PRODUCTION EQUIPMENT

PRESSES

Aim of the subject: Explanation of design principals of different kind presses , their applications, examples, calculations.

SYLABUS OF LECTURES AND EXCERCISES

Class. IV. OS, VS
Profession: 23-19-8 Manufacturing Systems with Industrial Robots
23-20-8 Machines and Equipment for Manufacturing

Semester : Summer
Hours : 3 + 2

LECTURES :

1. INTRODUCTION
   Essential terms and definitions, classification, basic features and requirements
2. THEORY
   Design principals , Energy transmition and accumulation, Work space, Precission, Stiffness, Work Characteristics, Main Parameters
3. MECHANICAL PRESSES
   Crank Mechanism, Stroke and Transmition, Basic Calculations, Efficiency of energy transmition
4. LOAD ANALYSYS
   Calculation of Force, Torque, Friction influence, Jamming of Crank Mechanisms
5. Stepping Stroke Adjustment, Force Changes using double Excentres
6. Energy Transmition during Strike, Efficiency, Design Principles and Calculation of Friction Presses
7. Clutches and Brakes
   Main Requirements, Design Principals , Calculations
8. Frame Structures
   Requirements, Kinds, Calculation
9. HYDRAULIC PRESSES
   Design Principals, Main Power Calculation, Hydraulic Circuits Variety
10. Multiplicators
    Energy Transmition, The Hydraulic Pressure Multiplicators
11. Striking machines
12. Forming machines
13. Transport devices
14. Assembly equipment

1.

EXCERCISES, TUTORIALS

1. Calculation of Deformation Resistance, Acting Force, Resisting Force, Energy
2. Energy accumulation, accumulator calculation, Fly wheel
3. The Work Area Stiffness, Setup of Stroke and Force
4. Acting Force, Torque, Energy Calculation , Efficiency
5. Motor requirements, Torque Check
6. The Transmition Mechanism Design
7. Design and calculation of Clutch and Brake
8. Presses, main parameters selection, feasibility
9. Hydraulic Press Structure
10. Examples on hydraulic circuit design
11. Examples on striking machines , work, structure
12. Examples on forming machines ,
13. Modularity in transpor and assembly devices
14. Test, subject recapitulation, evalution for credit

LITERATURE:

Own notes from lectures and excercises

POKORNY,P.: Text book - set of lecture copies

REQUIREMENTS:

Full attendance of lectures and excercises is supposed, satisfactory reports of developed tasks submitted within gived periodneccessary for credit.

Exam includes written and oral part.

Liberec 17.2.1994

Doc.Ing.Přemysl Pokorný, CSc.

2.

QUESTIONS 2 - PRESSES

1. DEFINITION OF FORMING MACHINES, DIFFERENTIATION OF FORMING MACHINES, DEFINITION OF WORKING AREA

2. COMPARISON OF ENERGY CONSUMPTION TO MACHINE TOOLS, DEFINITION OF SPECIFIC RESISTANCE COEFFICIENT, TOOL SPEED AND DEFORMATION SPEED.

3. ENERGY ACCUMULATORS, CALCULATION OF POWER REQUIRED AND WORK TIME RATIO COEFFICIENT, CONDITIONS FOR DIRECT OR ACCUMULATOR DRIVE

4. WORKING AREA STIFFNES, BALANCING OF PART STIFNESSES, PERFORMANCE PRECISSION

5. BASIC TECHNICAL PARAMETERS, DEFINITIONS OF ACTING FORCE, RESISTING FORCE, EFFICIENT ENERGY, EFFICIENCY

6. WORK CHARACTERISTICS, THE COEFFICIENT OF CHARACTERISTICS USAGE , TWO BASIC CHARACTERISTIC TYPES AND THE WORK AREA STIFFNES INFLUENCE

7. DIFFERENT MECHANISMS USED IN PRESS DESIGN, SPECIFICATIONS OF PRESSES WITH ACTING FORCE DEPENDENCY

8. ANALYSYS OF CRANK MECHANISM, DEVELOPMENT OF STROKE FUNCTION AND TRANSIENT FUNCTION

9. ANALYSYS OF ACTING FORCE, RESISTANT TORQUE ON EXCENTICAL SHAFT.

10. STEPPED STROKE ADJUSTMENT BY DOUBLE EXCENTER, FORCE CHANGES

11. ANALYSYS OF FORCE LOADS ON CRANK MECHANISM, FRICTION ARM , JAMMING CONDITIONS AND RELEASING POSSIBILITY.

12. CONDITIONS FOR GEAR WHEELS, SHAFTS, AND TRANSMITION RATIOS DESIGN

13. CLUTCHES USED IN MECHANICAL PRESSES, CALCULATION OF POSITIVE CLUTCH, CONDITIONS AND DESIGN OF FRICTIONAL CLUTCH

14. BRAKES, PURPOSE , OPPERATION, DESIGN

15. LEVER ARM CALCULATION AND DESIGN

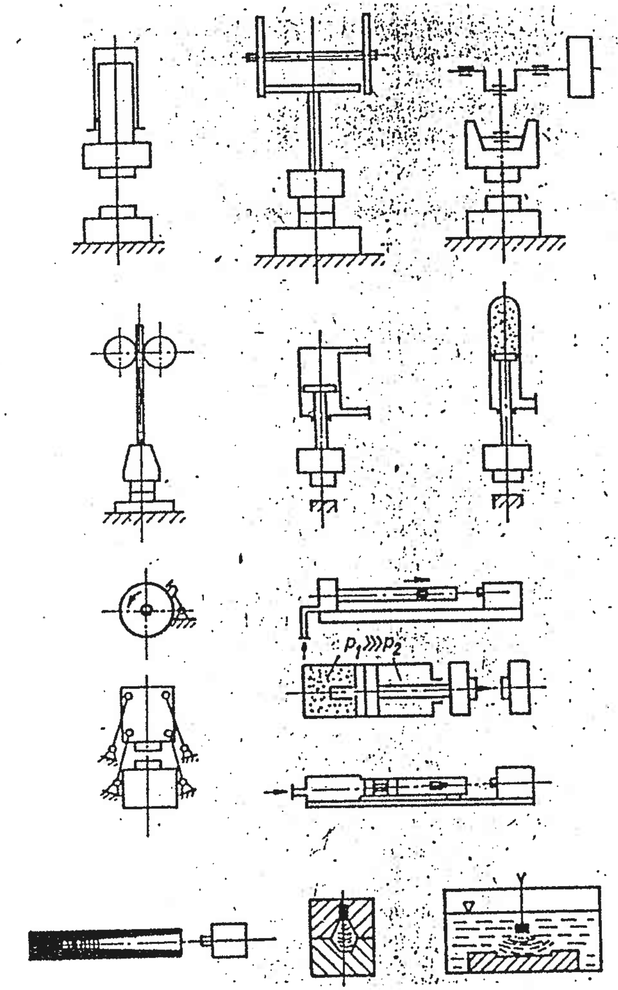
16. STAND TYPES AND CALCULATIONS ("C" OR "O")

17. STRIKING ENERGY EXCHANGE

18. FRICTIONAL PRESSES, DESIGN , CALCULATION

DIFFERENIATION OF FORMING MACHINES

I



I. SPEED $V_s \leq 0{,}5\ m\,s^{-1}$

II. SPEED $V_s = 5 \div 10\ m s^{-1}$

III. SPEED $V_s \leq 30\ m s^{-1}$

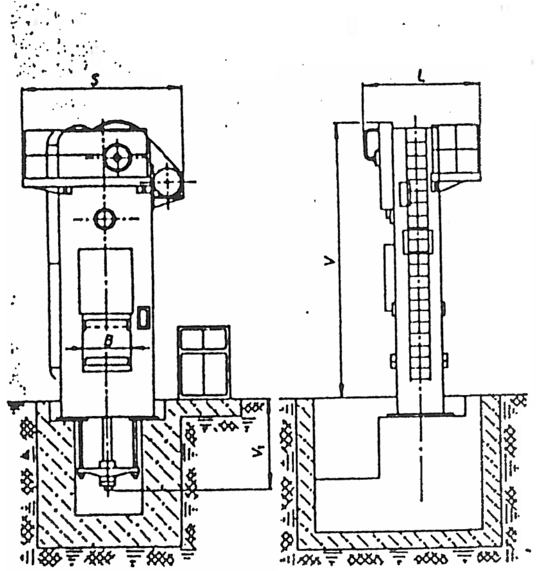
IV. SPEED $V_s \leq 300\ m s^{-1}$

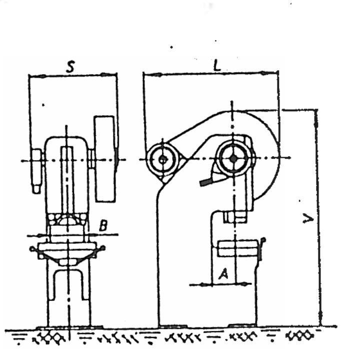
II

III

IV

xplanations relating to certain technical data of mechanical forming machines.





Nominal pressure (force) (Mp) in the maximum force allowed to load the press.
Effective stroke (mm or °) is the distance of the slide from the lower dead point within which the nominal pressure (force) can be exerted.
Number of strokes of slide is the number of movements of the slide throughout the stroke length between its dead points per minute in continuous idle motion.
Number of utilizable strokes of slide is the maximum allowed number of individual repeated strokes of the slide per min.
Throat A (mm) is the perpendicular distance between axis of slide and face of frame in the working space.
Width between uprights (columns) B (mm) is the minimum distance of the internal surfaces of the frame under the slide guide.
Width between uprights (columns) B_1 (mm) is the distance between internal surfaces of slide guides.

Dimensions of press (from operator's place):

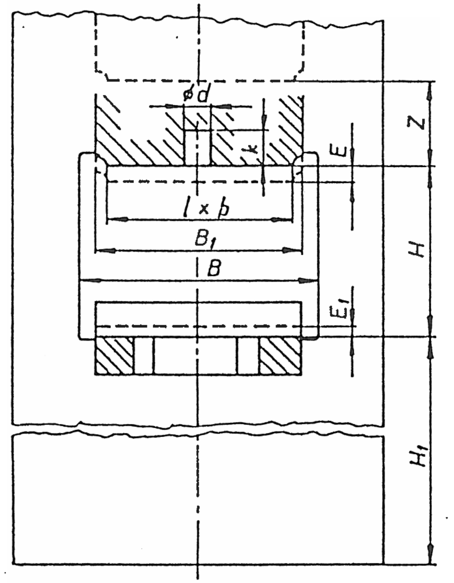
S (mm) is the maximum dimension of press from left to right, termed also length,

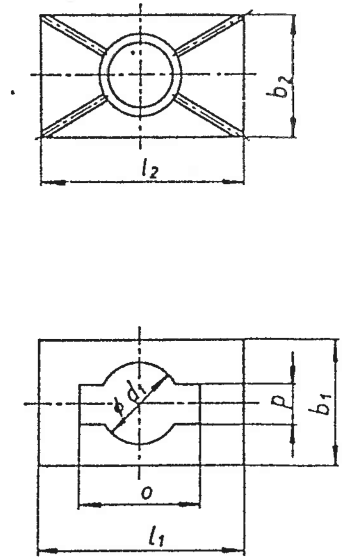
L (mm) — maximum dimensions of press from front to rear, also termed width,

V (mm) — height of press above floor,

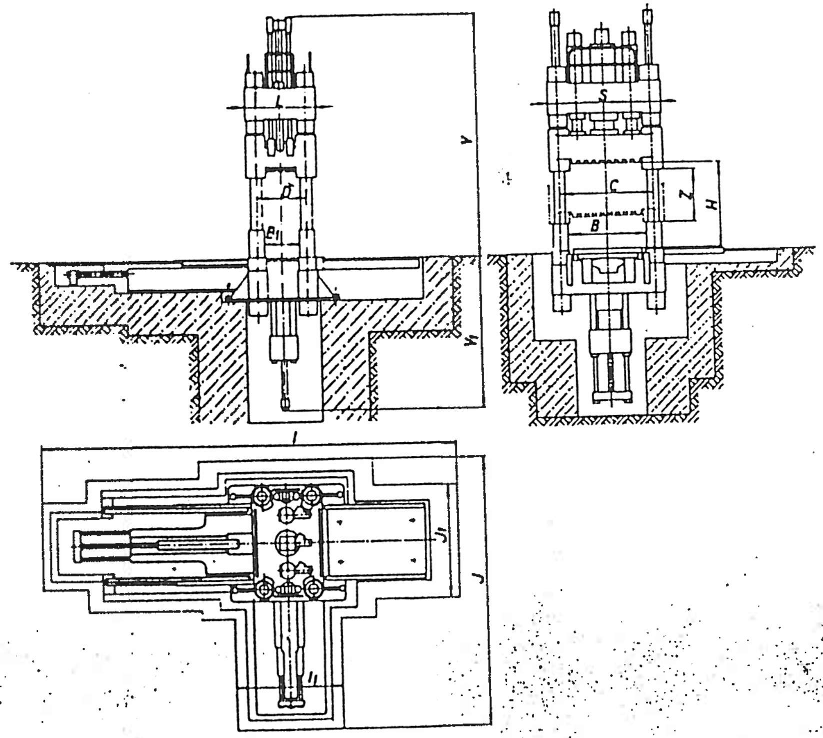
V_1 (mm) — height of press or its equipment below floor.

Stroke Z (mm) is the path of the slide between its dead points.





Shut height H (mm) is the distance between the clamping surfaces of bed and slide in its bottom dead point (with eccentric presses at maximum stroke) with slide adjustment E up and bed adjustment E_1 down.
Slide adjustment E (mm) is the distance, by which the shut height H can be reduced.
Bed adjustment E_1 (mm) is the distance, by which the shut height H can be reduced.
Clamping (working) surface of slide 1 × b (mm) is destinated for mounting of the top portion of the tool.
Clamping hole in slide ⌀ d/k (mm) is destinated to receive or center the top portion of the tool. Its axis is identical with the slide axis.
Clamping (working) surface of table $l_1 \times b_1$ (mm) is destinated for mounting of the bottom portion of tool or clamping plate.
Hole in bed ⌀ d_1/oxp (mm) is a through opening in the center of the clamping area of the bed for the removal of waste, pressings or for the use of a die cushion.
Clamping bed plate of dimensions $l_2 \times b_2$ (mm) and thickness h_2 (mm) is a baseplate for the bottom portion of the tool. It is fitted with clamping slots and outlet opening.
Working height H_1 (mm) is the distance between clamping surface of press bed and floor. With eccentric presses having an adjustable bed the working height is determined by the mean position of bed.
Weight of press (kg) is the approximate weight of a complete press incl. standard accessories.
Note: For all forming machines having a clutch, brake or other device actuated by compressed air a pressure of air 6 kp/cm² in the supply line is required.



Forming or working force (pressure — Mp) termed also according to the type of operation performed, f. i. pressing, precompressing, complementary compression, closing, straightening, bending, extrusion, is the maximum force permitted to load the press.
Return force (Mp-kp) (force of return pull of working cylinders), force of return auxiliary cylinders is the force which moves a working element (plunger, piston) or mechanism to its initial position.
Speeds (mm/s) are denominated according to the type of operations or movements of working elements for example pressing, extrusion, approach, descent, closing, return speed etc. (The approach or descent speed is that speed at which the movable element of the tool approaches the stationary element of the tool or the working space, usually at low pressure).
Maximum (minimum) daylight H of press (mm) is the maximum (minimum) possible distance of clamping (working) surfaces.
Stroke Z (mm) in the maximum possible length of travel of the pressing crosspiece (pressing platen, slide).
Width between uprights B, B1 (mm) is the minimum possible distance between internal surfaces of columns or walls of uprights in the longitudinal or transverse axis of press.
Throat A (mm) is the minimum distance of axis of pressing crosspiece (pressing platen, slide) from that surface of frame which defines the working space.
Spacing of columns C, D (mm) is the distance of column axis in the longitudinal or transverse axis of machine.
Clamping (working) surface (mm) is the surface designed for clamping of tools.

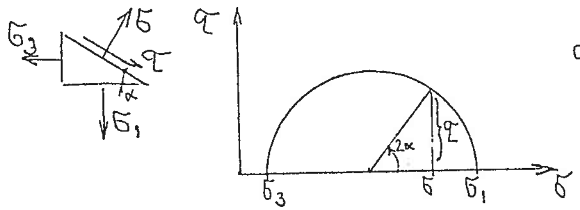
Dimensions of press (from the operator's place):

S (mm)	maximum dimension of press from left to right, also termed length
L (mm)	maximum dimension of press from front to rear, also termed width
V (mm)	height of press above floor
V1 (mm)	height of press or its equipment below floor
I/I1 (mm)	are plan dimensions of press foundation in the longitudinal axis of press
J/J1 (mm)	are plan dimensions of press foundation in the transverse axis of press

SPECIFIC DEFORMATION RESISTANCE

DEF. . – UNDERSTOOD MASS RESISTANCE (FORMED) AGAINST MAXIMUM STRESS IN MAXIMUM DEFORMATION DIRECTION

MOORE THEORY ANALYSYS ; (MULTI AXIAL STRESS)



$$\tau = \frac{\sigma_1 - \sigma_3}{2} \cdot \sin 2\alpha$$

$max\ \alpha = 45°$

$$\tau_{max} = \frac{\sigma_1 - \sigma_3}{2}$$

$\sigma_1 - \sigma_3 = 2\,\tau_{max} \rightarrow k_p\ [Nm^2]$ – FORMING STRENGTH

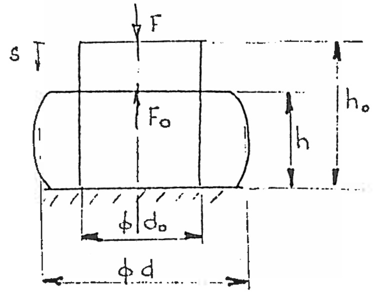
$k \hat{=} \sigma_1 = k_p + \sigma_3$ – DEFORMING RESISTANCE

$k_p \rightarrow R_e - (\sigma_k) \sim$ Yield STRESS – small deformations

$k_p \rightarrow R_m - (\sigma_p) \sim$ FATIGUE STRESS – large deformations

$k = R_e \cdot \left(1 + \frac{1}{3}\mu \cdot \frac{d}{h}\right)$ – IN PRESSING (FORGING)

μ – POISONE CONSTANT ≈ 0,35



RESISTANT FORCE

$F_0 = k \cdot S$

k – SPEC. DEF. RESISTANCE
S – CROSS SECTION AREA

S – CHANGES → $V \hat{=}$ CONSTANT

$$V_0 = \frac{\pi d_0^2}{4} \cdot h_0 = \frac{\pi d^2}{4} \cdot h = V \Rightarrow$$

$$d = d_0 \cdot \sqrt{\frac{h_0}{h}} \ ; \ S = \frac{V_0}{h}$$

THEN $F_0 = R_e \cdot \left(1 + \frac{1}{3}\mu \cdot \frac{d}{h}\right) \cdot \frac{V}{h}$

$$= R_e \cdot \frac{V}{h_0 - s}\left(1 + \frac{1}{3}\mu \cdot d_0 \sqrt{\frac{h_0}{(h_0 - s)^3}}\right)$$

SPECIFIC DEFORMATION COEFFICIENT [MPa]

WORK CHARACTER	ALUMINIUM	BRASS	STEEL
FORGING MEDIUM	400 ÷ 700	1000-1600	1200-2000
GREAT	600 ÷ 800		
CALIBRATION	1000÷1200	1000-1600	1200-2000
EXTRUSION	400÷700	1000-1600	1200-2000
	800÷1200	1800-2500	2000-3000
DEEP DRAWING	800-1200	1600-2000	2500-3000
SHEERING	173+0,23 Rm	171+0,285 Rm	110+0,56 Rm

Fj ≙ (1,2÷1,3) Fom ;   Fom ≑ p.S [N]

PROGRESSION OF PRESS SIZES   Rm = FATIGUE - STRESS

GEOM.PROGRESSION R5 = $\sqrt[5]{10}$ = 1,6   Fj [MN;(kN)]

