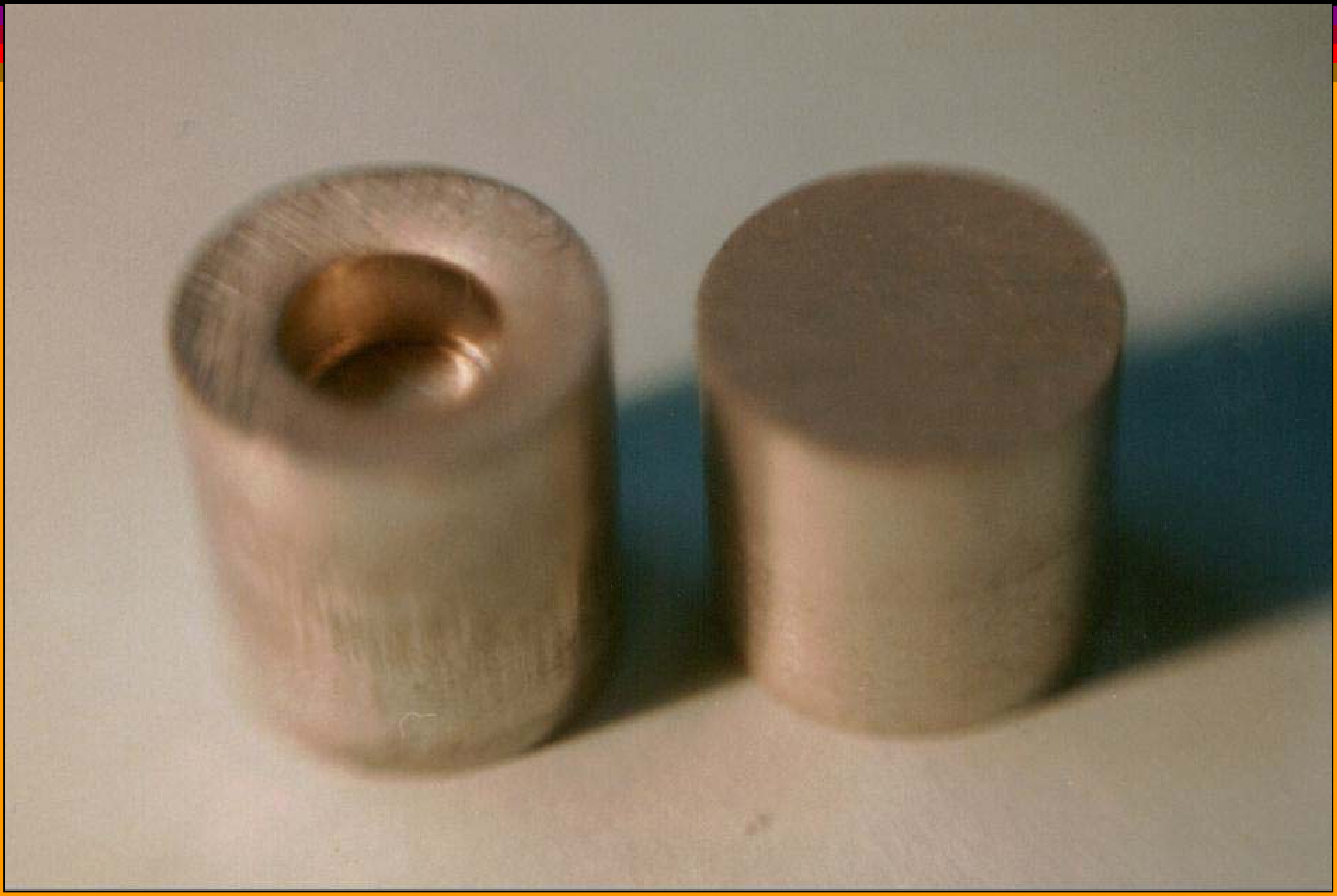
Lower and upper punches

Die set-up

Universal compression machine