I. 0,08   0,125   0,2   0.32   0,5   0,8   1,25   2 ....

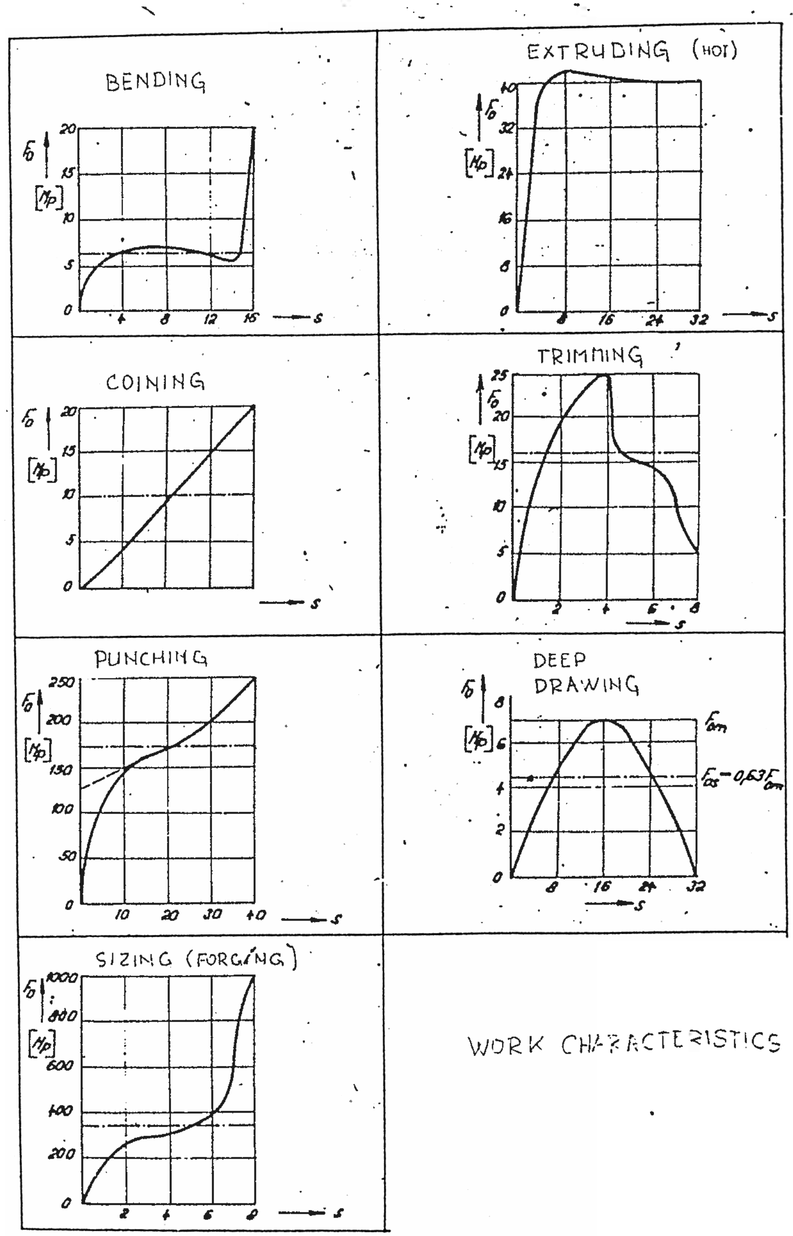
II. 0,063   0,1   0,16   0,25   0,4   0,63   1   1,6 ...

PRECISSION - GRADE   STIFFNESS (WORKING AREA)

I. c = (2 ÷ 3) $\sqrt{Fj}$ [MN mm⁻¹]

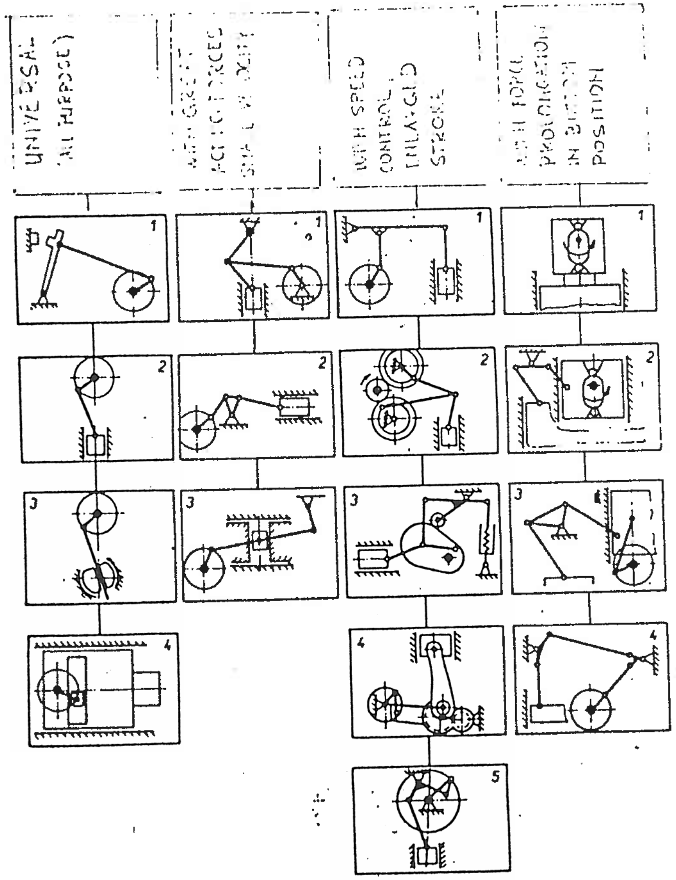
II. c = (1,5 ÷ 2) $\sqrt{Fj}$

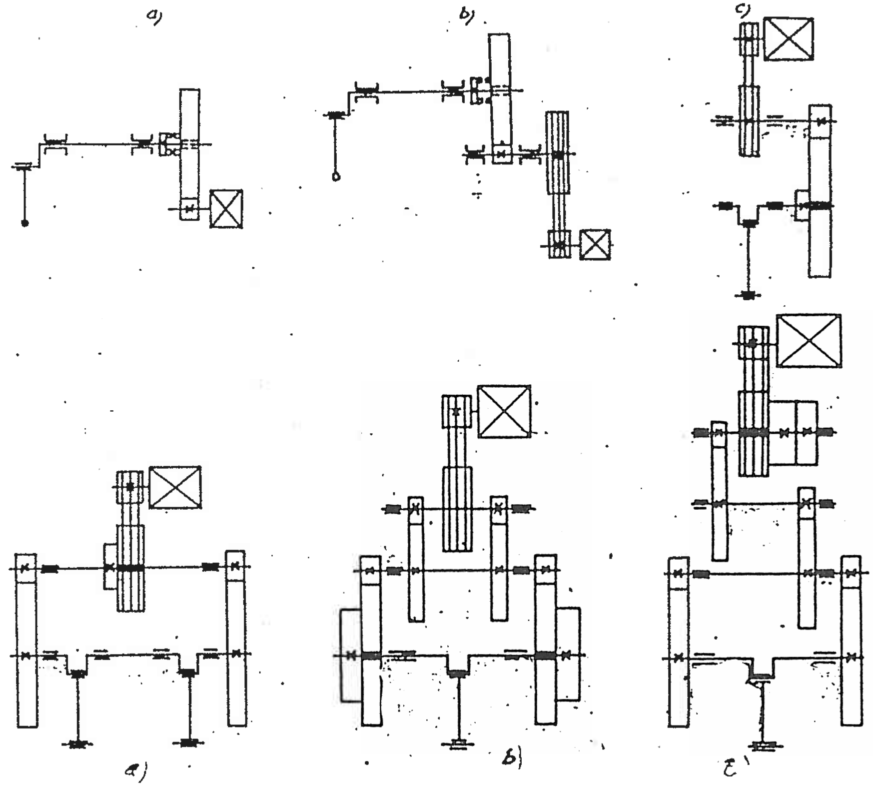
III. c = (1 ÷ 1,5) $\sqrt{Fj}$

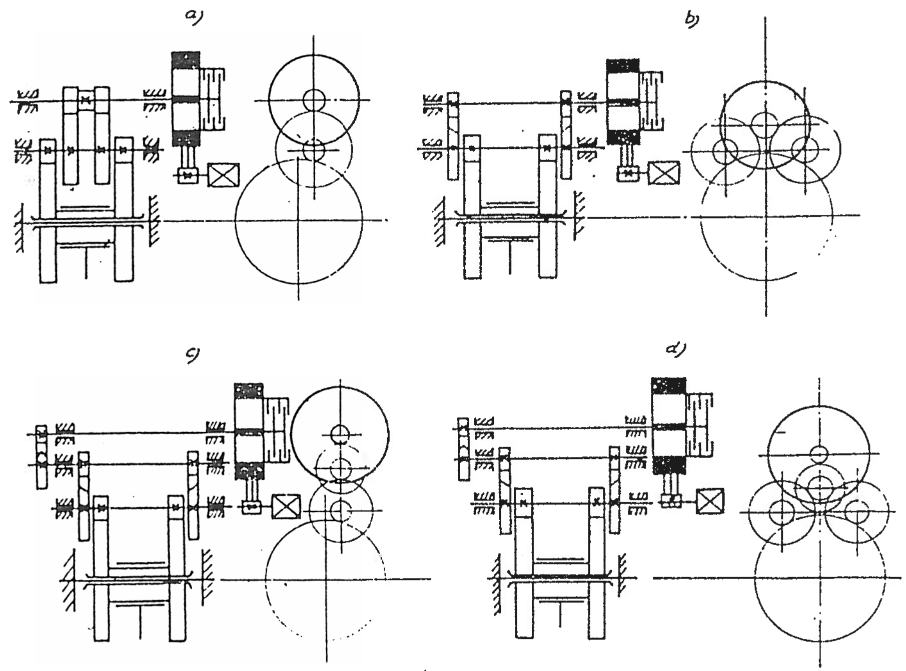


WORK CHARACTERISTICS

MECHANISMS USED [illegible]

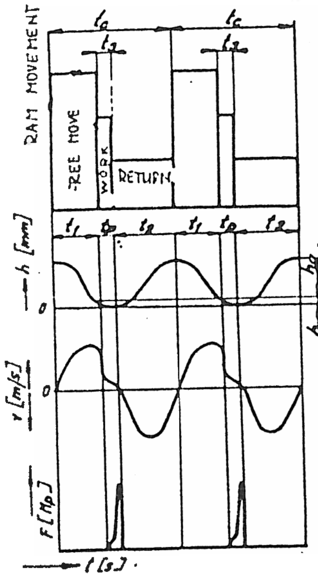




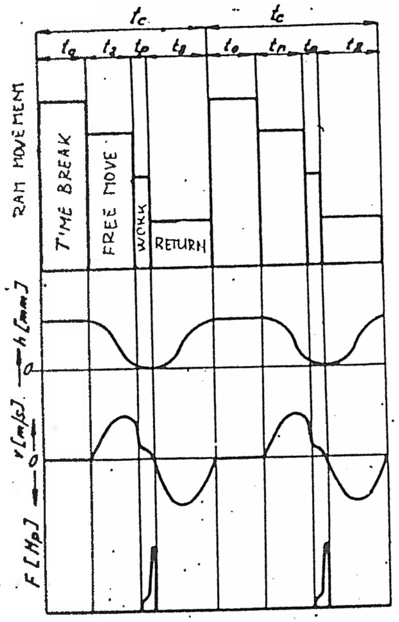


WORK CYCLE

CONTINUOUS



INTERUPTIVE



GRADE (RATIO) OF CYCLE TIME EFFICIENCY COEFFICIENT $\quad K_t = \frac{t_p}{t_c} \leq 1$

$$A_c = P_j \cdot t_c = P_{max} \cdot t_p \quad \rightarrow \quad \frac{t_p}{t_c} = \frac{P_j}{P_{max}} = \frac{1}{K_p} = \frac{1}{(2.5 \div 3)} = (0.3 \div 4)$$

$$P_j = \frac{A_c}{t_c} = \frac{1}{t_c} \int_0^{t_c} P(t)\,dt \qquad \text{POWER}$$

IF $K_t < 0.4$ INDIRECT DRIVE

$K_t > 0.4$ DIRECT DRIVE

ENERGY ACCUMULATORS

1. FLY WHEEL - KINETIC ENERGY ACCUMULATOR

ENERGY OF ROTATING CYLINDER $\quad W = \frac{1}{2} I \omega_0^2$

ν - SLIP COEFFICIENT $= 0.29$ INTERUPTIVE CYCLE

$= 0.13$ CONTINUOUS CYCLE

$$\nu = \frac{\omega_0 - \omega_1}{\omega_0} \; ;$$

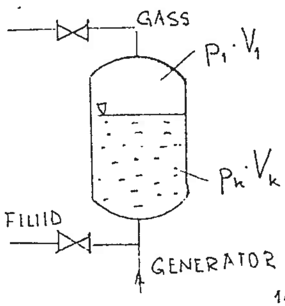
ENERGY CONSUMPTION $\quad \Delta W = \frac{1}{2} I (\omega_0^2 - \omega_1^2)$

$$\frac{\Delta W}{W} = Z \text{ - USABILITY GRADE (RATIO)} = \frac{(\omega_0^2 - \omega_1^2)}{\omega_0^2} = \frac{\omega_0 - \omega_1}{\omega_0} \cdot \frac{2\omega_0 - (\omega_0 - \omega_1)}{\omega_0}$$

$$Z = \nu \cdot (2 - \nu) \;\begin{cases} = 0.5 & \text{- INTERUPTIVE} \\ = 0.25 & \text{- CONTINUOUS} \end{cases}$$

$$I = \frac{\pi (D^4 - d^4)}{32} \cdot \rho \cdot h \; ; \quad \Delta W \cong A_u \; ; \quad W = \frac{A_u}{Z} \; ;$$

2. HYDRAULIC ACCUMULATOR - PRESSURE ENERGY



$W = p_1 \cdot V_1$ - HYDRAULIC ACC. ENERGY

$\nu_p = \frac{p_1 - p_2}{p_1}$ - PRESSURE DROP COEFF. $= 0.1$

ENERGY CONSUMPTION $\quad \Delta W = \Delta V_k \cdot p_s$

WHERE $\quad p_s = \frac{p_1 + p_2}{2} = \frac{p_1}{2} (2 - \nu_p)$

1. ISOTHERMIC PROCESS $\quad T = \text{CONSTANT}$

$$\underline{1.} \quad p_1 \cdot V_1 = p_2 \cdot V_2 \; ; \quad \Delta V_k = V_2 - V_1 = V_1 \left(\frac{V_2}{V_1} - 1\right) = V_1 \left(\frac{p_1}{p_2} - 1\right) =$$

$$= V_1 \left(\frac{1}{1 - \nu_p} - 1\right) = V_1 \cdot \frac{\nu_p}{1 - \nu_p}$$

THEN $\quad \Delta W = V_1 \cdot p_1 \cdot \frac{2 - \nu_p}{2} \cdot \frac{\nu_p}{1 - \nu_p} = W \cdot Z_p \qquad [Z_p = 0.106]$

2. POLYTROPIC PROCESS $\quad m = 1.4$

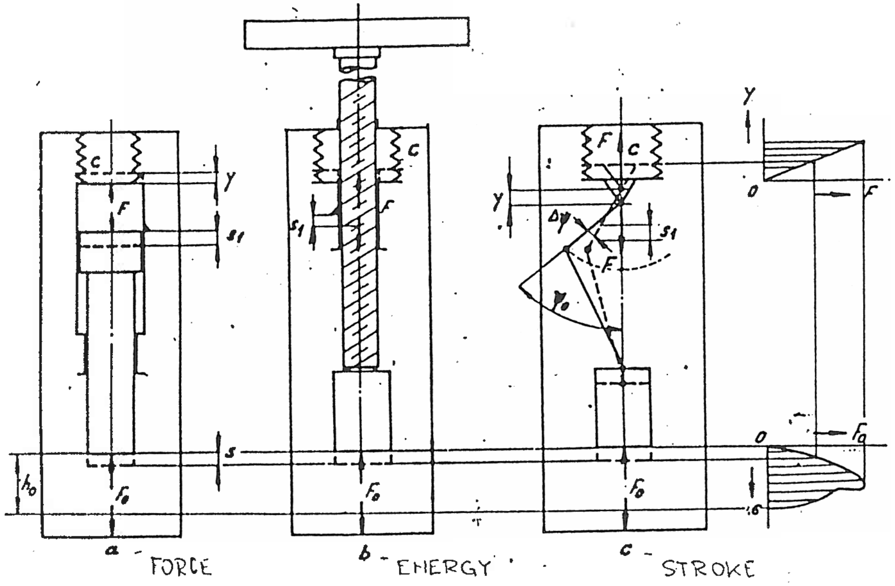
$$\underline{2.} \quad p_1 \cdot V_1^m = p_2 \cdot V_2^m \; ; \quad \Delta V_k = V_2 - V_1 = V_1 \left(\frac{V_2}{V_1} - 1\right) = V_1 \left(\left(\frac{p_1}{p_2}\right)^{\frac{1}{m}} - 1\right) =$$

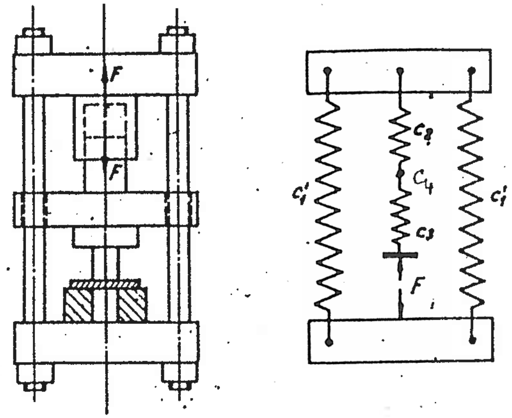
$$= V_1 \left(\left(\frac{1}{1 - \nu_p}\right)^{\frac{1}{m}} - 1\right)$$

THEN

$$\Delta W = V_1 \, p_1 \cdot \frac{2 - \nu_p}{2} \cdot \left\{\left(\frac{1}{1 - \nu_p}\right)^{\frac{1}{m}} - 1\right\} = W \cdot \bar{Z}_p \qquad [\bar{Z}_p = 0.08]$$

Z_p - USABILITY GRADE (RATIO)





c_r = structure stiffnes

$c_r = c_1' + c_1' = 2c_1$

c_m = stiffnes of mechanizm

$\frac{1}{c_m} = \frac{1}{c_2} + \frac{1}{c_3} + \frac{1}{c_4}$ Rigidity

The total work area RIGIDITY : $\frac{1}{c}$

$$\frac{1}{c} = \frac{1}{c_r} + \frac{1}{c_m}$$

WORK AREA STIFFNES

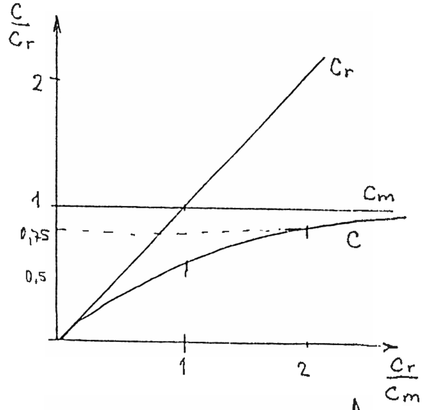
$$c = \frac{c_r \cdot c_m}{c_r + c_m}$$

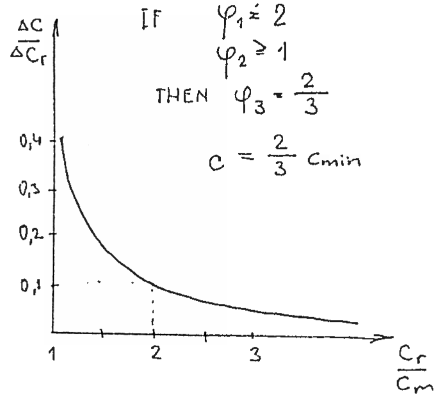
IF $c = \frac{c_r \cdot c_m}{c_r + c_m}$ → THEN $\frac{c}{c_r} = \frac{c_m}{c_r + c_m} = \frac{1}{1 + \frac{c_r}{c_m}} \Rightarrow \frac{\Delta c}{\Delta c_r}$