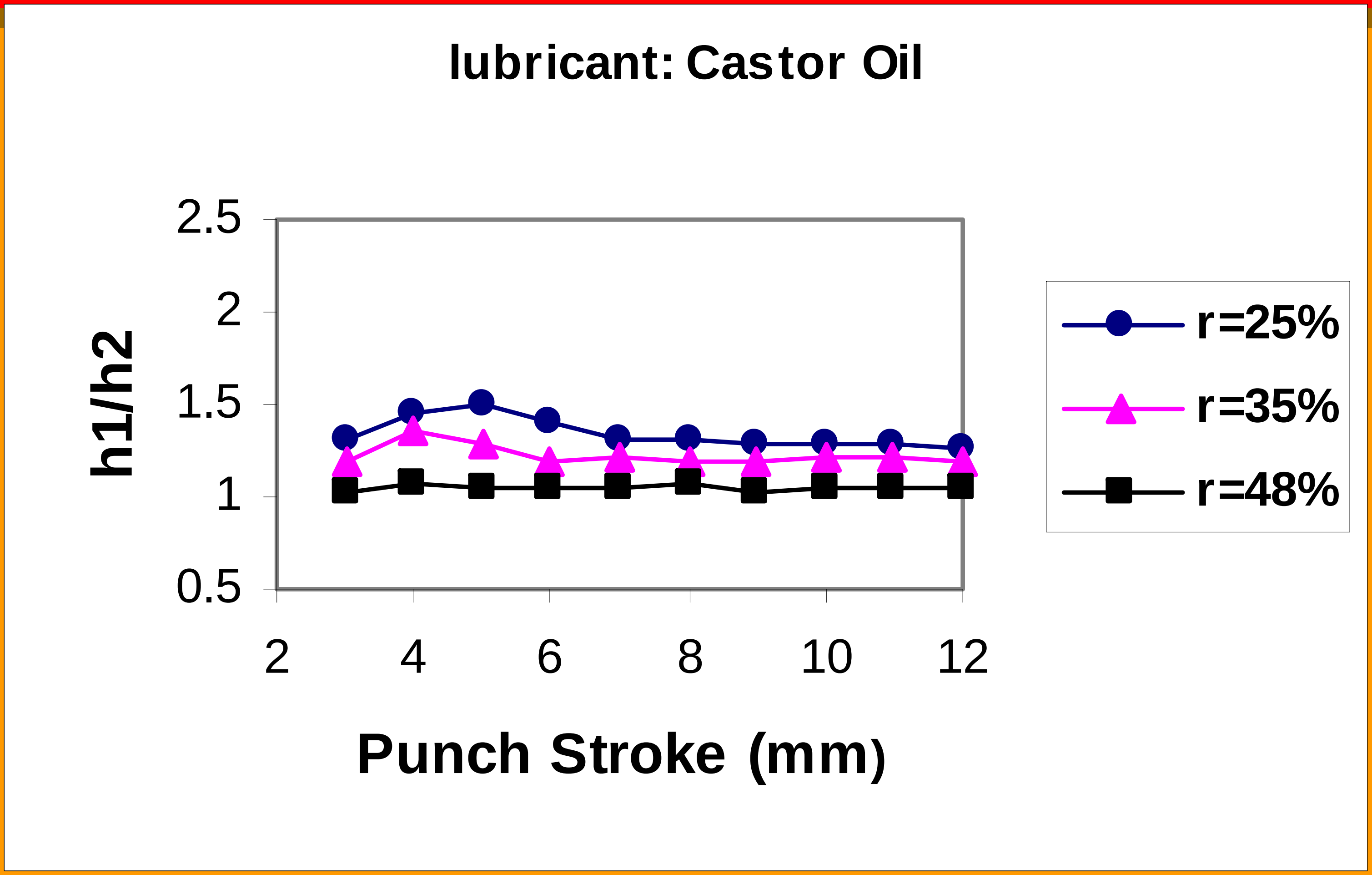


Billet and final shape

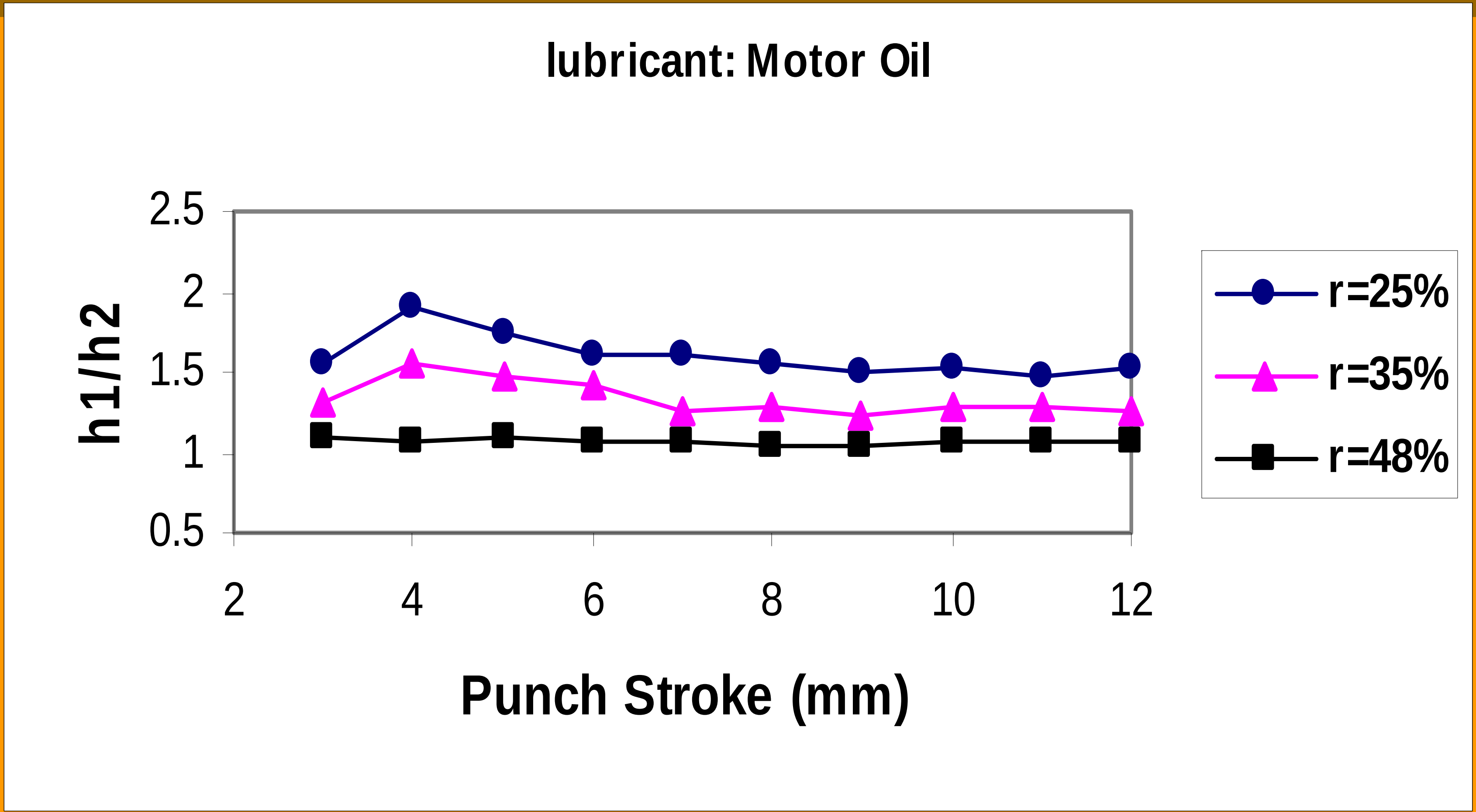