SUGGEST $\frac{c_r}{c_m} \geq 1 = \varphi_1$ & → $c_r = \varphi_1 \cdot c_m$

$$c = \frac{c_r}{1 + \frac{c_r}{c_m}} = \frac{\varphi_1 \cdot c_m}{1 + \varphi_1}$$

IF $\frac{c_{min}}{c_m} \leq 1 = \varphi_2$ THEN $c = \frac{\varphi_1}{1+\varphi_1} \cdot \frac{c_{min}}{\varphi_2} \doteq \frac{1}{\varphi_3} \cdot c_{min}$

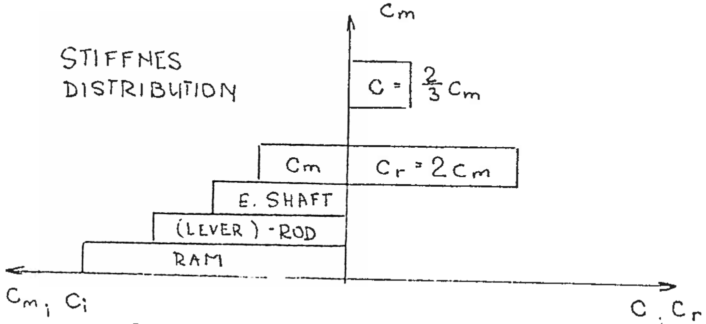


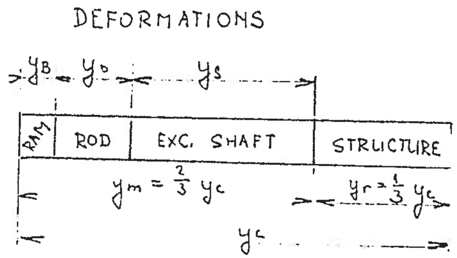


IF $\varphi_1 \doteq 2$, $\varphi_2 \geq 1$

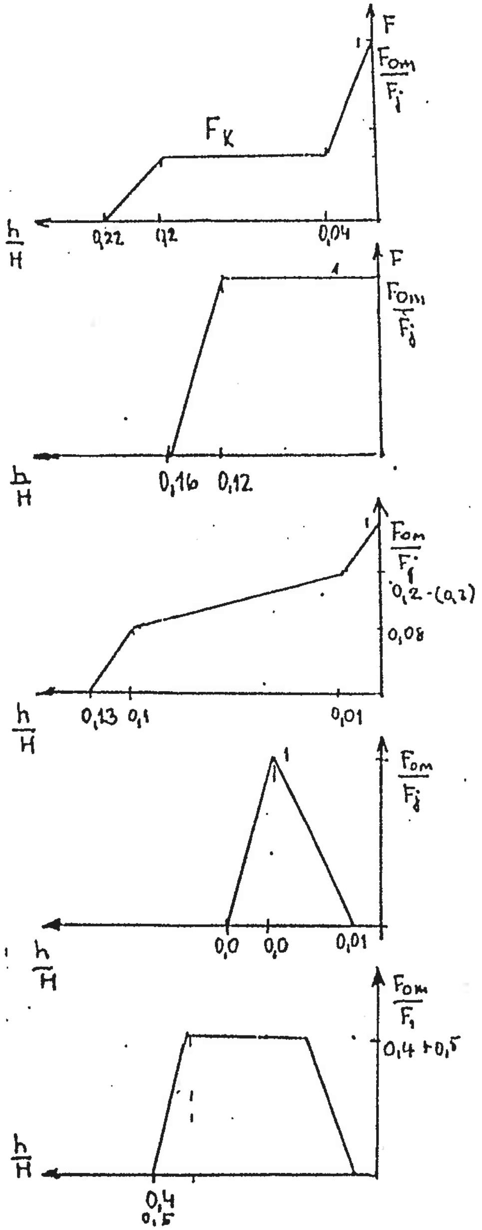
THEN $\varphi_3 = \frac{2}{3}$

$$c = \frac{2}{3} c_{min}$$





WORK CHARACTERISTICS + MACHINE RATIOS



1. FRESSING (HOT) T ≥ (0,6–0,7) Tт
   BENDING

   $\frac{h}{H} = 0,15$; $F_K \doteq 0,3\ F_{om}$

   BENDING

   $\frac{h}{H} = 0,22$ $F_K \doteq 0,32\ F_{om}$

2. COLD FRESSING T ≤ (0,4–0,5) Tт

   (EXTRUDING)

   $\frac{h}{H} = 0,16$

3. FORGING

   $\frac{h}{H} = 0,13$

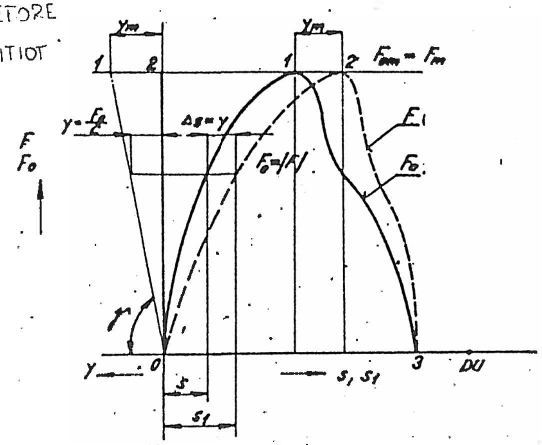
4. TRIMMING

   $\frac{h}{H} = 0,007$

5. DEEP DRAWING

   $\frac{h}{H} = 0,4$ Fom 0,4 Fj

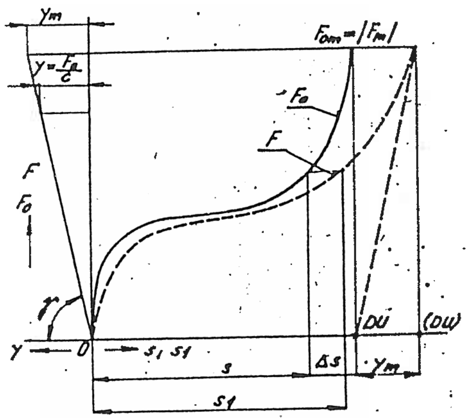
1. END BEFORE BOTTOM POSITION

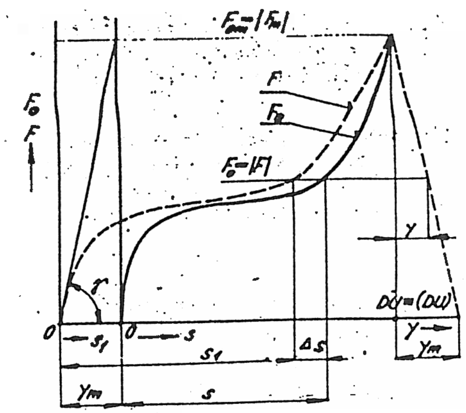


$$s_1 = s + \frac{F_o}{c} = s + \frac{F}{c}, \qquad \Delta s = s_1 - s = \frac{F_o}{c} = y$$

$$h(\bar{\varphi}_z) = h - \frac{F_o}{c}$$

2. END AT BOTTOM POSITION – NEEDS NEGATIVE SHUT SETTING



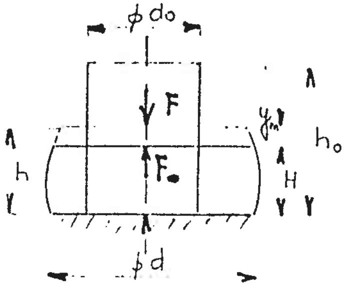


$$y_m = \frac{F_{om}}{c} \; ; \; \Delta s = y = \frac{F_o}{c}$$

$$s_1 = s + y_m - \Delta s = s + \frac{F_{om} - F_o}{c}$$

$$h(\bar{\varphi}_z) = h + \frac{F_{om} - F_o}{c}$$

PRECISION



FORCE BALANCE AT BOTTOM POSITION

$$F_o - F_m = 0$$

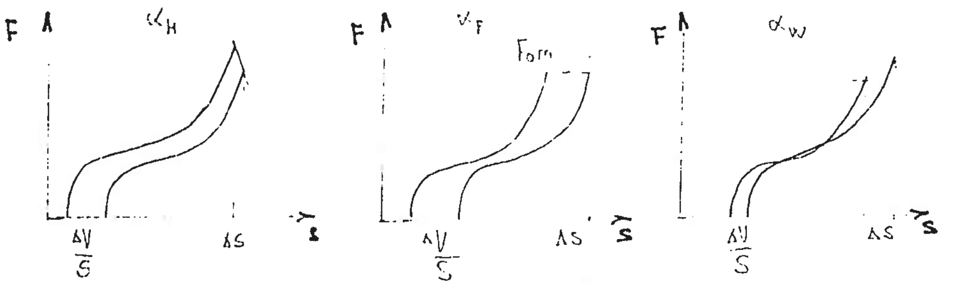
$$F_o = R_e \cdot \frac{V}{h} \left(1 + \frac{1}{3}\mu \cdot \frac{d}{h}\right) \approx k \cdot S$$

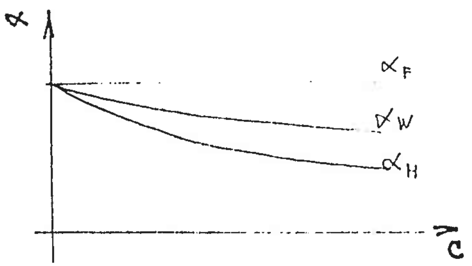
$$F_m = c \cdot y_m = c \cdot [h - H]$$

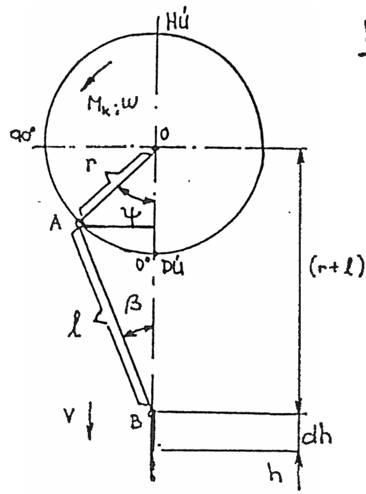
$$R_e \cdot V = c \cdot (h - H) \cdot h$$

$$ch^2 - cH \cdot h - R_e \cdot V = 0$$

$$h_{1,2} = \frac{1}{2}\left\{H + \sqrt{H^2 + 4\frac{R_e \cdot V}{c}}\right\} \Rightarrow \frac{dh}{dV} = \frac{R_e}{c\sqrt{H^2 + 4\frac{R_e \cdot V}{c}}} \approx \frac{\Delta h}{\Delta V} = \alpha_H$$







$$h = r(1 - \cos\psi) + l(1 - \cos\beta) \quad \text{- STROKE}$$

$$r \cdot \sin\psi = l \cdot \sin\beta \Rightarrow \sin\beta = \frac{r}{l} \cdot \sin\psi$$

$$\frac{r}{l} = \lambda \cdot \quad \lambda = 0{,}06 \div 0{,}25$$

$$\cos\beta = \sqrt{1 - \sin^2\beta} = \sqrt{1 - \lambda^2 \cdot \sin^2\psi}$$

Binomial PROGRESION

$$\{1 - (\lambda^2 \sin^2\psi)\}^{\frac{1}{2}} = 1 - \frac{\lambda^2}{2}\sin^2\psi + \frac{\lambda^2}{8} \cdot \sin^4\psi$$

STROKE FUNCTION

$$h(\psi) = r\left(1 - \cos\psi + \frac{\lambda}{2}\sin^2\psi\right)$$

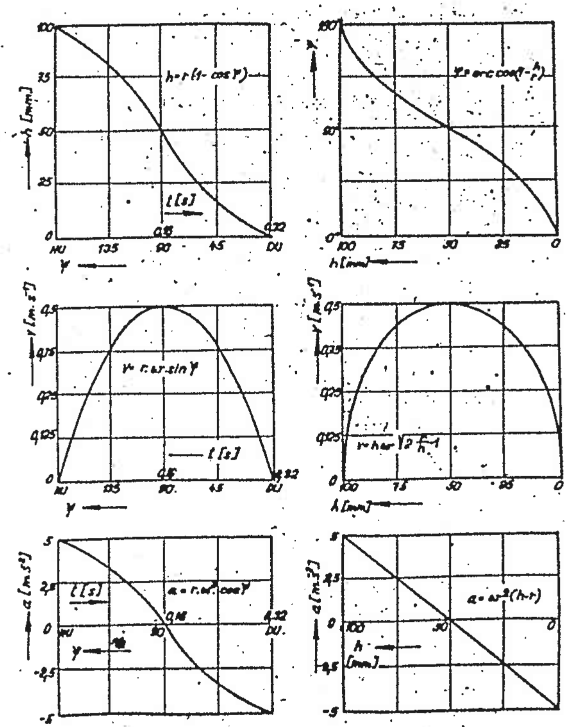
TRANSIENT FUNCTION

$$\frac{dh}{d\psi} \cdot \frac{1}{r} = \left(\sin\psi + \frac{\lambda}{2} \cdot \sin 2\psi\right) \rightarrow i(\psi)$$

$$h(t) = r \cdot \left(1 - \cos\omega t + \frac{\lambda}{2}\sin^2\omega t\right) \quad \text{STROKE}$$

$$v = \frac{dh}{dt} = r\left(\sin\omega t + \frac{\lambda}{2}(2\sin\omega t \cos\omega t)\right) \cdot \omega = r \cdot \omega\left(\sin\psi + \frac{\lambda}{2}\sin 2\psi\right) \quad \text{SPEED}$$

$$a = \frac{dv}{dt} = r \cdot \omega^2 (\cos\psi + \lambda \cos 2\psi) \quad \text{ACCELERATION}$$



$$\psi = \arccos\left(1 - \frac{h}{r}\right)$$

$$v = h \cdot \omega\sqrt{2\frac{r}{h} - 1}$$

$$a = \omega^2 (h - r)$$

STROKE FUNC. $h/r = (1-\cos\alpha) + \frac{\lambda}{4}(1-\cos 2\alpha)$

α°	λ 0,50	0,40	0,30	0,25	0,20	0,18	0,16	λ 0,14	0,12	0,10	0,08	0,06	0,04	0,02
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0,0057	0,0053	0,0049	0,0047	0,0046	0,0045	0,0044	0,0043	0,0043	0,0043	0,0041	0,0040	0,0039	0,0039
10	0,0227	0,0212	0,0197	0,0190	0,0182	0,0179	0,0176	0,0173	0,0170	0,0167	0,0164	0,0161	0,0158	0,0155
15	0,0508	0,0476	0,0441	0,0425	0,0408	0,0401	0,0395	0,0388	0,0381	0,0374	0,0368	0,0361	0,0354	0,0348
20	0,0895	0,0837	0,0778	0,0749	0,0720	0,0708	0,0697	0,0685	0,0673	0,0662	0,0650	0,0638	0,0626	0,0615
25	0,1383	0,1294	0,1205	0,1160	0,1116	0,1098	0,1080	0,1062	0,1044	0,1026	0,1008	0,0990	0,0973	0,0955
30	0,1965	0,1840	0,1715	0,1652	0,1590	0,1565	0,1540	0,1515	0,1490	0,1465	0,1440	0,1415	0,1390	0,1365
35	0,2630	0,2466	0,2301	0,2219	0,2137	0,2104	0,2071	0,2038	0,2005	0,1972	0,1940	0,1907	1,1874	0,1841
40	0,3373	0,3166	0,2960	0,2856	0,2753	0,2712	0,2670	0,2629	0,2588	0,2547	0,2505	0,2464	0,2423	0,2381
45	0,4179	0,3929	0,3679	0,3554	0,3429	0,3379	0,3329	0,3279	0,3229	0,3179	0,3129	0,3079	0,3029	0,2979
50	0,5039	0,4746	0,4452	0,4305	0,4159	0,4100	0,4041	0,3983	0,3924	0,3865	0,3807	0,3748	0,3689	0,3631
55	0,5941	0,5606	0,5270	0,5103	0,4935	0,4868	0,4801	0,4734	0,4667	0,4599	0,4532	0,4465	0,4398	0,4331
60	0,6875	0,6500	0,6125	0,5937	0,5750	0,5675	0,5600	0,5525	0,5450	0,5375	0,5300	0,5225	0,5150	0,5075
65	0,7827	0,7417	0,7006	0,6801	0,6595	0,6513	0,6431	0,6349	0,6267	0,6185	0,6102	0,6020	0,5938	0,5856
70	0,8787	0,8346	0,7904	0,7684	0,7463	0,7375	0,7286	0,7198	0,7110	0,7021	0,6933	0,6845	0,6757	0,6668
75	0,9744	0,9278	0,8811	0,8578	0,8345	0,8252	0,8158	0,8065	0,7972	0,7878	0,7785	0,7692	0,7599	0,7505
80	1,0689	1,0204	0,9719	0,9476	0,9234	0,9137	0,9040	0,8942	0,8846	0,8749	0,8652	0,8555	0,8458	0,8360
85	1,1609	1,1113	1,0617	1,0368	1,0120	1,0021	0,9922	0,9823	0,9723	0,9624	0,9525	0,9426	0,9326	0,9227
90	1,2500	1,2000	1,1500	1,1250	1,1000	1,0900	1,0800	1,0700	1,0600	1,0500	1,0400	1,0300	1,0200	1,0100

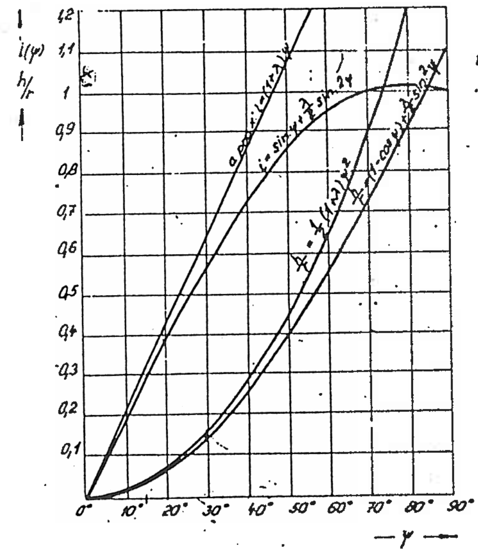
TRANSIENT FUNC. $i = (\sin\alpha + \frac{\lambda}{2}\sin 2\alpha)$

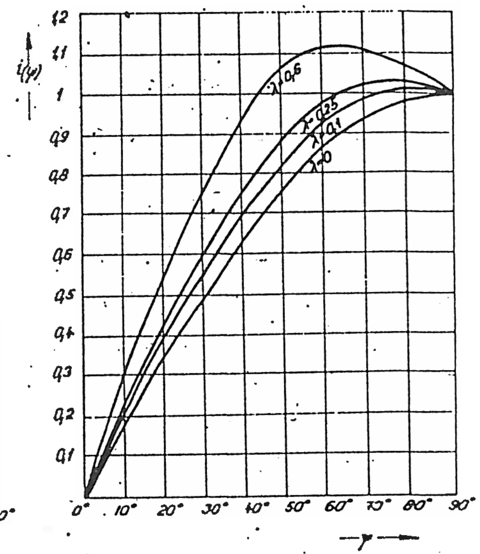
α°	λ 0,50	0,40	0,30	0,25	0,20	0,18	0,16	λ 0,14	0,12	0,10	0,08	0,06	0,04	0,02
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0,1306	0,1219	0,1132	0,1089	0,1046	0,1028	0,1011	0,0993	0,0976	0,0959	0,0941	0,0924	0,0907	0,0889
10	0,2591	0,2418	0,2249	0,2163	0,2078	0,2044	0,2010	0,1970	0,1941	0,1907	0,1873	0,1839	0,1804	0,1770
15	0,3838	0,3588	0,3338	0,3213	0,3088	0,3038	0,2988	0,2938	0,2888	0,2838	0,2788	0,2738	0,2688	0,2638
20	0,5027	0,4706	0,4384	0,4223	0,4063	0,3998	0,3934	0,3870	0,3806	0,3741	0,3677	0,3613	0,3549	0,3484
25	0,6141	0,5758	0,5375	0,5183	0,4992	0,4915	0,4839	0,4762	0,4686	0,4608	0,4532	0,4456	0,4379	0,4303
30	0,7165	0,6732	0,6299	0,6082	0,5866	0,5779	0,5693	0,5606	0,5520	0,5433	0,5346	0,5260	0,5173	0,5087
35	0,8085	0,7615	0,7145	0,6611	0,6676	0,6582	0,6488	0,6394	0,6300	0,6206	0,6112	0,6018	0,5924	0,5830
40	0,8890	0,8398	0,7905	0,7659	0,7413	0,7314	0,7216	0,7117	0,7019	0,6920	0,6822	0,6723	0,6625	0,6526
45	0,9571	0,9071	0,8571	0,8321	0,8071	0,7971	0,7871	0,7771	0,7671	0,7571	0,7471	0,7371	0,7271	0,7171
50	1,0122	0,9630	0,9137	0,8891	0,8645	0,8546	0,8448	0,8350	0,8251	0,8152	0,8054	0,7955	0,7857	0,7758
55	1,0541	1,0071	0,9601	0,9367	0,9132	0,9098	0,8944	0,8849	0,8756	0,8662	0,8658	0,8474	0,8380	0,8286
60	1,0825	1,0392	0,9959	0,9742	0,9526	0,9439	0,9353	0,9266	0,9180	0,9093	0,9006	0,8920	0,8833	0,8747
65	1,0978	1,0595	1,0212	1,0020	0,9829	0,9752	0,9677	0,9599	0,9523	0,9446	0,9369	0,9293	0,9216	0,9140
70	1,1004	1,0683	1,0364	1,0200	1,0040	0,9975	0,9911	0,9847	0,9783	0,9718	0,9654	0,9590	0,9526	0,9461
75	1,0910	1,0659	0,0419	1,0284	1,0159	1,0109	1,0059	1,0009	0,9959	0,9909	0,9859	0,9809	0,9759	0,9709
80	1,0703	1,0532	1,0361	1,0275	1,0190	1,0156	1,0122	1,0086	1,0053	1,0019	0,9985	0,9951	0,9916	0,9882
85	1,0396	1,0309	1,0222	1,0179	1,0136	0,118	1,0101	1,0083	1,0066	1,0049	1,0031	1,0014	0,9997	0,9979
90	1	1	1	1	1	1	1	1	1	1	1	1	1	1

$\alpha_j = 10 \div 90^\circ$ a $\lambda = \bar{0}$

$h_{10} = 3/400$ H; $h_{20} = 3/100$ H; $h_{30} = 1/15$ H; $h_{45} = 3/8$ H;

1/2 H.