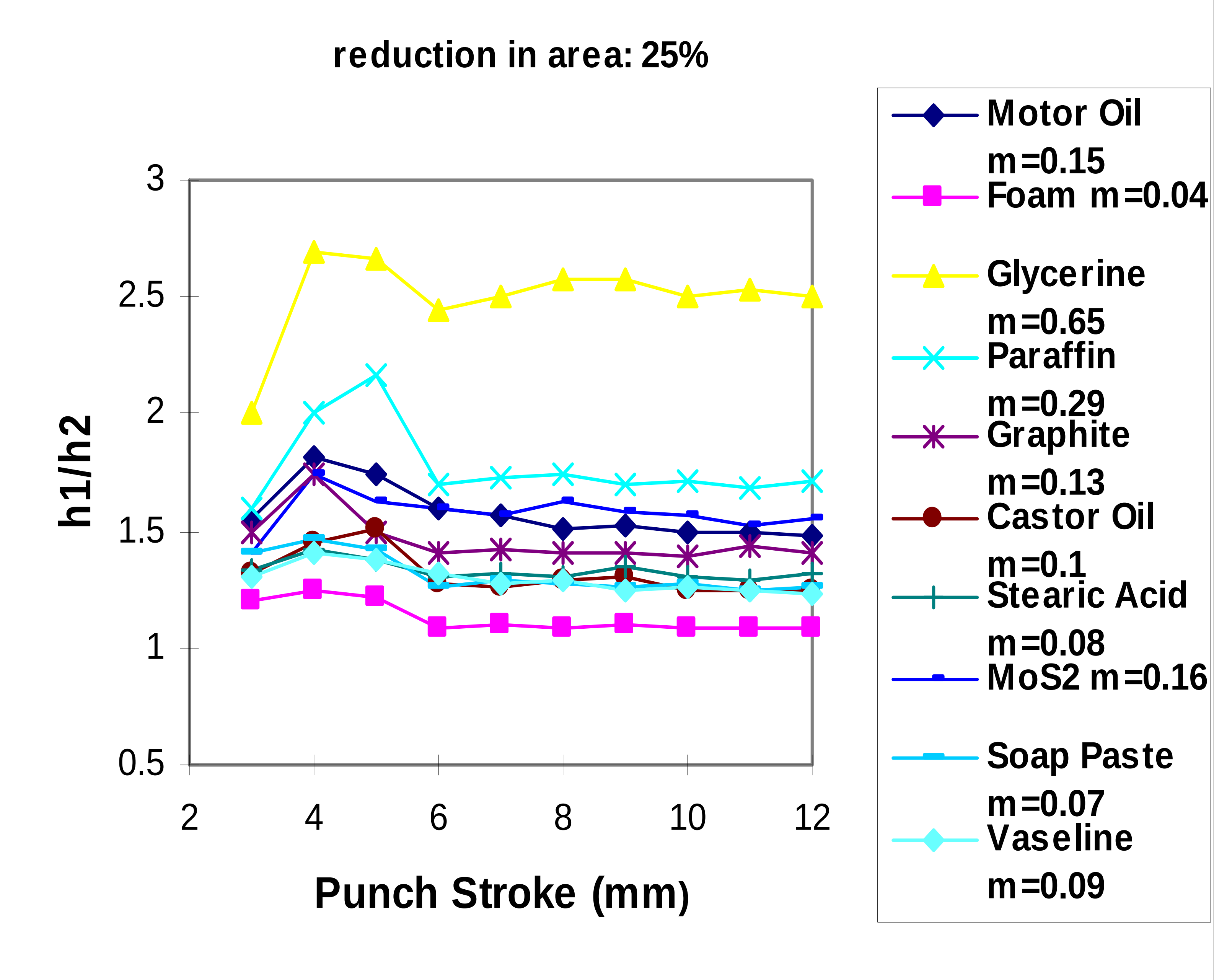
Results and Discussion

Ratio of cup heights (h1/h2) vs. punch stroke

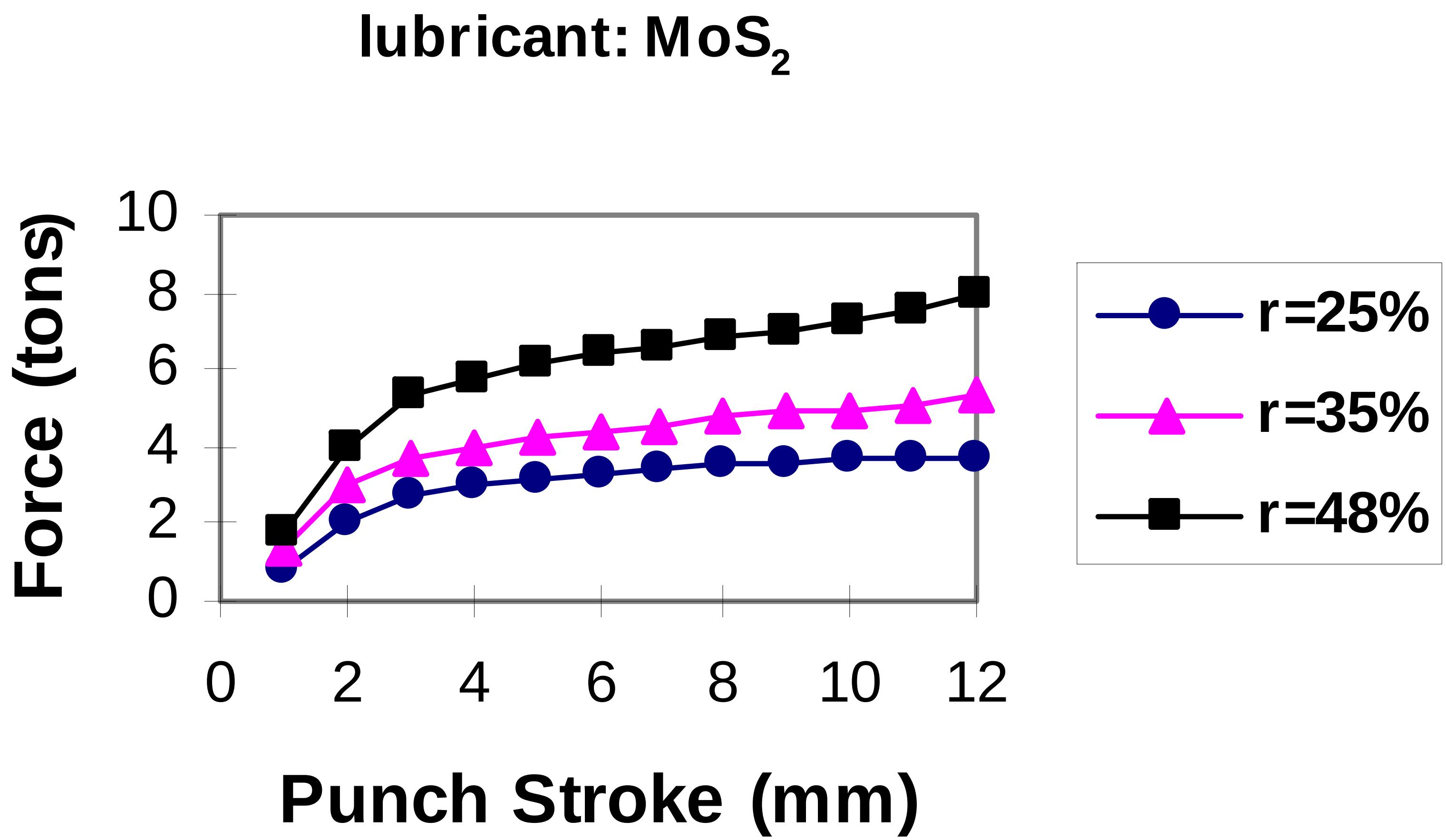


Punch stroke vs. (h1/h2)