$h \sim \frac{1}{2} r (1 + \lambda) \psi^2$,

$i(\psi) = (1 + \lambda) \cdot \psi$

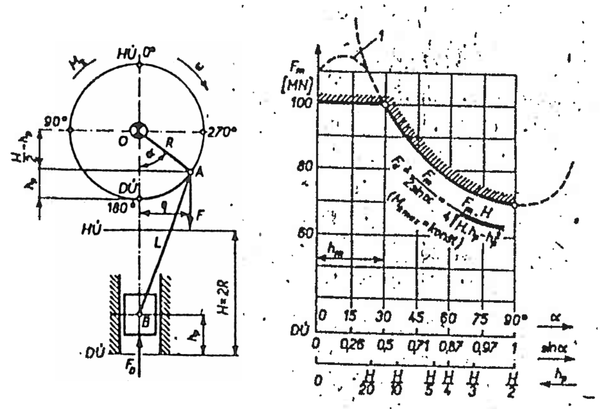
$\Delta = 0,2 \div 3,6$ %, pro $\psi \leq 30^\circ$ a $\lambda = \overline{0,06} \div 0,25$.; $\Delta = 3 \div 3,6$ %, pro $\psi \leq 20^\circ$ a $\lambda = 0,06 \div 0,25$.

$h_j = r (1 - \cos \alpha_j + \frac{\lambda}{2} \sin^2 \alpha_j)$.

$v_j = r\omega(\sin \alpha_j + \frac{\lambda}{2} \sin 2 \alpha_j) = r\omega i (\alpha_j)$ $\quad n_o = \frac{30 \cdot v_j}{\pi r i (\alpha_j)}$.

$a \doteq \omega^2 (h - r)$

CRANK (EXCENTRICAL) MECHANISM



BASIC FORCE – DEF. = FORCE WHICH THE MECHANISM IS ABLE TO APPLY AT THE OUTPUT.

M_k = konst. ENERGY BALANCE

$$M_k \cdot d\varphi = F(\varphi) \cdot dh \rightarrow F(\varphi) = M_k \cdot \frac{d\varphi}{dh}$$

$$\frac{dh}{d\varphi} = r \cdot i(\varphi) \qquad F(\varphi) = M_k \cdot \frac{1}{r \cdot i(\varphi)} = F_j \cdot \frac{r \cdot i(\alpha_j)}{r \cdot i(\varphi)} = F_j \frac{i(\alpha_j)}{i(\varphi)}$$

LIMITING ANGLE α_j SELECTION

MACHINE TYPE		α_j
EXCENTRICAL FORGING		5 ÷ 10
UNIVERSAL CRANK + EXCENTRICAL	F_j>160 M_p	20
	F_j<160 M_p	30
EXTRUDING		40 ÷ 45
DEEP DRAWING		70 ÷ 90

MACHINE TYPE	λ
UNIVERSAL C+E	
MEDIUM STROKE	0,08 ÷ 0,14
LONG STROKE	0,15 ÷ 0,2
DEEP DRAWING	0,18 ÷ 0,3
AUTOMATS WITH BOTOM MOVE	0,05 ÷ 0,08
EXCENTRICAL FORGING	0,15 ÷ 0,3
COINING	0,12 ÷ 0,3
AUTOMATS FOR COLD PUNCHING	0,1 ÷ 0,2

ENERGY TRANSMITION

CHARACTERISTIC FEATURES:

IMPULSE ENERGY CONSUME,
ARISED ENERGY LOSSES – BY FRICTION, ELASTICITY, RIGIDITY
UNSTABLE (NOT CONSTANT) CONDITIONS – HEAT, PROCESS CHARACT.

ENERGY DEFINITIONS

A_w:
- A_u – EFFECTIVE ENERGY – CONSUMED ON PLASTIC DEFORMATION
- A_y – ELASTIC ENERGY – CONSUMED ON ELASTIC DEFORMATION
- A_f – LOST ENERGY – DUE TO FRICTION RESISTANCE
  - A_{fu} – LOOSES IN FORMING PROCESS (EFFECTIVE STROKE)
  - A_{fy} – " – DURING ELASTIC DEFORMATION
  - A_{fN} – " – DURING FREE RUNING

A_{yz} – BACKUP OF ELASTIC ENERGY
A_{fa} – FRICTIONAL ENERGY LOST IN CLUTCH – CHANGED INTO HEAT
A_a – DYNAMIC ENERGY – CONSUMED ON INERTIA MOMENTS

TOTAL ENERGY WITHIN ONE CYCLE:

1. IN CONTINUOUS CASE:

$$A_{CT} = A_u + A_{fu} + A_{fy} + A_{fN} + A_{yz} \quad [J]$$

2. IN INTERUPTIVE CASE:

$$A_{CP} = A_{CT} + A_{fa} + A_a + \Delta A_f \quad [J]$$

ΔA_{fN} – INCREASE OF ENERGY DURING FREE RUNING

EFFICIENCY $\eta_r = \frac{A_u}{A_{CT}}$; $\eta_P = \frac{A_u}{A_{CP}}$ – 1

$$A_w = A_u + A_y + A_f = \frac{1}{\eta_{fy}} \cdot \int_{h_o}^{h} F_o \, dh = \int_{h_u} F_o \left(1 + \frac{p_u^f}{p_u^\gamma}\right)\left(1 + \frac{1}{c}\frac{dF_o}{ds}\right) dh$$

$$A_u = \int_{\psi_u} F_o \left(p_u^{\gamma_1} + p_u^f\right) \cdot d\bar{\psi}_y \quad \text{– WORK}$$

$$A_a = \frac{1}{2} I_r \cdot \omega_o^2 \quad \text{– INERTIA}$$

$$A_{fa} = (1 - 1{,}25)\, A_a \quad \text{– HEAT LOOSES}$$

$$A_{fN} \doteq \frac{d}{2} I_r \cdot \frac{\omega_o^2}{n_x} \quad \text{– FREE RUNING} \quad n_x = (16-25) \text{ rot.}$$

HINTS FOR POWER CALCULATION

IF	THEN				TOTAL
A_u	A_f	A_{fy}	$\frac{1}{\eta}\{A_a + A_{fa}\}$	A_{fn}	A_{cp}
1	0,5÷1,2	→0,4	0,3 ÷ 0,8	0,5÷1	2,4 ÷ 4

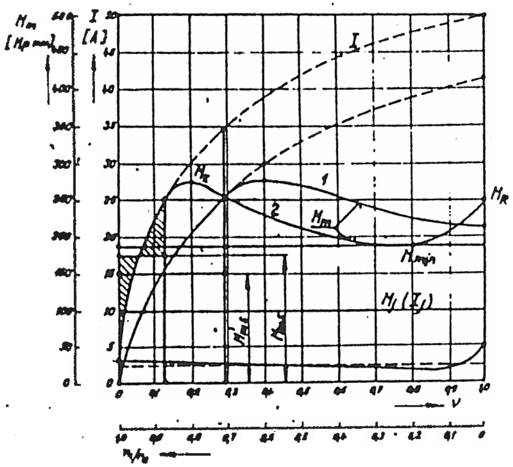
MOTOR POWER

$$P_m = \frac{A_{cp}}{t_c} \cdot k = \{1{,}2 \div 1{,}6\} \cdot \frac{\{2{,}4 \div 4\} A_u}{t_{cp}} \cdot 10^{-3} \, [kW]$$

TORQUE REQUIREMENT – FOR MOTOR – WHICH HAS WITHIN t_H (TIME OF FREE RUNING $t_N = t_{cp} - t_p$) [s] rise consumed number of rotations on FLYWHEEL.

$$M_M - M_o = I_r \cdot \frac{d\omega}{dt} \Rightarrow M_M \leq M_{MS}$$

$$M_M = I_r \cdot \frac{\omega_o \cdot \gamma}{t_N} + M_o \leq M_{ms}$$



FROM MOTOR CHARACTERISTICS

$$M_{ms} = \frac{M_k}{m+1} \left(\frac{\gamma}{\gamma_k}\right)^m$$

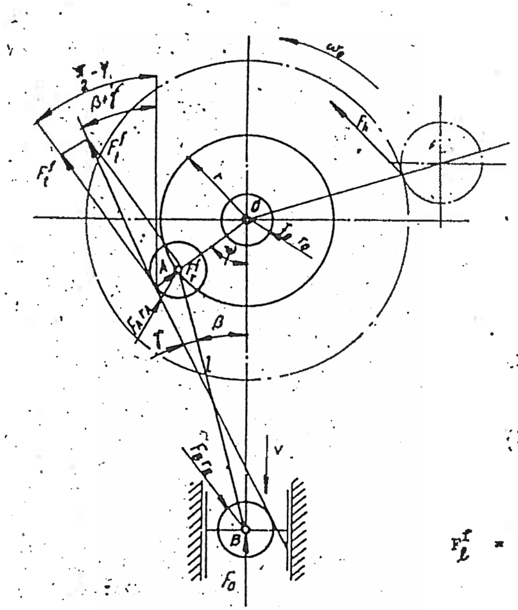
$M_k \doteq 2{,}75 \cdot M_j$

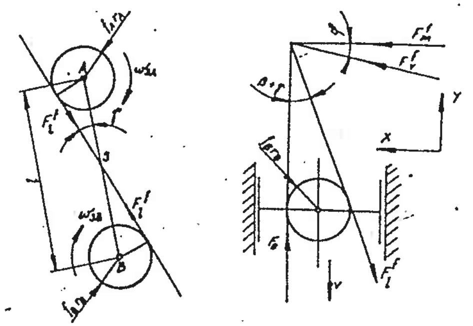
$\gamma = 0{,}12 \div 0{,}2$

$\gamma_k = 0{,}2 \div 0{,}4$

$m = 0{,}5 \div 0{,}4$

FORCE ANALYSYS – on elements of crank mechanism





$$F_v^f \cdot \cos\varphi - F_l^f \sin(\beta+\gamma) = 0$$

$$F_v^f \cdot \sin\varphi - F_l^f \cos(\beta+\gamma) + F_o = 0 .$$

$$F_l^f = F_o \frac{\cos\varphi}{\cos\varphi \cdot \cos(\beta+\gamma) - \sin(\beta+\gamma) \cdot \sin\varphi}$$

$$F_l^f = F_o \frac{\cos\varphi}{\cos(\beta+\gamma+\varphi)} .$$

$$F_v^f = F_l^f \frac{\sin(\beta+\gamma)}{\cos\varphi} = F_o \frac{\sin(\beta+\gamma)}{\cos(\beta+\gamma+\varphi)} .$$

$$F_{vn}^f = F_l^f \cdot \sin(\beta+\gamma) = F_o \frac{\cos\varphi \cdot \sin(\beta+\gamma)}{\cos(\beta+\gamma+\varphi)}$$

$$F_t^f = F_l^f \cos\left[\frac{\pi}{2} - \psi - (\beta+\gamma)\right] = F_l^f \sin(\psi+\beta+\gamma)$$

$$F_t^f = F_o \frac{\cos\varphi \cdot \sin(\psi+\beta+\gamma)}{\cos(\beta+\gamma+\varphi)}$$

$$\sin\beta = \frac{r}{l} \cdot \sin\psi = \lambda \cdot \sin\psi$$

$$\sin\gamma = \frac{f_A \cdot r_A + f_B \cdot r_B}{l} \doteq tg\,\gamma$$

ENERGY BALANCE ON CRANK MECHANISM

$$M_o^f \cdot d\psi = F_o\, dh + f_v F_n^f \cdot dh + f_B F_l^f r_B\, d\beta + f_A F_l^f r_A\, (d\psi + d\beta) + f_{01} F_{01} \cdot r_{01}\, d\psi + f_{02} F_{02} \cdot d\psi$$

$$M_o^f = F_o p_k^\psi + f_s F_o \left[r_B \frac{d\beta}{d\psi} + r_A \left(1 + \frac{d\beta}{d\psi}\right) + \frac{F_{01}}{F_o} r_{01} + \frac{F_{02}}{F_o} \cdot r_{02} \right]$$

$$r.\cos\psi\, d\psi = l\, \cos\beta\, .d\beta \qquad \frac{d\beta}{d\psi} = \frac{r}{l}\frac{\cos\psi}{\cos\beta} \approx \lambda\cos\psi$$

MOMENT (+ RESISTANT) TORQUE (DUE FRICTION)

$$M_o^f = F_o p_k^\psi + f_s F_o \left[r_A (1 + \lambda\cos\psi) + r_B \lambda\cos\psi + \frac{F_{01}}{F_o} r_{01} + \frac{F_{02}}{F_o} r_{02} \right] = F_o (p_k^\psi + p_k^f)$$

$$r_0 = \frac{F_{01}}{F_o} r_{01} + \frac{F_{02}}{F_o} r_{02}$$; average radius ; $F_{01} \doteq F_{02} \triangleq \frac{F_o}{2}$

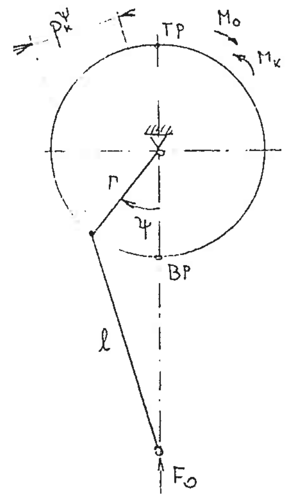
$$p_k^f = f_s \left[r_A (1 + \lambda\cos\psi) + r_B \lambda\cos\psi + r_0 \right]$$

$$p_k^{f'} = f_s \left[r_A (1 + \lambda) + \lambda\, r_B + r_0 \right]$$

THE FRICTION COEFFICIENT RANGE

MACHINE TYPE	f_s
UNIVERSAL PRESSES	0,04 ÷ 0,05
EXCENTRICAL FORGING PRESSES	0,03 ÷ 0,04
	0,01 ÷ 0,03

RESISTING TORQUE



$F(\psi) = |F_o|$

$M \triangleq M_o = F(\psi) \cdot r \cdot i(\psi) = F_o \cdot \underbrace{r \cdot i(\psi)}_{p_k^\psi}$

$p_k^\psi = r \cdot i(\psi)$ IDEAL TORQUE ARM

Force increase due to friction resistance

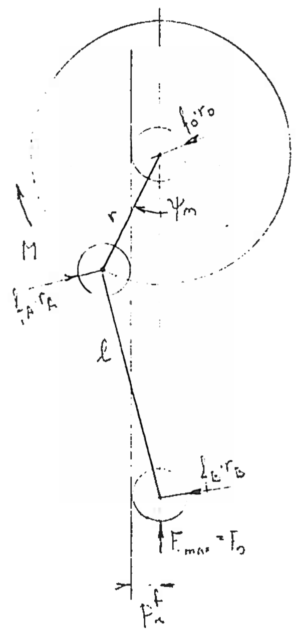
$\Delta F_o \doteq$

$$\eta_f = \frac{\Delta F_o}{F_o} = \frac{\Delta M_o}{M_o} = \frac{F_o \cdot p_k^f}{F_o \cdot p_k^\psi} = \frac{p_k^f}{p_k^\psi}$$

p_k^f = FRICTIONAL ARM

$$M_o^f = M_o \cdot \left(1 + \frac{p_k^f}{p_k^\psi}\right) = F_o \left(p_k^\psi + p_k^f\right)$$

JAMMING OF CRANK MECHANISM – NOT WANTED !



$M_o^f = F_o (p_k^\psi + p_k^f)$

CONDITIONS: – $F_o > F$, $M_o^f > M_k$

– $p_k^\psi = p_k^f$.