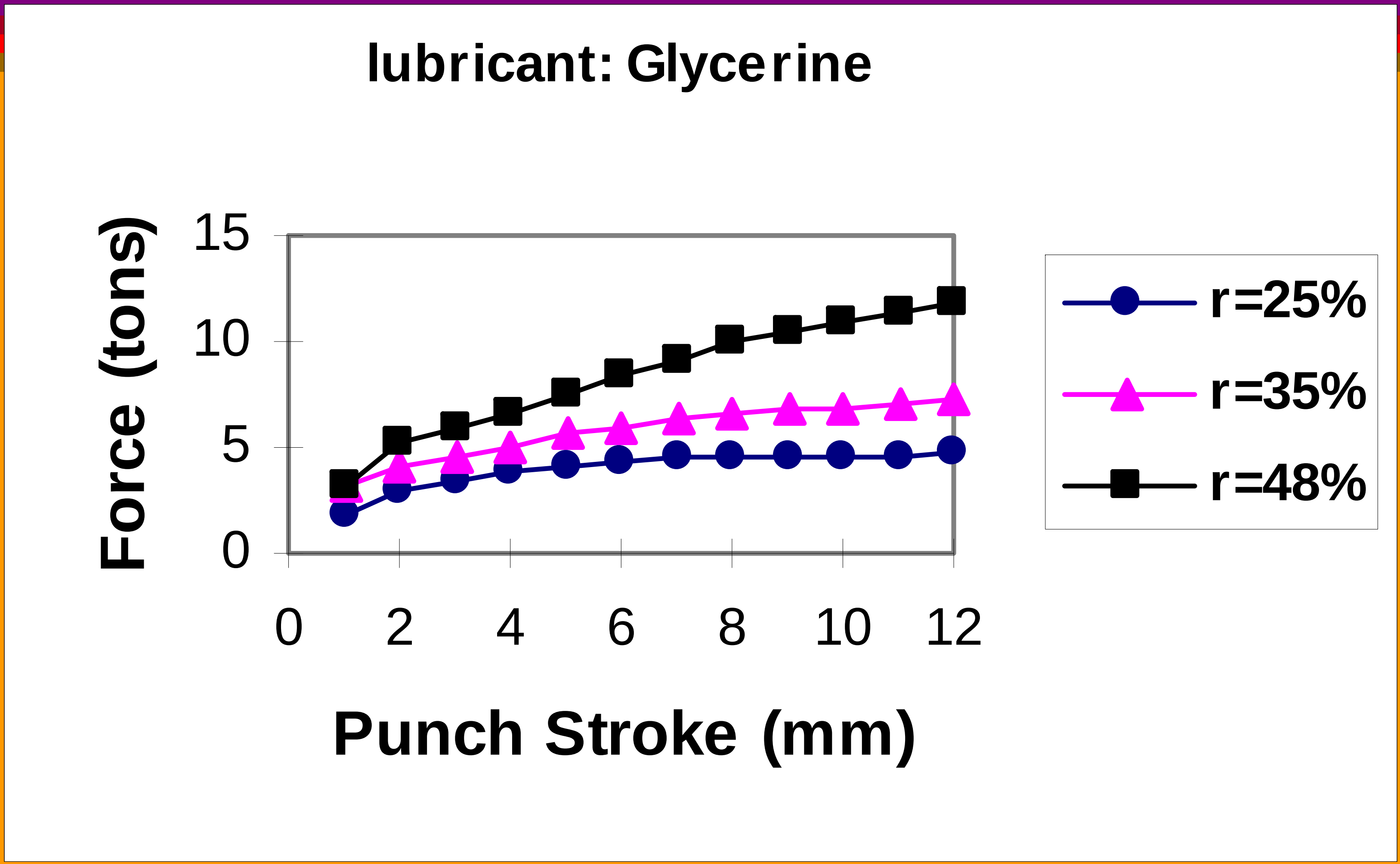


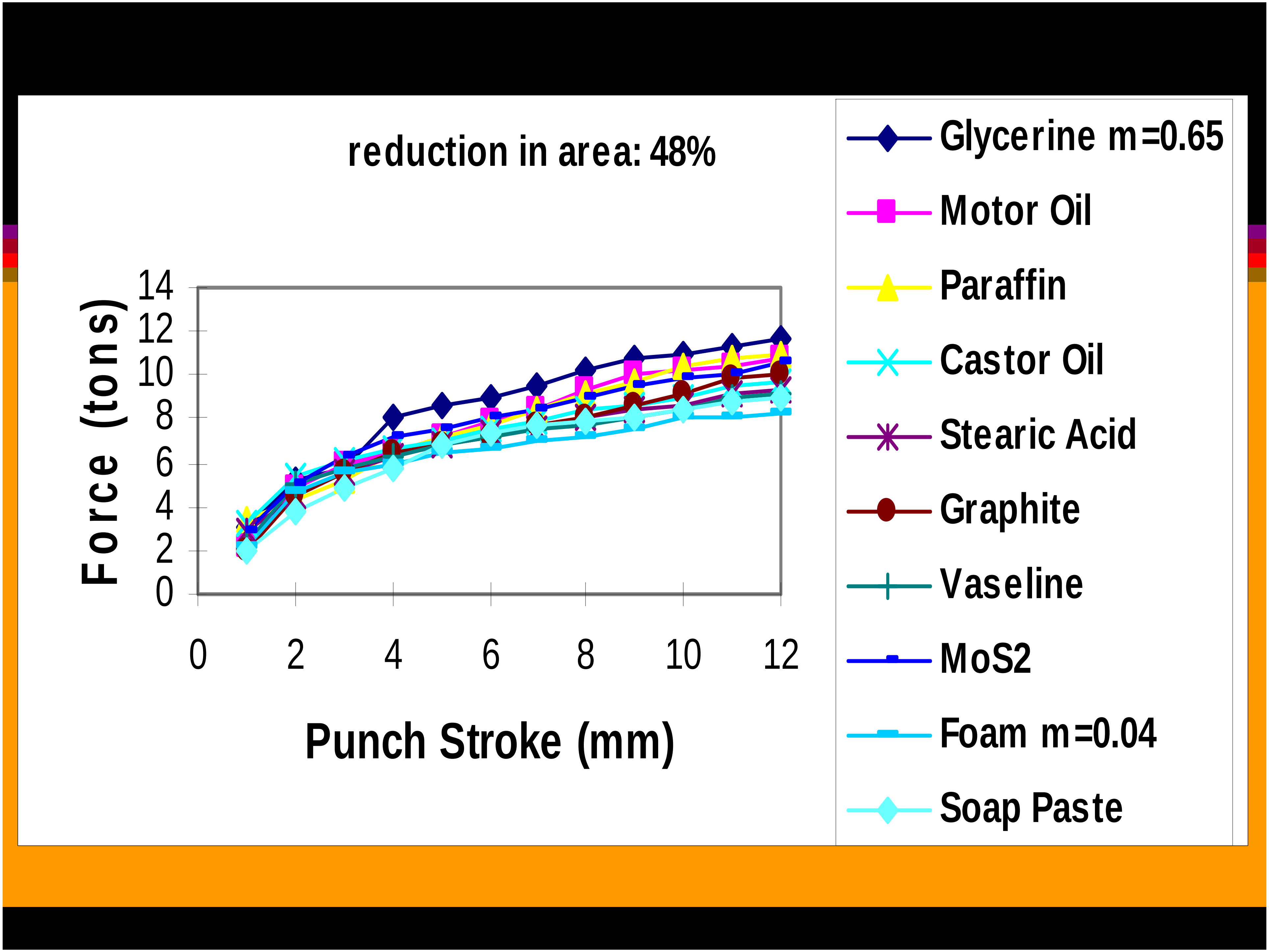

reduction in area: 25%
h1/h2
3
2.5
2
1.5
1
0.5
2
4
6
8
10
12
Punch Stroke (mm)
Motor Oil m=0.15
Foam m=0.04
Glycerine m=0.65
Paraffin m=0.29
Graphite m=0.13
Castor Oil m=0.1
Stearic Acid m=0.08
MoS2 m=0.16
Soap Paste m=0.07
Vaseline m=0.09

The force - stroke curve

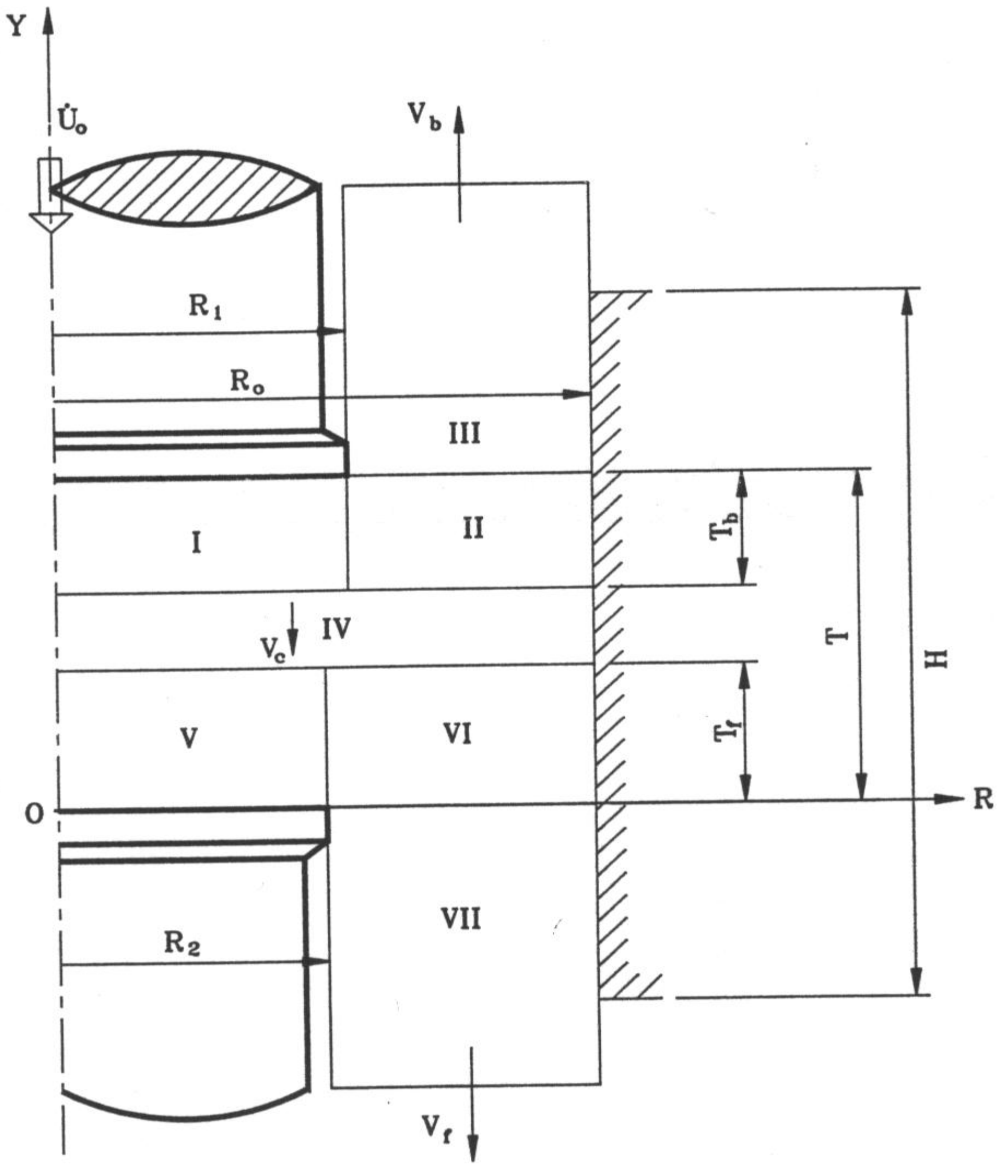


The force - stroke curve





reduction in area: 48%
Force (tons)
0
2
4
6
8
10
12
14
Punch Stroke (mm)
Glycerine m=0.65
Motor Oil
Paraffin
Castor Oil
Stearic Acid
Graphite
Vaseline
MoS2
Foam m=0.04
Soap Paste