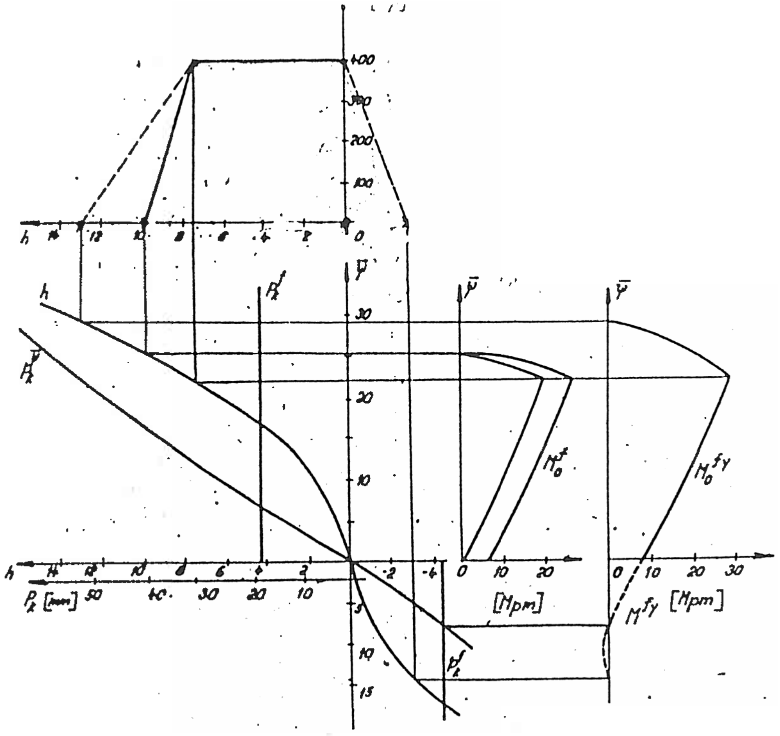
– REVERSE MOTION

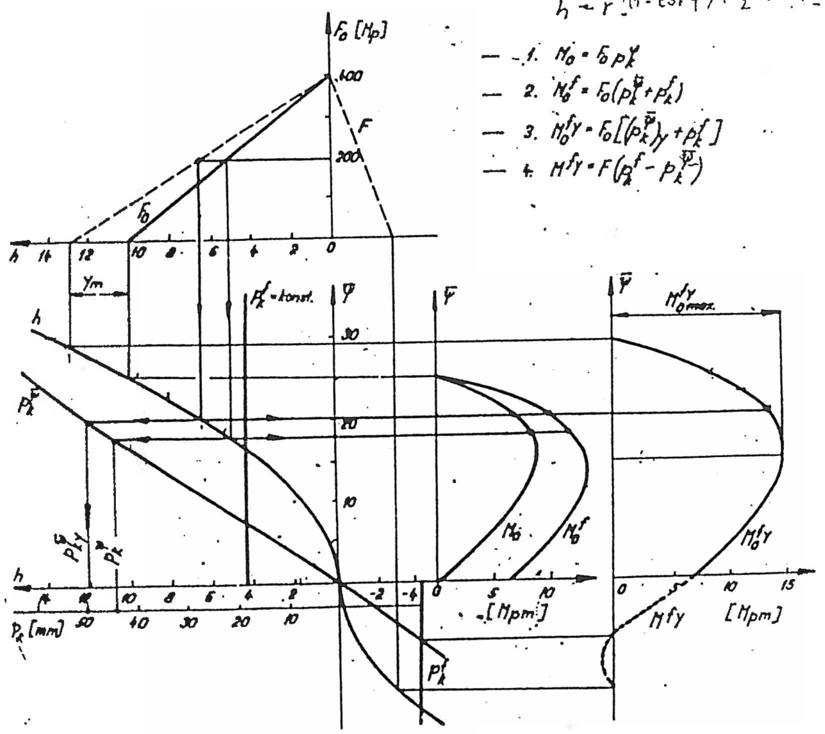
from $p_k^\psi = r \cdot i(\psi) = r \cdot (1+\lambda) \cdot \psi = p_k^f$

$$\psi_m = \frac{p_k^f}{(1+\lambda) \cdot r}$$

Improvement ≐ decrease f_s – by lubrication

RELEASE : APPLY TORQUE IN REVERSE DIRECTION





RESISTANT TORQUE – GRAPHICAL - NUMERICAL ANALYSYS

TWO MAIN CASES :

1. MAXIMAL FORCE AND PROCESS ENDING BEFORE REACHING BOTTOM POSITION
2. MAXIMAL FORCE ACCEDED AT A BOTTOM POSITION

i.e. 1. $S_1 = s + y = s + \frac{F_0}{c}$ or $h_{(\bar{\psi})} = h - \frac{F_0}{c}$

i.e. 2. $S_1 = s + y_m - y = s + \frac{F_{0m} - F_0}{c}$ or $h_{(\bar{\psi})} = h + \frac{F_{0m} - F_0}{c}$

FROM GRAPHS –

TABLE : p_k^f = CONSTANT

F_0 [N]	s_i, h [mm]	ψ $(\bar{\psi}_y)$ [°]	$p_k^{(\bar{\psi}_y)}$ [mm]	$p_k^{(\bar{\psi}_y)} + p_k^f$	$M_0^{f\psi} = F_0 \cdot \{p_k^{(\bar{\psi}_y)} + p_k^f\}$ [Nm]

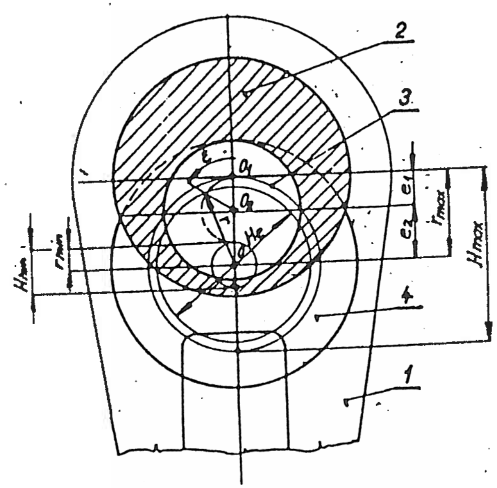
MAXIMAL TORQUE : $M_0^{f\psi} = F_0\,(p_k^f + p_k^{\psi})\,(1 + \frac{1}{c}\frac{dF_0}{ds})$

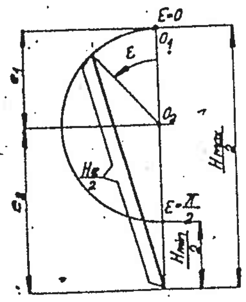
$\frac{dM_0^{f\psi}}{d\psi} = 0 \Rightarrow \psi_{M_{max}}$ – $\frac{dF_0}{ds} = 0$; p_k^f = CONSTANT

$\frac{dM_0^{f\psi}}{d\psi} = \frac{dp_k^{\psi}}{d\psi} = \frac{d}{d\psi}\{r \cdot i(\psi)\} = \frac{d}{d\psi} \cdot r\{\sin\psi + \frac{\lambda}{2}\sin 2\psi\} = \cos\psi + \lambda \cdot \cos 2\psi$

$2 \cdot \lambda \cdot \cos^2\psi + \cos\psi - \lambda = 0 \Rightarrow \psi_{M_{max}} \hat{=} \cos\psi_m = \frac{-1 + \sqrt{1 + 8\lambda^2}}{4\lambda}$

STROKE ADJUSTMENT BY ...
(ECCENTRIC BUSH)





$$e_1 = \frac{H_{max} - H_{min}}{4} = \frac{H_{min}}{4}(a_H - 1) \qquad e_2 = \frac{H_{max} + H_{min}}{4} = \frac{H_{min}}{4}(a_H + 1)$$

$$r_{max} = e_2 + e_1 = \frac{H_{max}}{2} \qquad r_{min} = e_2 - e_1 = \frac{H_{min}}{2}$$

$$\left(\frac{H_e}{2}\right)^2 = e_1^2 + e_2^2 - 2 \cdot e_1 \cdot e_2 \cdot \cos(180 - \varepsilon)$$

$$\frac{H_e}{2} = \sqrt{e_1^2 + e_2^2 + 2 e_1 e_2 \cos\varepsilon} \quad ; \quad a_H = \frac{H_{max}}{H_{min}} \quad e_1 = \frac{H_{min}}{4}(a_H - 1) \quad e_2 = \frac{H_{min}}{4}(a_H + 1)$$

$$\frac{H_e}{2} = \frac{H_{min}}{2} \cdot \sqrt{(a_H+1)^2 + (a_H-1)^2 + 2(a_H^2-1)\cos\varepsilon}$$

$$\cos\varepsilon = \frac{\left(\frac{H_e}{H_{min}}\right)^2 - 2(a_H^2+1)}{2(a_H^2-1)} \quad , \quad n_\varepsilon = \frac{Z}{360°} \cdot \varepsilon°$$

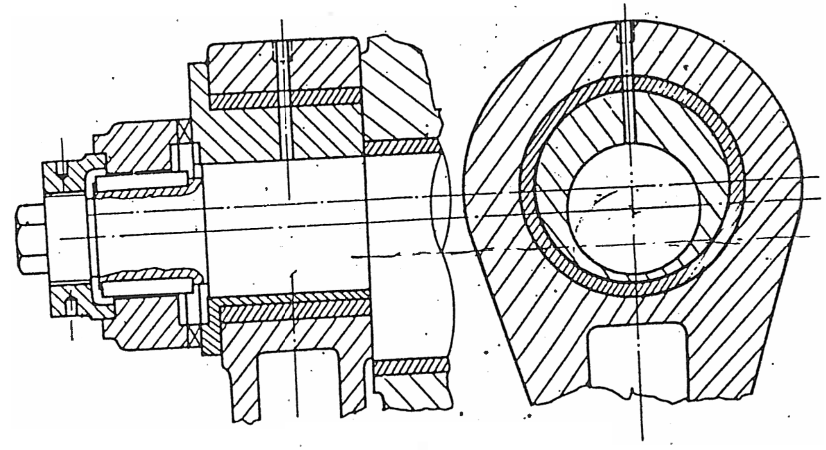
$$M_j = F(\psi)\frac{H_e}{2} \cdot i(\psi) = F_{max}\frac{H_{min}}{2} \cdot i(\alpha_{max}) = F_{min}\frac{H_{max}}{2} i(\alpha_{min}) = \text{konst.}$$

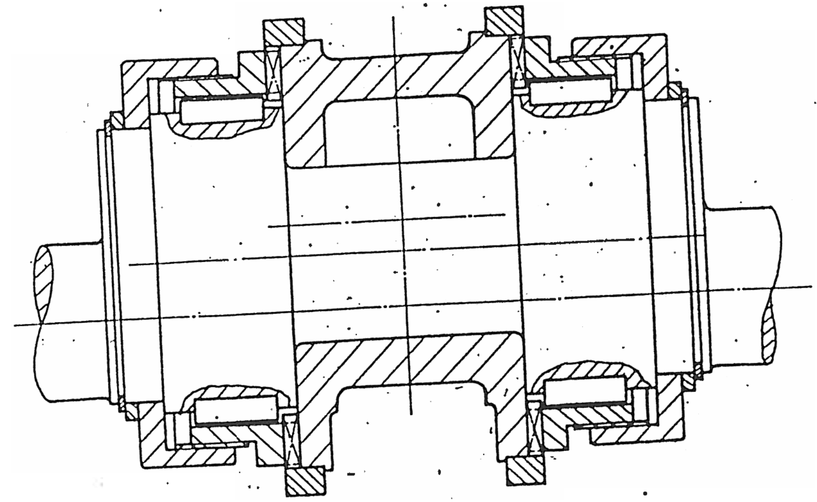
$$a_H = \frac{H_{max}}{H_{min}} = \frac{F_{max}}{F_{min}} \cdot \frac{i(\alpha_{max})}{i(\alpha_{min})} = a_F \cdot a_\alpha \qquad a_F = \frac{F_{max}}{F_{min}} , \quad a_\alpha = \frac{i(\alpha_{max})}{i(\alpha_{min})}$$

$$\omega_o = \frac{2\,v(\psi)}{H_e \cdot i(\psi)} = \frac{2\,v_{max}}{H_{max} \cdot i(\alpha_{min})} = \frac{2\,v_{min}}{H_{min}\, i(\alpha_{max})} = \text{konst}$$

$$a_H = \frac{H_{max}}{H_{min}} = \frac{v_{max}}{v_{min}} \cdot \frac{i(\alpha_{max})}{i(\alpha_{min})} = a_v \cdot a_\alpha$$

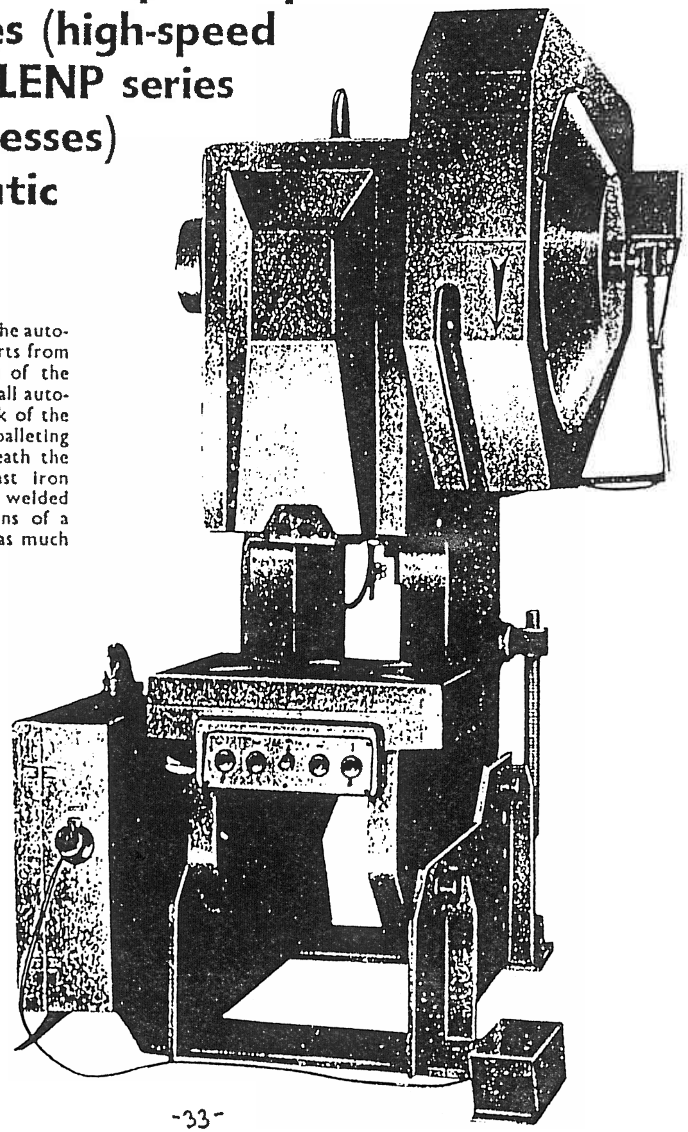
ECCENTRIC BUSH ARANGEMENTS





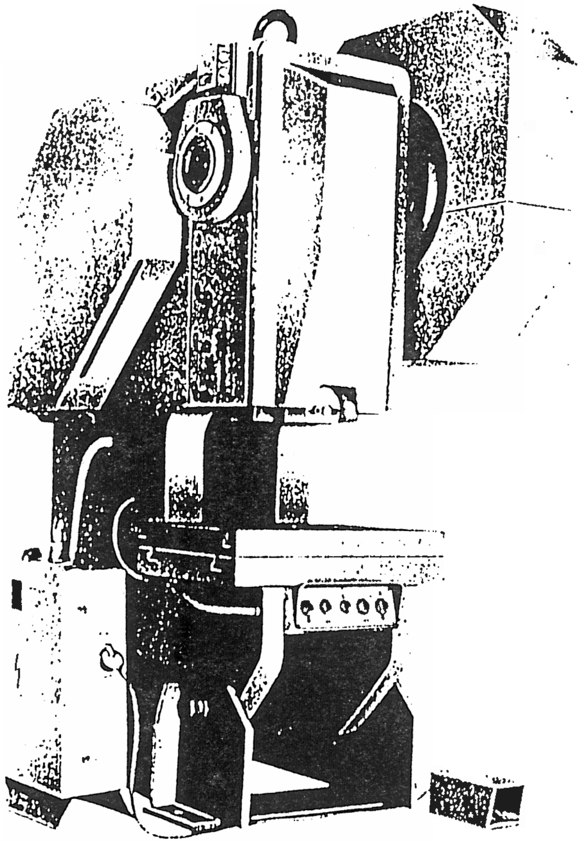
Inclinable eccentric power presses of LENR series (high-speed presses) and LENP series (low-speed presses) with pneumatic clutch

They are especially suitable for the automated production of various parts from strip material. The inclination of the stand permits the pressings to fall automatically through the open back of the stand into bins or other palleting equipment kept ready underneath the press table. The C-shaped cast iron stand is secured in the bed welded from steel plates and by means of a screw it can be tilted through as much as 30 deg.



MAIN SPECIFICATION

		LENR 25 A	LENR 40 A	
Rated capacity	Mp	25	40	
Depth of throat	mm	190	220	
Clear width	mm	220	250	
Forming energy — in working with single strokes — in continuous stroking	kpm kpm	40 20	80 40	
Maximum thickness of cut metal sheet of 40 kp/sq.mm tensile strength — in working with single strokes — in continuous stroking	mm mm	3.2 1.6	4 2	
Maximum blanking area of material of 40 kp/sq.mm tensile strength		630	1000	
Shut height (ram in bottom position, uppermost adjustment, maximum length of ram stroke set - measured from table)	mm	220	250	
Length of ram stroke	mm	8—80	8—90	
Number of ram strokes per min. (in continuous stroking)		125	110	
Adjustment of ram	mm	55	60	
Clamping hole in ram - dia./depth	mm	32/60	40/75	
Working area of table - left to right × front to back	mm	530×370	630×430	
Drop hole in table - dia./depth × width	mm	200/250×160	220/280×180	
Thickness of bolster plate	mm	55	60	
Hole for insert in bolster plate - dia. of hole/dia. of recess	mm	160/180	200/220	
Hole in insert of bolster plate - dia.	mm	80	100	
Inclination of stand		0—30°	0—28°	
Motor output	kW	2.2	3.	
Consumption of drawn-in air per one clutch engagement	litres	3	3	
Socket for connection to pressure-air line — pressure — measurement	atm. inches	6 3/8	6 1/2	
Weight of press	kg	1500	2400	
Weight of press with seaworthy packing	kg	1850	3200	
Contents boxed and number of cases	cu.m/pcs	3.8/1	7.5/1	



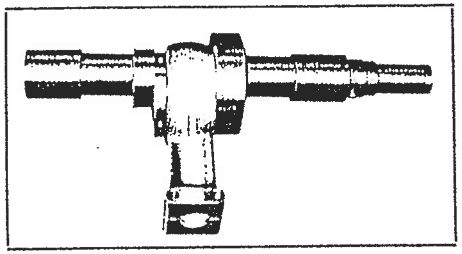
Outstanding features of the eccentric power presses of the LENR, LENP and LESP series consist in that the press stand with clear width is C-shaped and the eccentric shaft is mounted longitudinally, i. e. right to left

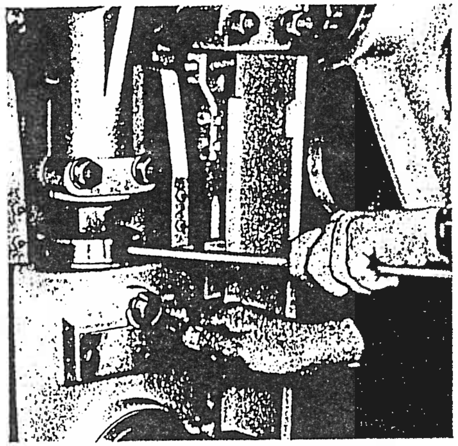
This arrangement enables a better utilization of the working area, a larger field for application of mechanization means and ensures a higher rigidity of the machines. Its versatility makes it an indispensable supplement for every press shop.

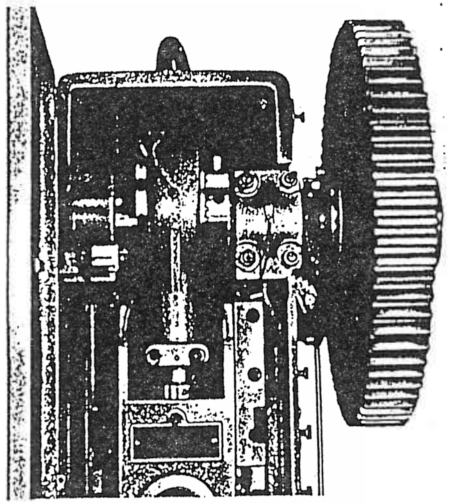
Practically, all normal cold press work can be carried out on them: blanking, punching, trimming, bending, straightening, flanging, drawing, riveting, etc.

The working area is completely open from three sides and on the fourth side a through-passage is provided in the stand. As a result, the design arrangement permits the application of various ancillary equipment and automation devices enabling a high output to be obtained and all working capacities of the presses to be utilized.

According to the work to be handled, it is possible to select either the high-speed version (LENR) or lowspeed version with back gear (LENP, LESP). The latter version features a higher kinetic energy and the rated power can be applied over a longer path of stroke.





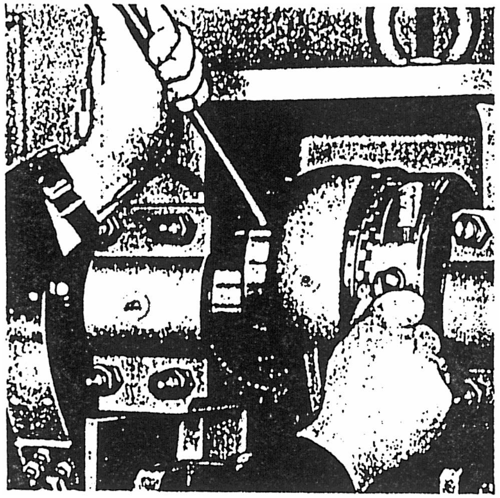


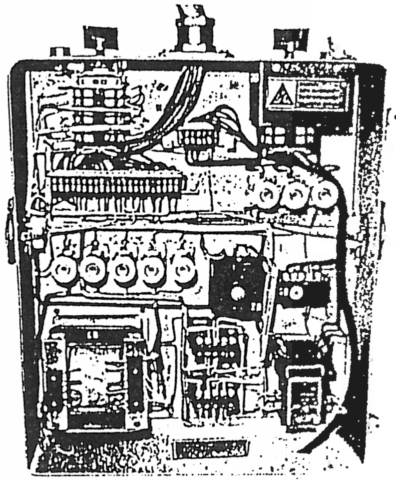
STAND

The section and measurements of the cast iron stand of modern styling are selected with a view that a high standard of rigidity is provided. For the presses of the described conception, this rigidity is of considerable importance, especially during automated work in continuous operation.

DRIVE AND CONTROL

The drive is taken from a motor and transmitted by V-belts to the flywheel, through the back gear and pneumatic clutch to the eccentric shaft (crankshaft) and through the connecting rodto the ram. The highspeed versions of the presses have no back gear and the flywheel is mounted direct on the eccentric shaft. The bracket carrying the motor is swinging thus permitting the V-belts to be correctly tensioned. The eccentric shaft runs in bronze bushings and to its cam disc the rocker arm driving the various optional attachments can be attached. A perfect reliability of the pneumatic clutch mechanically coupled to the brake ensures full safety of work on the presses. The electropneumatic starting mechanism combined with selectable methods of press control permits the press to be started by two hands (by pushbuttons) or by foot (by treadle), for run with individual strokes, continuous stroking and (or »inching«) for setting up press tools). When the press is started by hand, the operator' s both hands are fully occupied by keeping the starting pushbuttons depressed throughout the full period of the working stroke.
Starting by the foot treadle can be used only when the press tools are provided with a protection or when the safety of the operator is ensured in some other way. In working with individual strokes, a locking device prevents the ram from an undesirable repetition of the stroke. The braking effect of the brake, located on the eccentric shaft, can be set by a nut, by means of which the clearance between the brake disc and clutch disc can be set.





RAM

The long guide gibs that can be easily and finely set provide for a high-precision guiding of the ram. The ram can be adjusted for height by hand rotation of the ball joint. This arrangement allows the press tools to be quickly and accurately set up. The ball joint is secured against self-loosening by two screws compressing the split end of the connecting rod. The ram is protected by an easy-to change shear pin protecting. In case of an overload, the most important press parts against damage. The length of stroke of the ram can be changed by turning the eccentric bush provided with a graduated scale for reading the length of stroke set. The upper knock-out device is operated as the ruler assembled in the ram bears on the stops secured on the press stand. As the ram moves upwards, the latter device ejects the pressing by means of a pin located in the press tool. The shank of the upper tool half is fixed in the bore provided in the ram.

TABLE AND BOLSTER PLATE

The table and bolster plate are arranged in such a manner that the press tools and various ancillary attachments can be assembled in a rapid and simple manner.

The bolster plate is provided with clamping slots and round drop hole. The latter can be used also for fixing an air-operated or spring-controlled hold-down (optional extras). Alternatively, the drop hole can be stopped by an insert. In the bottom part of the table sufficient space is provided for location of the hold-down.

ELECTRICAL EQUIPMENT

The electrical equipment for controlling the press is housed in the switchgear box. With all the types of presses described in this catalogue, the switchgear box is located outside the press. On the box are located also the pushbuttons for starting and stopping the electric motor. The electrical equipment complies with the relevant Czechoslovak Standard Specification ČSN 34 1630. It is designed for operation under normal climatic conditions and for operation with a power supply of 380 V, 50 cycles. If the client requires some other execution, it is necessary to state the requirement in the order and to specify the particulars.

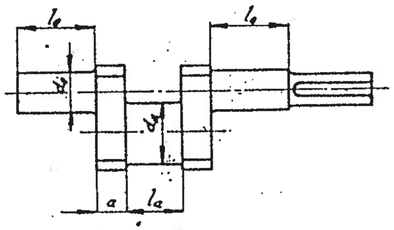
EXCENTRICAL & CRANK SHAFT DESIGN

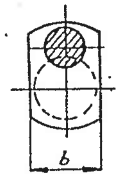
SHAFT BEARING DIMENSION d_o

MACHINE TYPE	d_o [cm]	F_j [Mp], [t]
UNIVERSAL CRANK + EXCENT.		
SINGLE CONNECTION ONE - POINT	$1{,}4\sqrt{F_j + 2}$	<200
	$1{,}18\sqrt{F_j + 60}$	>200
DOUBLE CONNECTION TWO - POINT	$1{,}4\sqrt{F_j}$	<160
	$0{,}9\sqrt{F_j + 300}$	>160
EXENTRICAL FORGING	$1{,}025\sqrt{F_j + 100}$	-

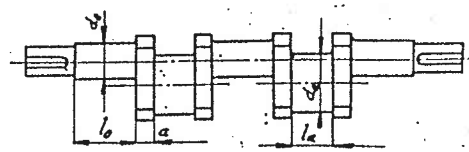
CRANK SHAFT :

SINGLE : - ONE POINT



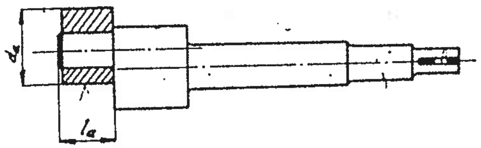


DOUBLE : TWO POINTS



d_a	(1,2[x] až 1,5) d_o	1,5 d_o	(1,27[x] až 1,5) d_o	1,35 d_o
l_o	(1,7 až 2,5) d_o	2 d_o	(1,68 až 2,1) d_o	1,9 d_o
l_a	(1,3 až 2,1) d_o	1,5 d_o	(1,2 až 1,4) d_o	1,3 d_o
b	(1,6 až 1,8) d_o	1,7 d_o	(1,5 až 1,75) d_o	1,6 d_o
a	(0,62 až 0,85) d_o	0,7 d_o	0,6 d_o	0,6 d_o

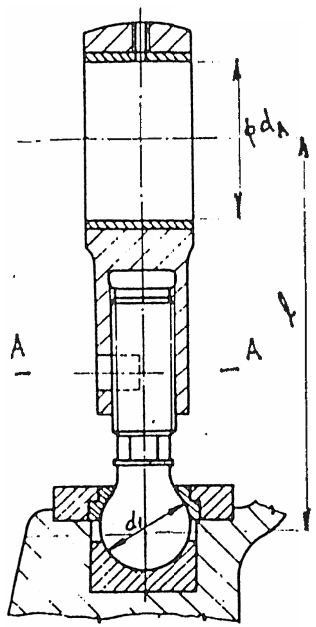
EXCENTRICAL SHAFT :



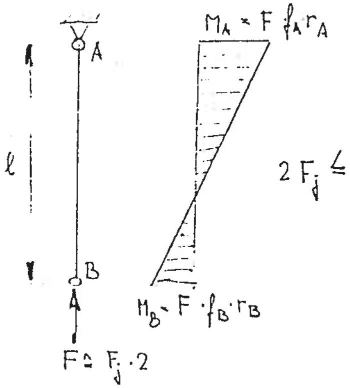
$d_a = 1{,}55\sqrt{F_j}$	$l_a \doteq d_a$
F_j (M_p)	d_a, l_a (cm)

CONNECTING ROD

BALL ENDED

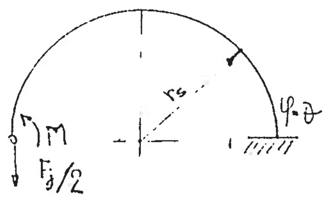


SUBSTITUTE FOR BRACEMENT :



$$2F_j \leq \frac{\pi^2 \cdot E \cdot I}{l^2_{max}}$$

UPPER HOUSING



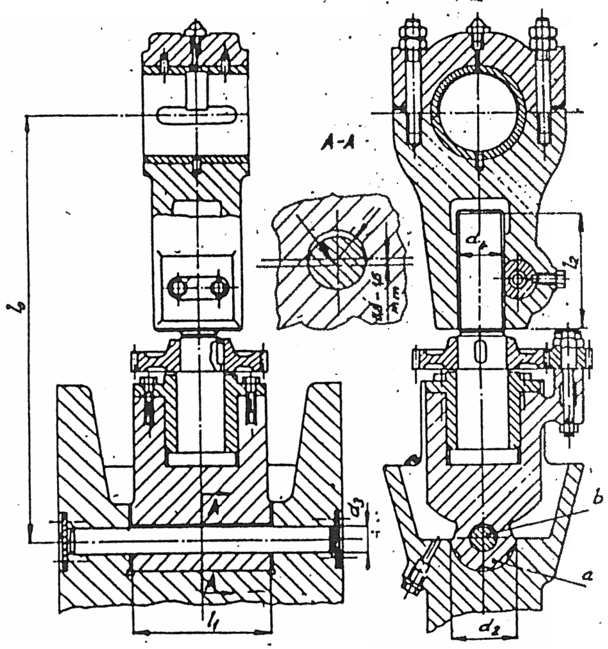
$$\varphi = \frac{\partial U}{\partial M} = \vartheta \rightarrow M$$

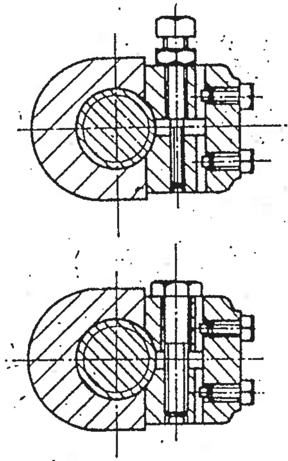
$$\sigma_r \geq \frac{M \cdot D/2}{I}$$

THREAD - $p_p = \begin{cases} 40\ [MPa]\ CI \\ 80\ [MPa]\ ST \end{cases}$

A-A- FIXING

CYLINDER ENDED





CLUTCHES

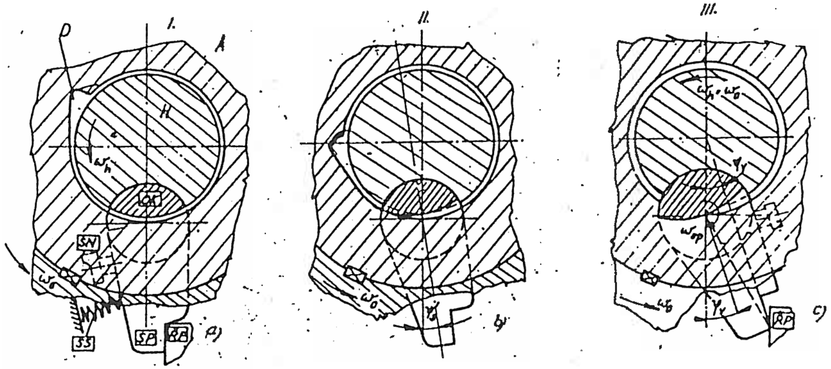
1. **POSITIVE**
2. **FRICTIONAL**

} PURPOSE - TO CONNECT CRANK (EXCENTRICAL) SHAFT TO DRIVING MECHANISM

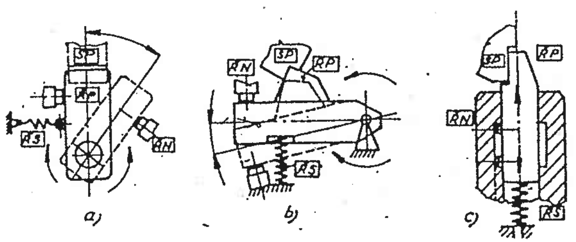
REQUIREMENTS :

1. RELIABLE ACTING , WITHIN THE SHORTEST TIME POSSIBLE
2. SATISFACTORY TORQUE TRANSMITION - $M_{sp} = k \cdot M_k$ or M_o
3. CONTROL SYSTEM ALLOWING CONTINUOUS OR INTERUPTIVE RUN
4. SYSTEM SAFETY FOR SETTING RUNNING CONDITIONS
5. LITTLE NECESSITY FOR MAINTANANCE

1. POSITIVE - ROTARY PIN - CLUTCH



CONTROL MECHANISMS

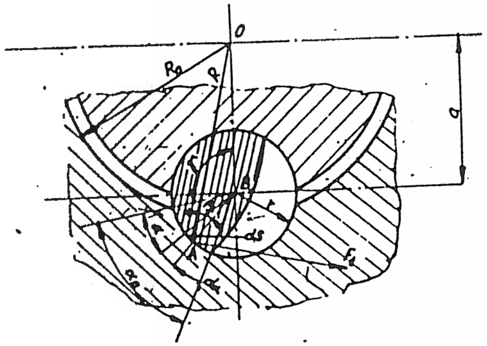


TIME DELAY FOR ENGAGEMENT $t_1 = \frac{2\pi}{p \cdot \omega_2}$ [s] where p = number of slots

TIME FOR CLUTCH DISENGAGEMENT $t_2 = \frac{\psi_v}{\omega_o}$ [s]

PLACED ONLY ON CRANK SHAFT .
USABLE IN SMALL SPEEDS , SMALL FORCES (UP TO $F_j \leq 1.6$ MN)

ROTARY PIN - CALCULATION



$\frac{L_k}{r} \sim 6; \quad a < R_0$

TORQUE

$M_{sp} \doteq F_t \cdot R$

$F_t \doteq p_s \cdot S$

$dS = L_k \cdot r \cdot \sin\beta \cdot d\alpha$

ELEMENTARY TORQUE $\quad dM_{sp} = p_s \cdot L_k \cdot r \cdot a \cdot \sin(\gamma + \alpha)\, d\alpha$

WHERE : p_s = ALLOWED SPECIFIC PRESSURE $\sim 200 \div 250$ [MPa]

L_k - PIN ENGAGEMENT LENGTH [mm]

r = PIN RADIUS

$\sin\beta = \frac{a}{R} \sin(\gamma + \alpha) \qquad \cos\gamma = \frac{r^2 + a^2 - R_0^2}{2ra}$.

$$M_{sp} = p_s \cdot a \cdot L_k \cdot r \left[\cos\gamma - \cos(\gamma + \alpha_0)\right]$$

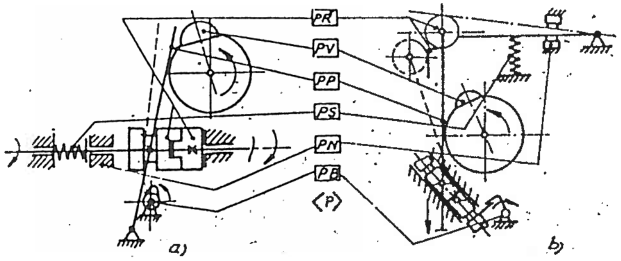
SPECIFIC PRESSURE $\quad p_s = \frac{M_{sp}}{r \cdot L_k \cdot a\left[\cos\gamma - \cos(\gamma + \alpha_0)\right]} \leq 200$ [MPa]

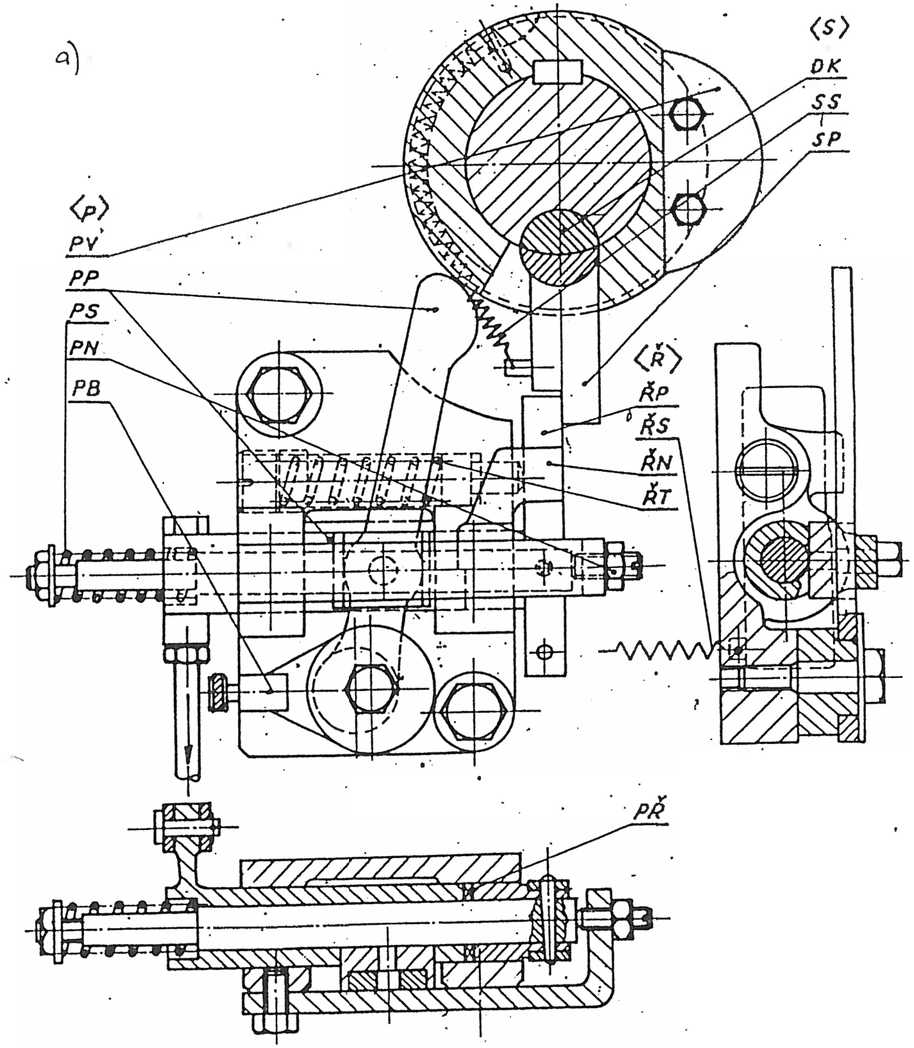
MAX. SHEER STRESS $\quad \tau_D \geq \frac{M_k}{R} \frac{1}{2S_A}$ WHERE S_A - TOTAL CROSS SECTION AREA

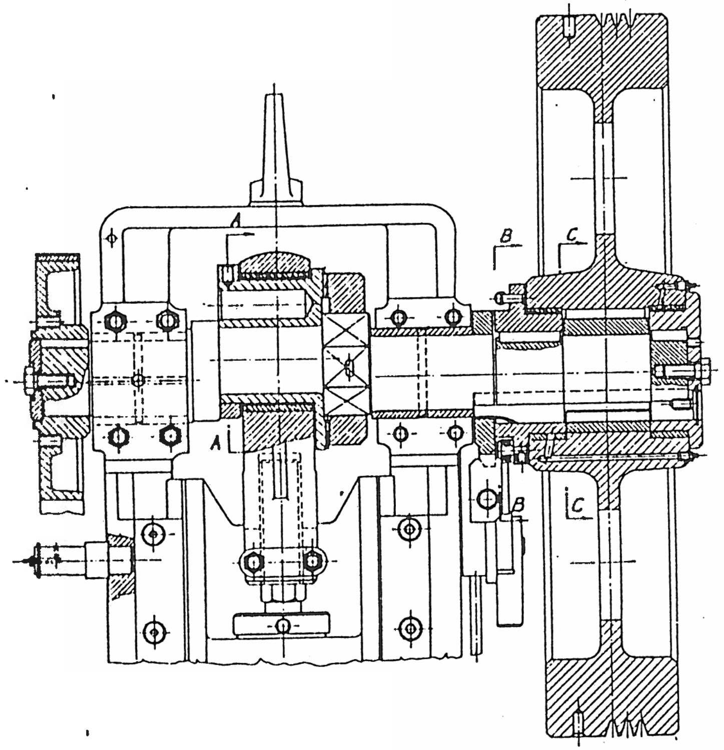
$M_{sp} \triangleq M_{max}$ from M_k, M_0, M_D

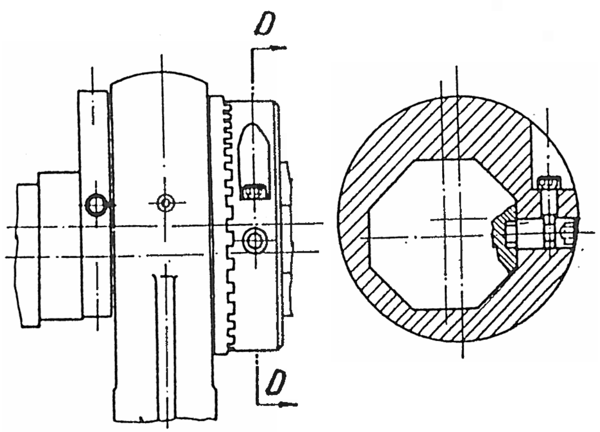
$$M_D = \omega_0 \sqrt{\frac{I_1 \cdot I_2}{I_1 + I_2} \cdot \frac{1}{e_k}} = \omega_0 \sqrt{\frac{I_2}{e_k}} \quad \text{WHEN } I_1 \gg I_2$$

$e_k = \frac{2 \cdot L}{G \cdot I_p}$ SHAFT RIGIDITY (TORSIONAL DAMPING)









2. FRICTIONAL CLUTCH

MAY BE PLACED EITHER ON CRANK OR ADVANCED SHAFT.