Deformation model

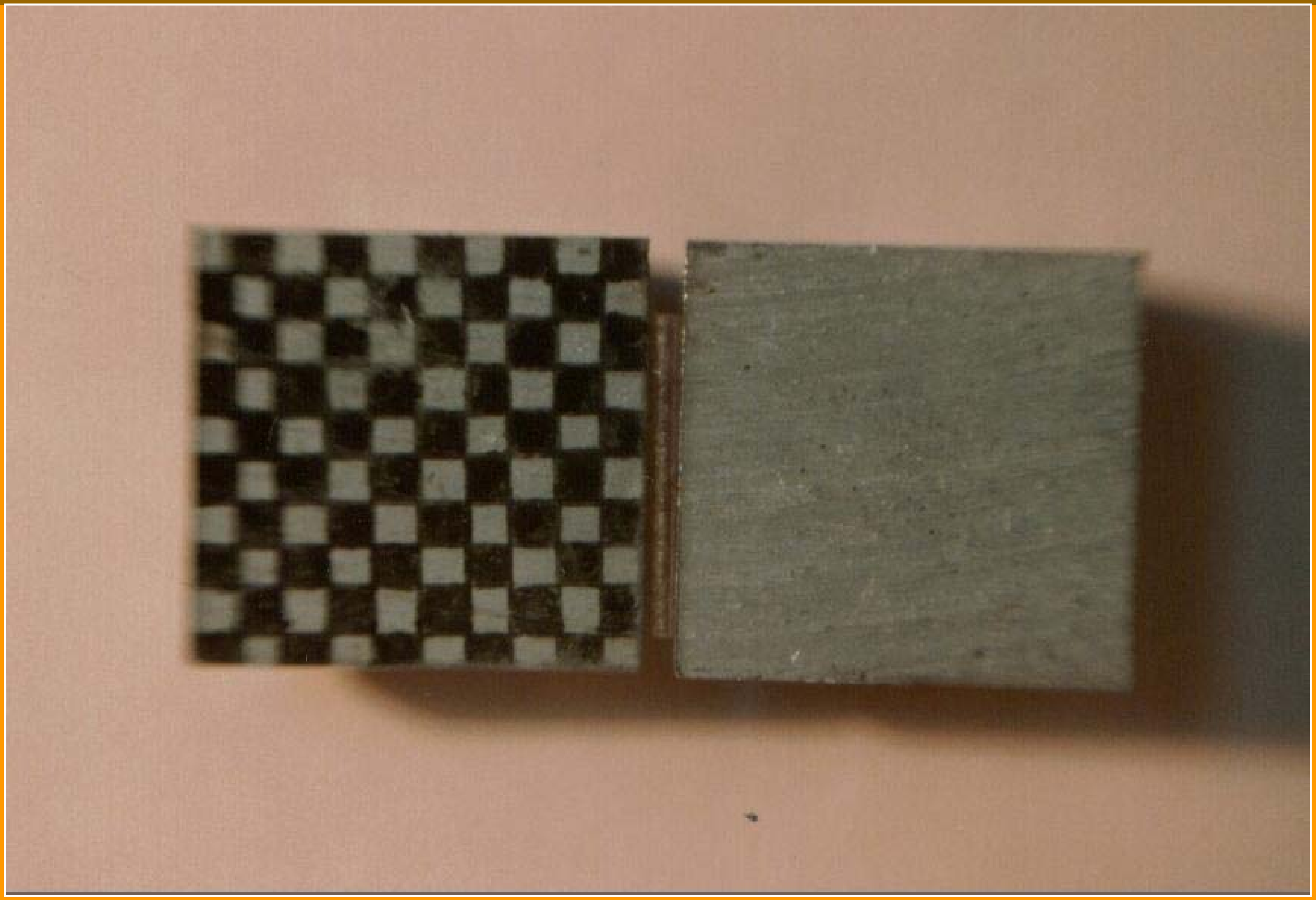
Upper - bound equation

$$J^* = \frac{2}{\sqrt{3}}\sigma_o \int_V \sqrt{\frac{1}{2}\dot{\varepsilon}_{ij}\dot{\varepsilon}_{ij}}\, dV + \int_S K|\Delta V_i|\, dS + \int_{S_m} mK|\Delta V_i|\, dS - \int_{S_T} T_i V_i\, dS$$