TORQUE $M_{sp} = F_t \cdot R_s = (1{,}1 \div 1{,}3)\ M_k$

$M_{sp} = p \cdot S \cdot f \cdot R_s \cdot m$

WHERE: p = ALLOWED PRESSURE (DUE TO FRICTIONAL MATERIAL) $= 0{,}4 \div 0{,}6$ [MPa]

S - FRICTIONAL AREA $\approx \pi \cdot (R_1^2 - R_2^2)$

INTER RADIUS $R_2 = (1{,}6 \div 1{,}8)\ d$ [mm]

OUTER -"- $R_1 = (1{,}4 \div 2)\ R_2$ [mm]

THICKNES $t = 0{,}1\ (R_1 - R_2)$ [mm]

MEAN RADIUS $R_s = \dfrac{R_1 + R_2}{2}$ [mm]

FRICTION COEFF. $f = 0{,}35 \div 0{,}4$ (FERODO)

NUMBER OF FRICTION SURFACES = m

HEAT (ENERGY) LOAD COEFFITIENT

$$K = \frac{\beta\ I_r (\omega_o^2 - \omega_c^2) \cdot n_z}{2\pi (R_1^2 - R_2^2)} \leq (3 \div 10) \quad ; \quad \beta = \begin{cases} (1{,}05 \div 1{,}1) & \text{exc. shaft} \\ (1{,}25 \div 1{,}35) & \text{advanced shaft} \end{cases}$$

n_z NUMBER OF POSSIBLE ENGAGEMENTS $\sim \leq n_o \cdot C_z$ – $C_z = 0{,}5 \div 0{,}65$, $C_z = 0{,}3 \div 0{,}45$

WITH n_o RISING C_z - LOWERS

TEMPERATURE RISE (HEAT TRANSFER TO AIR)

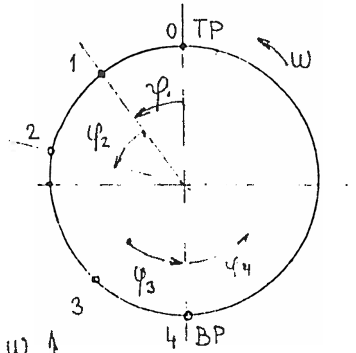
$$\frac{n_o \cdot C_z}{60} \frac{1}{2} I_r (\omega_o^2 - \omega_c^2) = \alpha\ (t_s - t_o) \cdot S_A$$

HEAT TRANSIENT COEFF $\alpha = (20 \div 100)$ [$kJ\ m^{-2} h^{-1} K^{-1}$] ↑ with speed

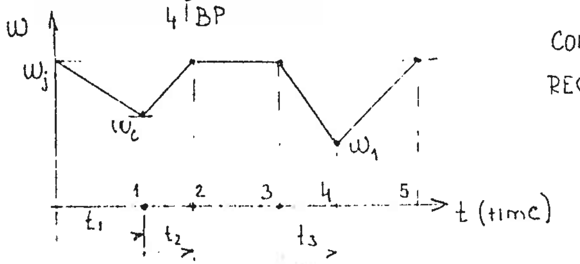
OUTER (OVERALL) AREA S_A - [m^2] - May be extended (RIBONS, HOLES)

MAX. ALLOWED TEMP. $t_s \leq 160°C$ (or K)

CLUTCH PERFORMANCE (CALCULATION)



1. → φ_1 – "START UP" ANGLE
2. → φ_2 – "RUN FOR" ANGLE
3. → φ_3 – "WORKING" LOOSE ANGLE
4. → φ_4 – RUN UP – FOR ω_0



CONSUMED ENERGY MUST BE REGAINED FROM MOTOR

1. $\omega_c = \omega_0 \cdot \sqrt{\frac{I_1}{I_1 + 2 I_2}}$; $M_D = \frac{M_{sp}}{2}$;

INERTIA MOMENTS
I_1 = DRIVING MASSES
I_2 = FOLLOWING MASSES
I_c = SUMMONED MASSES

$t_1 = \frac{2 I_2}{M_D} \cdot \omega_0 \sqrt{\frac{I_1}{I_1 + 2 I_2}}$

$\varphi_1 = \frac{I_2 \cdot \omega_0^2}{M_D} \cdot \frac{I_1}{I_1 + 2 I_2}$

ω_0 – nominal ang. speed
ω_{ms} – motor sychron. speed

2. $T^* = \frac{I_c (\omega_0 - \omega_c)}{M_{sp}}$

$\varphi^* = T^* \cdot \frac{(\omega_0 + \omega_c)}{2}$

$$\tau = \frac{(\omega_0^2 - \omega_c^2)(\omega_{ms} - \omega_0)^m (m+1)(m+2)}{2\{(\omega_{ms} - \omega_c)^{m+1} [\omega_{ms} + (1+m)\omega_c] - (\omega_{ms} - \omega_0)^{m+1} [\omega_{ms} + (1+m)\omega_0]}$$

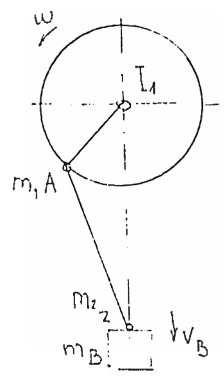
$t_2 = T^* \cdot \tau$ [s]

$\varphi_2 = \varphi^* \cdot \tau$ [rad]

3. SAME AS PREVIOUS ; EXCEPT $\omega_c \approx \omega_1$, where $\omega_1 = \omega_0 (1 - \nu)$

DYNAMIC BEHAVIOUR (CALCULATION)

INERTIA FEATURES



$A = \frac{1}{2} I \cdot \omega^2$; ~ $\frac{1}{2} m \cdot v^2$

$\frac{dA}{dt} = P = I \cdot \omega \cdot \frac{d\omega}{dt} + \frac{dI}{dt} \cdot \frac{\omega^2}{2} = M_a \cdot \omega$

$\omega = \frac{d\varphi}{dt}$; $M_a = I \frac{d\omega}{dt} + \frac{\omega^2}{2} \frac{dI}{d\varphi} = M_{a1} + M_{a2}$

$I_r \cdot \omega^2 = (I_1 + m_1 \cdot r^2) \cdot \omega^2 + (m_2 + m_B) \cdot v_B^2$

$v_B = r \cdot i(\varphi) \cdot \omega$

$I_r \cdot \omega^2 = \{I_1 + m_1 \cdot r^2\} \cdot \omega^2 + [(m_2 + m_B) \cdot r^2 \cdot i^2(\varphi) \cdot \omega^2]$

$I_r = I_1 + m_1 r^2 + (m_2 + m_B) \cdot r^2 \cdot i^2(\varphi)$,

$\frac{dI_r}{d\varphi} = 2 (m_2 + m_B) \cdot r^2 \cdot i(\varphi) \cdot \frac{di(\varphi)}{d\varphi}$

$M_{a1} = [I_1 + m_1 r^2 + (m_2 + m_B) \cdot r^2 \cdot i^2(\varphi)] \cdot \frac{d\omega}{dt}$

$M_{a2} = \{\omega^2 (m_2 + m_B) \cdot r^2 \cdot i(\varphi)\} \frac{di(\varphi)}{d\varphi}$

MOMENT OF INERTIA $M_a = M_{a1} + M_{a2}$

$i(\varphi) > i^2(\varphi) > \frac{di(\varphi)}{d\varphi}$ – small

MAIN INFLUENCE IS

$M_a = [I_1 + m_1 \cdot r^2] \frac{d\omega}{dt}$

BRAKES

MUST STOP ROTATING MASSES AND FIX RAM IN THE TOP POSITION.

TYPES : 1. BELT
2. JAWS
3. DISC

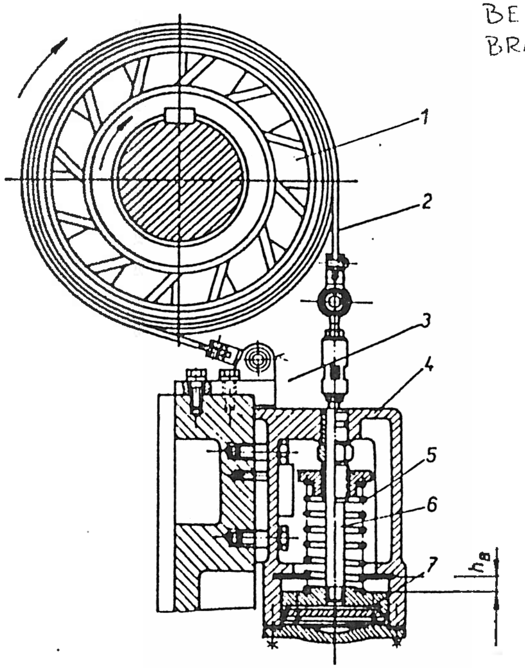
CONTROL - MAINLY MECHANICAL, ACTING WHEN AIR PRESSURE INTO CLUTCH IS INTERUPTED

TORQUE ~ $\frac{1}{2} I_{r_2} \cdot \omega_0^2 = (2-\eta_m) \cdot M_B \cdot \psi_B \rightarrow M_B$

$\frac{2\pi}{360} \cdot \psi_B^\circ = 8^\circ \div 15^\circ$ $n_0 = 15 \div 100$ $- \psi_B = \psi_e \cdot i$

$30^\circ \div 60^\circ$ $n_0 = 100 \div 300$

BELT BRAKE



$S_2 = S_1 \cdot e^{\alpha f} = F$

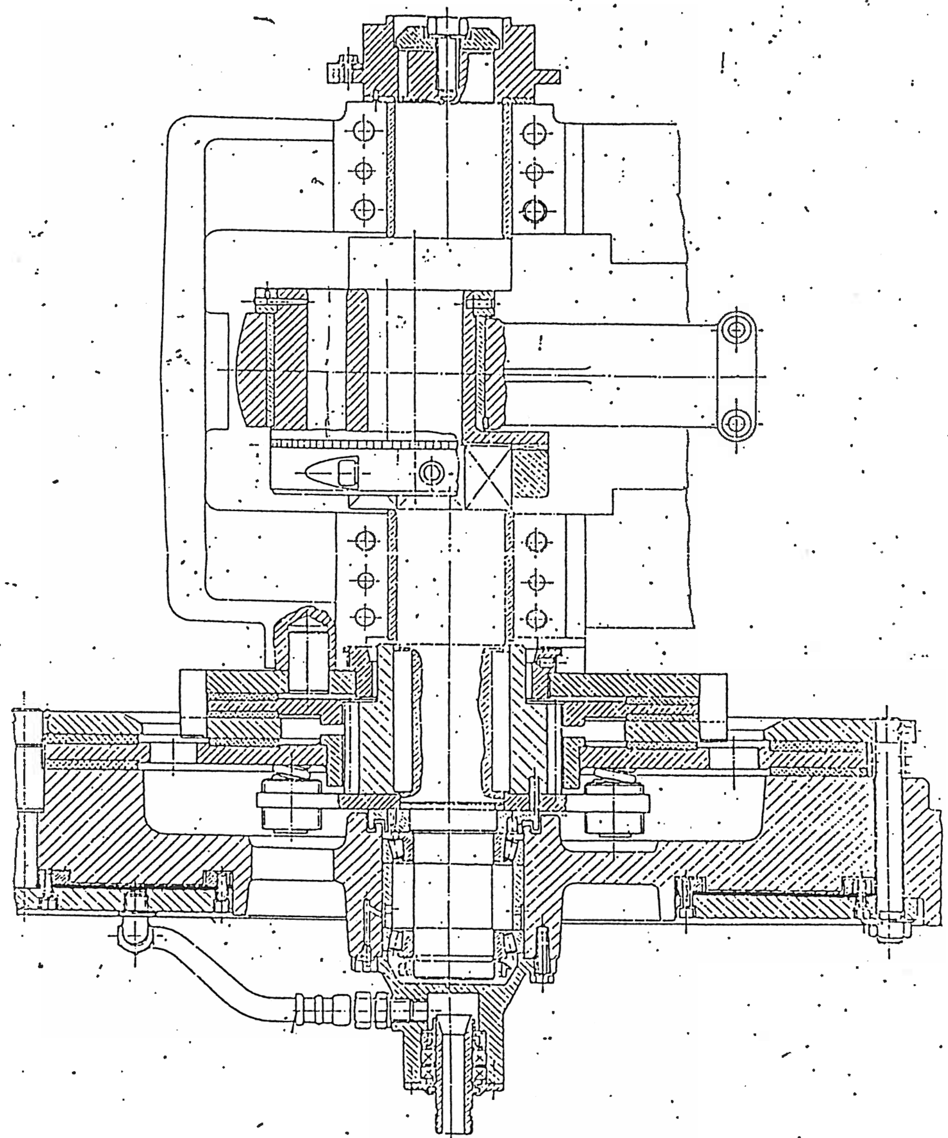
$M_B - S_2 \frac{D}{2} + S_1 \frac{D}{2} = 0$

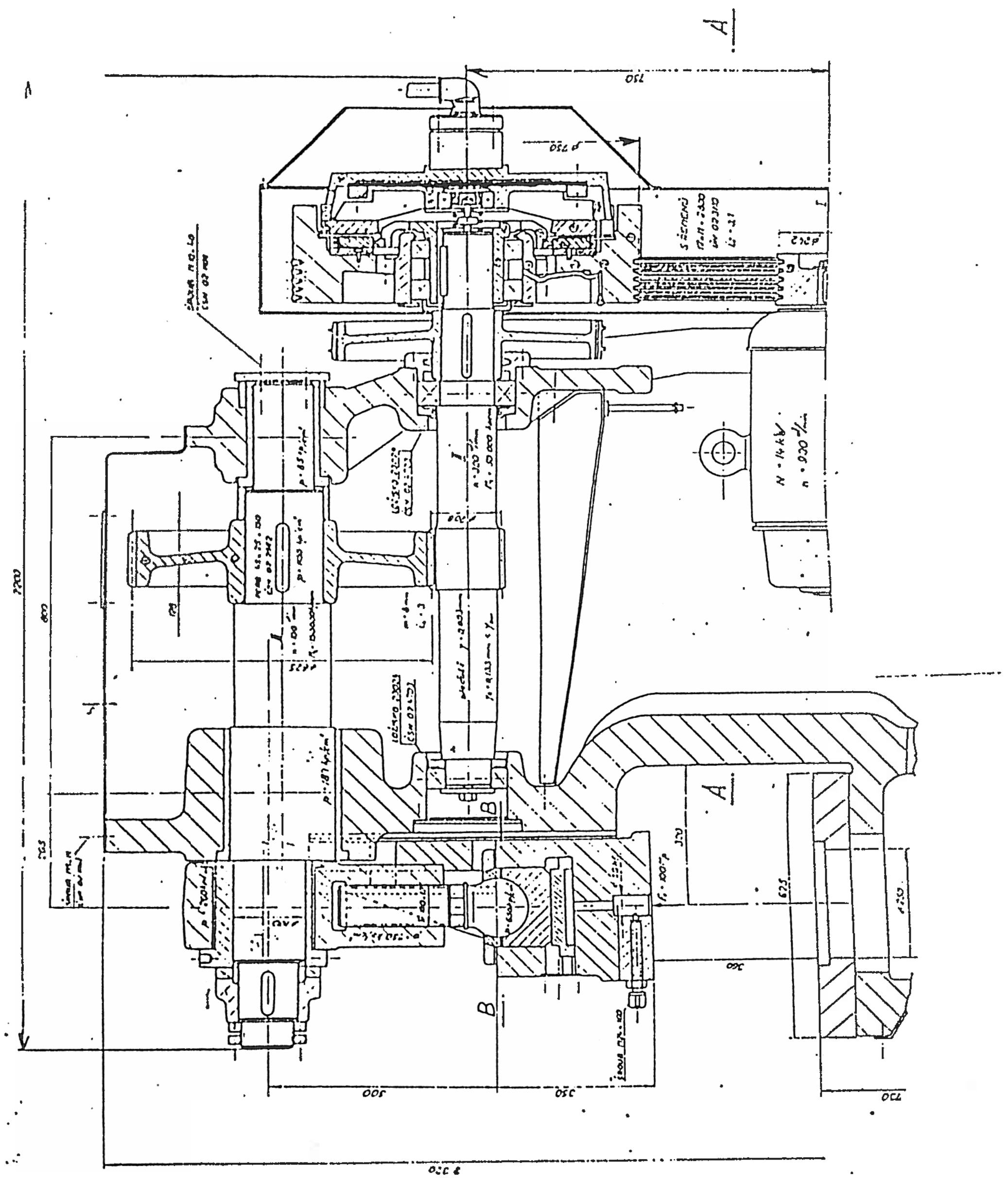
$M_B = F \cdot \frac{D}{2} \cdot \frac{e^{\alpha f} - 1}{e^{\alpha f}}$

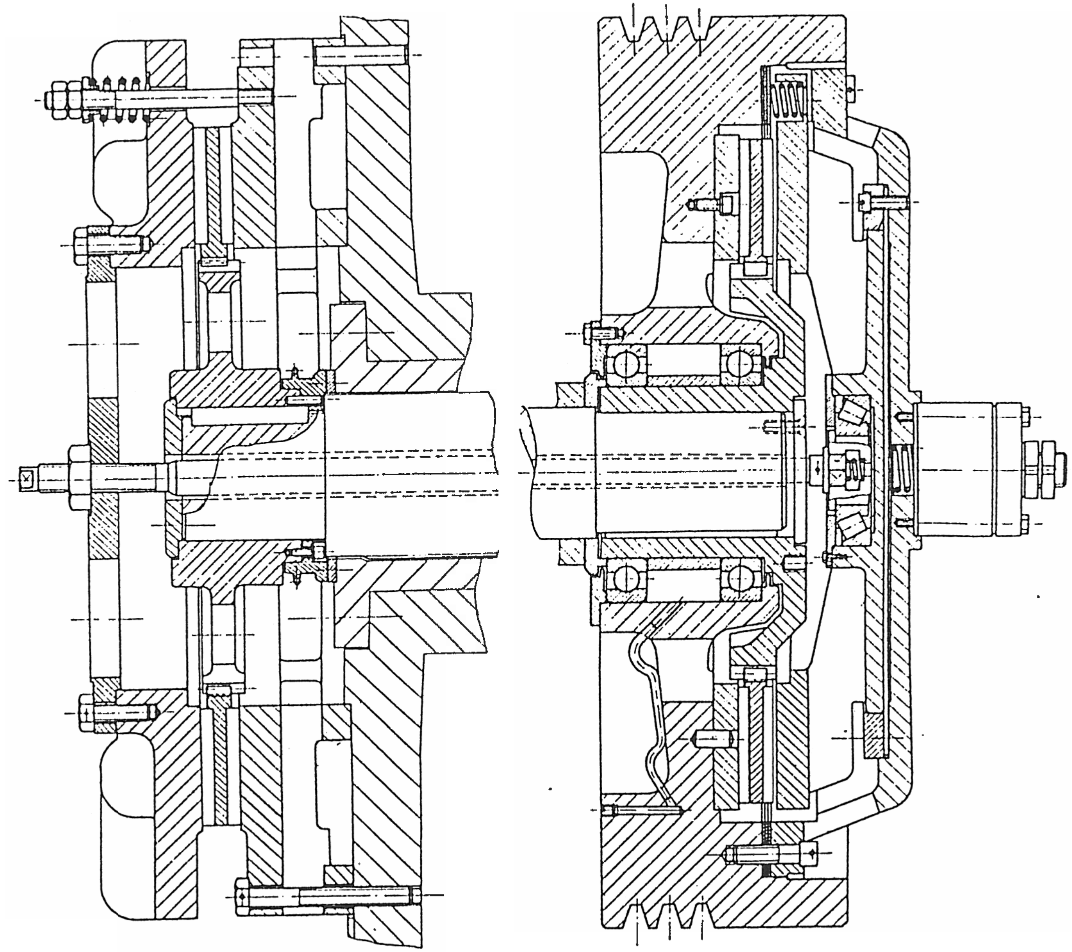
$p = (0{,}15 \div 0{,}2)$ [MPa]