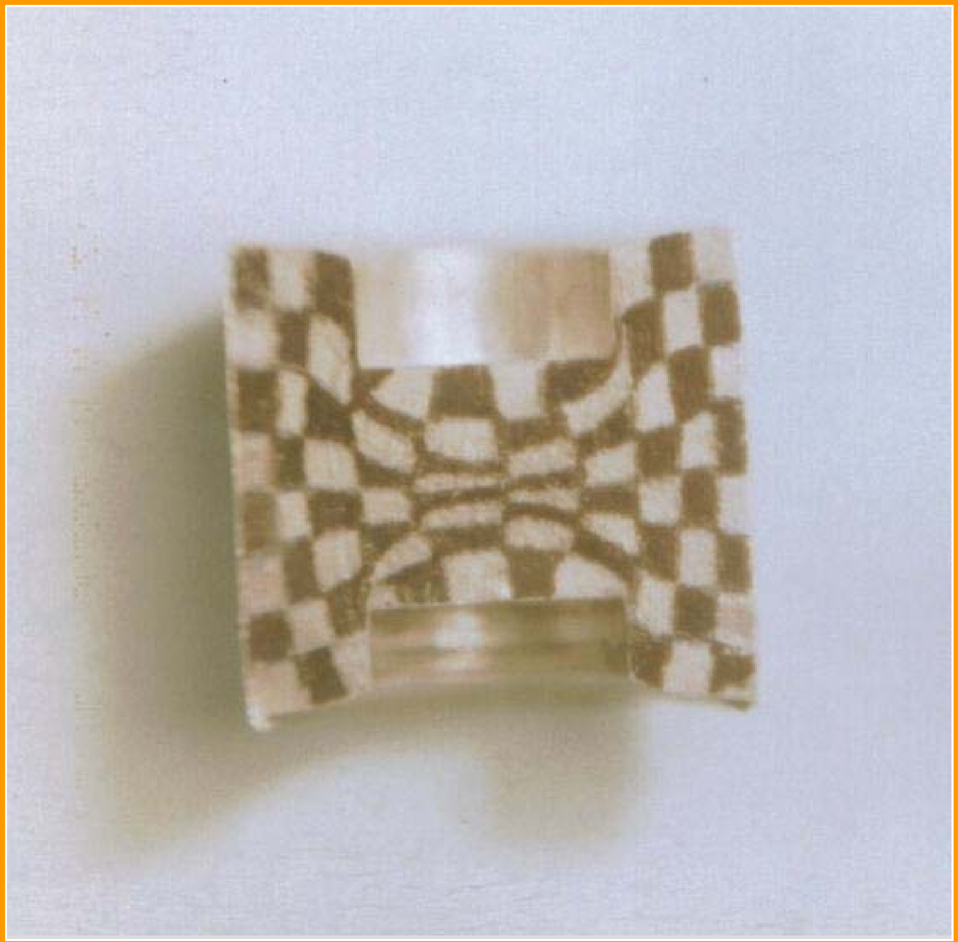
$$
\begin{aligned}
\frac{P}{\sigma_o} = {} & \frac{1-\lambda}{\sqrt{3}R_1{}^2}\Big[\ \frac{1+m}{2T_b}R_1{}^3 + \frac{2\left(2R_o{}^2 - R_oR_1 - R_1{}^2\right)R_1{}^2}{3(R_o+R_1)T_b} + \\
& \frac{(mR_1+R_o)R_oR_1T_b}{R_o{}^2-R_1{}^2} + \sqrt{3}R_1{}^2 + \frac{R_1{}^2}{R_o{}^2-R_1{}^2}(2R_o{}^2 - \sqrt{3R_1{}^4+R_o{}^4} \\
& -R_o{}^2\ln\frac{\sqrt{3R_1{}^4+R_o{}^4}-R_o{}^2}{R_1{}^2}) + \frac{2mR_o{}^2R_1l_1}{R_o{}^2-R_1{}^2}\ \Big] + \frac{mR_o}{\sqrt{3}\left(R_o{}^2-R_1{}^2\right)}(H+T_o-2T) \\
& + \frac{\lambda}{\sqrt{3}R_1{}^2}\Big\{\ \frac{1+m}{2T_f}R_2{}^3 + \frac{2\left(2R_o{}^2-R_oR_2-R_2{}^2\right)R_2{}^2}{3(R_o+R_2)T_b} + \\
& \frac{R_o}{R_o{}^2-R_2{}^2}[m\left(2R_o{}^2-R_2{}^2\right)+R_oR_2]T_f + \\
& \sqrt{3}R_2{}^2 + \frac{R_2{}^2}{R_o{}^2-R_2{}^2}(2R_o{}^2 - \sqrt{3R_2{}^4+R_o{}^4} - R_o{}^2\ln\frac{\sqrt{3R_2{}^4+R_o{}^4}-R_o{}^2}{R_2{}^2}) - \\
& 2mR_oT_b + 2mR_2l_2\frac{R_o{}^2}{R_o{}^2-R_2{}^2} + 2mR_o(T-T_b-T_f) - \\
& \frac{mR_o{}^3}{R_o{}^2-R_1{}^2}(\frac{H+T_o-2T}{2}) + \frac{mR_o{}^3}{R_o{}^2-R_2{}^2}(\frac{H-T_o}{2})\ \Big\}
\end{aligned}
$$

relative extrusion pressure

Original grid before deformation



Experimentally grid distortion



Conclusions

The following conclusions are drawn from this thesis:

- A new test method has been proposed for the evaluation of friction and lubrication.
- As the reduction in area decreases, the cup height ratio (h1/h2) increases.
- For studying friction, r = 25% is suggested as a proper reduction in area.
- Friction calibration curves have been plotted for various lubricants in cold extrusion process.

Conclusions:

- **Present work has shown that in cold extrusion, the solid and semisolid lubricants are generally more effective than liquid lubricants.**
- **Friction has a strong influence on the extrusion force.**
- **The deformation force increases with reduction in area increasing.**

Conclusions:

- The upper - bound approach was used to determining relative extrusion process.
- The comparison of the experimental grid distortions and analytical results showed excellent agreement.

Recommendations:

Future research should be aimed at:

- Finding ratio of cup heights (h1/h2) versus punch stroke at the temperatures above the recrystallisation temperature.
- Finding ratio of cup heights (h1/h2) versus punch stroke under impact forge extrusion conditions.(the strain rate will be important)

- **The study of cup - cup extrusion process by the finite element method(F.E.M.).**
- **fabrication of composite components by using the cup - cup extrusion process.**
- **Investigation of cup - cup extrusion process by means of the noncircular punches.**