$I_p = I_2 + I_1 \left(\frac{n_1}{n_2}\right)^2 + I_0 \left(\frac{n_0}{n_2}\right)^2$ $[\mathrm{kg\,m^2}]$ $\rightarrow = I_2 + I_1 \cdot i_2^2 + I_0 \cdot i_2^2 i_1^2$

$I_r = I_0 + \Sigma m_z \left(\frac{v_z}{\omega_0}\right)^2$

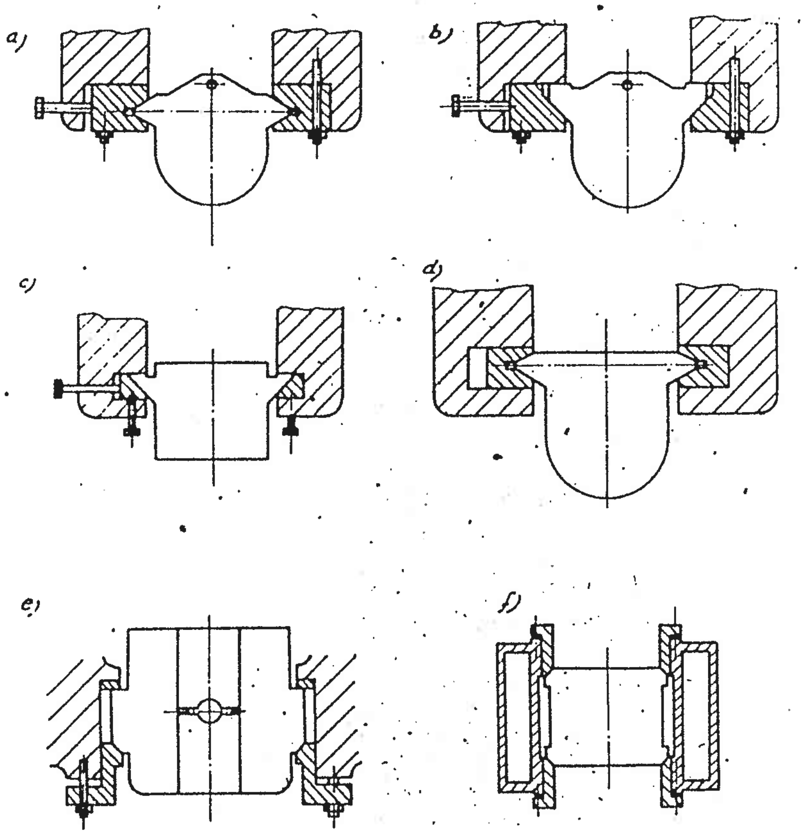



A
B

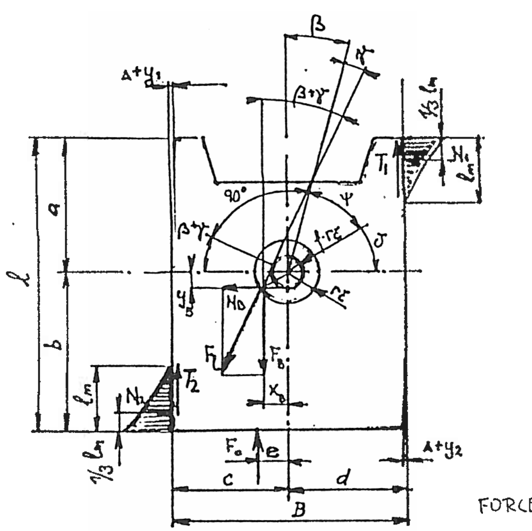


RAM

RAM SLIDEWAYS



$$l/B = \begin{cases} 1. & 1{,}4 - 2{,}5 \quad \text{ONE POINT} \\ 2. & 0{,}4 - 0{,}5 \quad \text{TWO POINTS} \\ 3 & 2{,}5 - 3 \quad \text{FORGING PRESSES} \end{cases}$$



$\Delta + y \doteq 0{,}05 + 0{,}5$ mm

$l_m \doteq \left(\frac{1}{4} \div \frac{1}{8}\right) l$

$f = 0{,}06 \rightarrow tg\varphi \rightarrow \varphi = 3°30'$

$T_1 = N_1 \cdot f \quad ; \; T_2 = N_2 \cdot f$

$F_O \doteq F_j$

$N_B = F_l \cdot \sin(\beta+\gamma) = F_B \cdot tg(\beta+\gamma)$

$F_B = F_l \cdot \cos(\beta+\gamma)$

$F_l = F_o \dfrac{\cos\varphi}{\cos(\beta+\gamma+\varphi)} \doteq F_j \dfrac{\cos\varphi}{\cos(\beta+\gamma+\varphi)}$

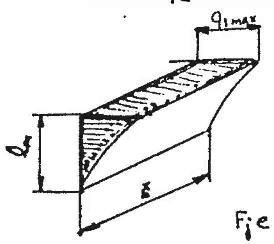
$x_B = r_\varepsilon \cdot \cos\delta \quad - \quad \delta = 90° - (\beta+\gamma+\psi)$

$y_B = r_\varepsilon \cdot \sin\delta \qquad \sin\psi =$

BALANCE :

FORCES $\rightarrow F_j + T_1 + T_2 - F_B = 0 \quad ; N_1 + N_B - N_2 = 0$

MOMENTS $\rightarrow F_j \cdot e - F_B \cdot x_B - N_1 \cdot a - N_2 \cdot b - T_1 \cdot d + T_2 \cdot c + N_B \cdot y_B = 0$



$F_j + f(N_1+N_2) - \dfrac{N_B}{tg(\beta+\gamma)} = 0 \quad \rightarrow \quad F_j + f(N_1+N_2) + \dfrac{N_1 - N_2}{tg(\beta+\gamma)} = 0$

$F_j + N_1 \underbrace{\left(f + \frac{1}{tg(\,)}\right)}_{D_1} + N_2 \underbrace{\left(f - \frac{1}{tg(\,)}\right)}_{D_2} = 0 \quad \Rightarrow N_2 = -\dfrac{(F_j + N_1 D_1)}{D_2}$

$F_j e + \dfrac{N_1 - N_2}{tg(\beta+\gamma)} \cdot x_B - N_1 \cdot a - N_2 \cdot b - f N_1 \cdot d + f N_2 c - (N_2 - N_1) y_B = 0$

$F_j \cdot e + N_1 \underbrace{\left\{x_B \frac{1}{tg(\,)} - a - f\frac{B}{2} + y_B\right\}}_{C_1} - N_2 \underbrace{\left\{x_B \frac{1}{tg(\,)} + b - f\frac{B}{2} + y_B\right\}}_{C_2} = 0$

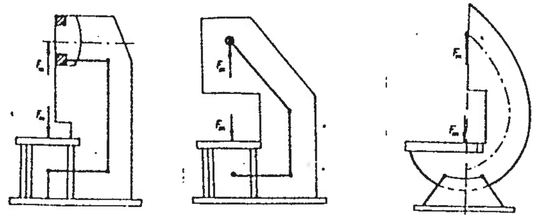
$F_j \cdot e + N_1 C_1 - N_2 C_2 = 0 \quad \rightarrow F_j \cdot e + N_1 \cdot C_1 + \dfrac{F_j + N_1 D_1}{D_2} C_2 = 0 \rightarrow N_1 = F_j \cdot$ ———

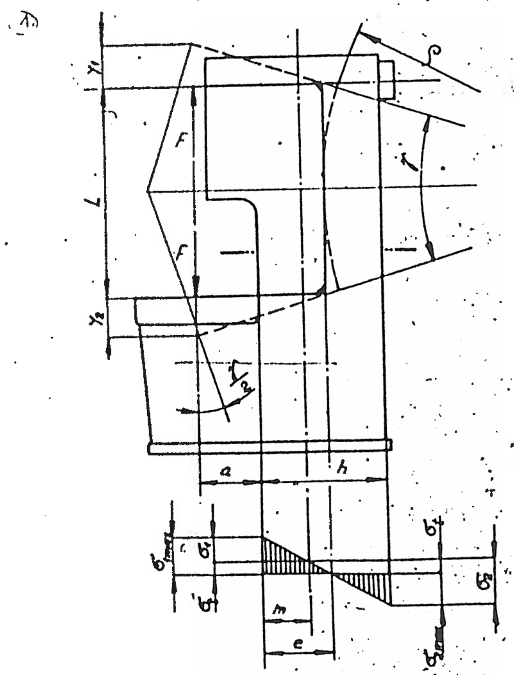
$N_{1,2} \leq \frac{1}{2}\, q_{1max} \cdot l_m \cdot s$

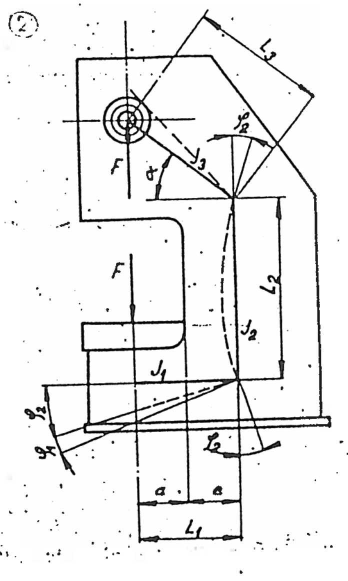
$q_{1max} \doteq$	10 MPa	-	14340.9	STEEL
	25 MPa	-	422424	CAST IRON
	30 MPa	-	423146.6	BRASS

STANDS (STRUCTURES)

OPEN - C, CC







$M = F\,(a+m)$; $\gamma = \frac{L}{\rho} = \frac{L+y_1+y_2}{\rho+a+e}$

$y = \frac{L(a+e)}{\rho}$,

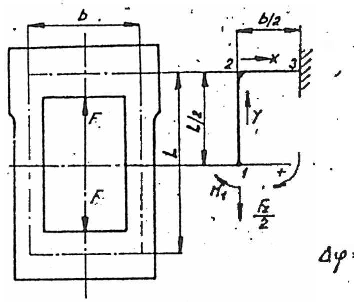
$\rho = \xi \cdot \frac{E \cdot I}{M}$;

$\sigma_1 = \frac{M \cdot m}{I}$, $\sigma_2 = \frac{M(b-m)}{I}$, $\sigma_t = \frac{F}{S}$

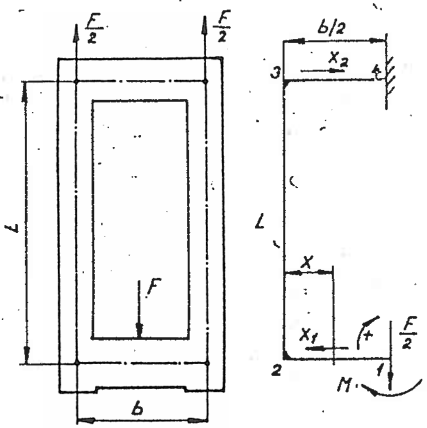
$e = b \cdot \frac{\sigma_{1max}}{\sigma_{1max}+\sigma_{2max}}$

$c_r = \frac{F}{y}$

CLOSED



$$\Delta\varphi = \frac{1}{E\,J_{12}} \int_0^{L/2} M\,dy + \frac{1}{E\,J_{23}} \int_0^{b/2} \left(M - \frac{F}{2}x\right) dx = 0$$



$$\Delta\varphi = \frac{1}{E\,J_{12}} \int_0^{b/2} M\,dx_1 + \int_0^{b/2} \frac{F}{2} x_1\,dx_1 + \frac{1}{E\,J_{23}} \left(\int_0^{L} \frac{F}{2} \cdot \frac{b}{2}\,dy + \int_0^{L} M\,dy \right) + \frac{1}{E\,J_{34}} \left(\int_0^{b/2} M\,dx_2 + \int_0^{b/2} \frac{F}{2} x_2\,dx_2 \right) = 0$$

HYDRAULIC PRESSES

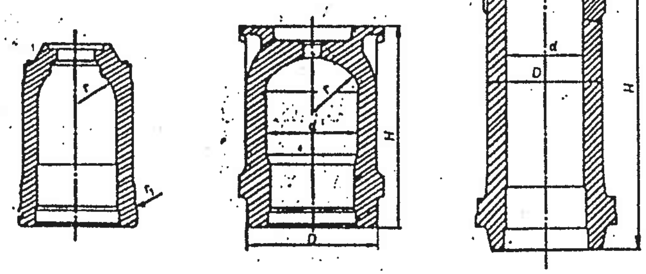
MAIN FEATURES -

1. ADVANTAGES
   - HIGH FORCES APPLICABLE
   - STROKE SETTING EASY
   - VARIABLE SPEED ENABLED
   - CONSTANT FORCE SETTING
   - EASY SPEED REVERSE

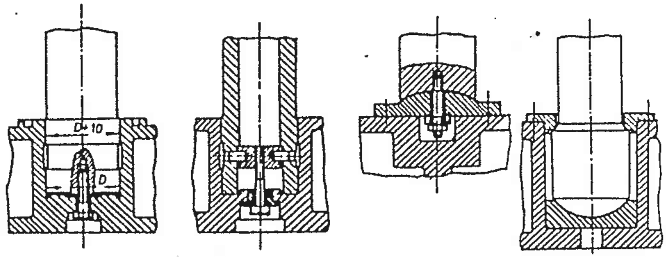
2. DISADVANTAGES
   - LOWER EFFICIENCY
   - COMPLICATED SYSTEM, MORE EXPENCIVE
   - LESSER PRODUCTIVITY (STROKE No IN TIME)
   - DIFFICULT MAINTANANCE AND DIAGNOSTICS

DRIVE TYPES
1. DIRECT (GENERATOR)
2. ACCUMULATOR
3. MULTIPLICATOR

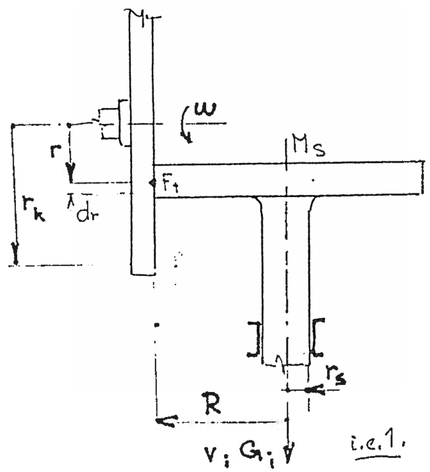
CYLINDER DESIGN



PISTON CONECTION TO PISTON ROD



FRICTION SCREW PRESS



SIMPLIFING CONDITIONS
1. f = constant
2. F_t - tangent
3. point connection

THREE WORK PHASES
1. START UP - DROPING
2. FORGING
3. LIFTING

i.e.1. $M_s + M_G = I \cdot \frac{d\omega_s}{dt_1}$

i.e.2. $A_u + A_y + A_f = \frac{1}{2} I \omega_s^2$

i.e.3 $M_s - M_G = I \frac{d\omega_s}{dt_3}$

1. $M_s = F_t \cdot R$; $M_G = G \cdot r_s \cdot tg(\alpha - \varphi)$ $\quad tg\varphi = f$, $tg\alpha = \frac{s}{2\pi}$

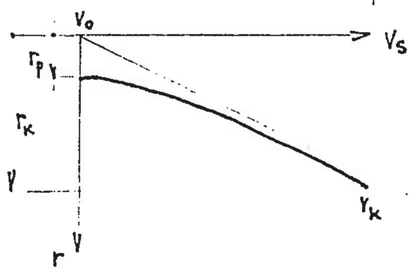
$\frac{s}{2\pi} = \frac{dr}{d\psi} \rightarrow d\psi = \frac{2\pi}{s} \cdot dr$

$\frac{d\psi}{dt} = \omega_s = \frac{v_s}{R} \rightarrow d\omega_s = \frac{dv_s}{R}$, $dt = \frac{d\psi}{\omega_s} = \frac{2\pi}{s}\frac{dr}{\omega_s} = \frac{2\pi}{s}\frac{R}{v_s} \cdot dr$

$\frac{d\omega_s}{dt_1} = \frac{s \cdot v_s}{2\pi \cdot R^2} \cdot \frac{dv_s}{dr} \rightarrow M_s + M_G = I \frac{s}{2\pi \cdot R^2} \frac{v_s \cdot dv_s}{dr} \rightarrow$

$dr = \frac{1}{M_s + M_G} \cdot \frac{I \cdot s}{2\pi \cdot R^2} \cdot v_s \cdot dv_s$ $\quad r_k$: $r = r_k$; $v_s = v_k = \omega \cdot r_k$ $\quad i_0 \rightarrow r = r_p$; $v_s = 0$

$$r = r_p + \frac{1}{M_s + M_G} \frac{I \cdot s \cdot v_s^2}{4\pi R^2}$$



$M_s + M_G = I \frac{dv_s}{dt} \cdot \frac{1}{R} \rightarrow dv_s = (M_s + M_G) \frac{R}{I} \cdot dt$

$\{r_k - r_p\} = \frac{1}{M_s + M} \cdot \frac{I \cdot s}{4\pi \cdot R^2} \cdot v_s^2$

$t = \sqrt{(r_k - r_p) \frac{4\pi}{s} \frac{I}{M_s + M_G}}$ STROKE TIME

$(r_k - r_p)$: H - STROKE

2.

$$A_u + A_y + A_f = \frac{1}{2} I \omega^2 = W$$

$$A_u = k_v \cdot F_{om} \cdot h_u$$

$$A_y = \frac{1}{2} \frac{F_{om}^2}{c}$$

$$A_f = (1-\eta_f) \cdot W$$

$$\eta_f \cdot W = k_v \cdot F_{om} \cdot h_u + \frac{1}{2} \frac{F_{om}^2}{c} \longrightarrow \text{ACTING FORCE}$$

$$F_{om} = c \left\{ \sqrt{\frac{2 \cdot W \cdot \eta_f}{c} + k_v^2 h_u^2} - k_v \cdot h_u \right\} \doteq c \cdot \sqrt{\frac{2 W \cdot \eta_f}{c}} \approx F_{max}$$

3.

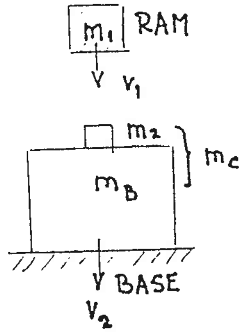
$$M_s - M_G = I \frac{d\omega_s}{dt} \qquad M_G = G \cdot r_s \cdot tg(\alpha + \varphi)$$

$$M_s - M_G = I \frac{S}{2\pi \cdot R^2} \cdot \frac{v_s \cdot dv_s}{dr}$$

$$dr = \frac{1}{M_s - M_G} \cdot \frac{I \cdot S}{2\pi \cdot R^2} \cdot v_s \cdot dv_s \qquad \begin{vmatrix} -r = r_p & - v_s = \omega \cdot r_p \\ -r = r_k & - v_s = 0 \end{vmatrix}$$

$$-r = r_k - \frac{1}{M_s - M_G} \cdot \frac{I \cdot S \cdot v_s^2}{4\pi \cdot R^2}$$

IMPACT WORK - HAMMERS



$$m_1 \cdot v_1 = (m_1 + m_c) \cdot v_s \Rightarrow$$

$$v_s = v_1 \frac{m_1}{m_1 + m_c}$$

$$A_u + A_{yr} = \frac{1}{2} m_1 v_1^2 - \frac{1}{2} (m_1 + m_c) \cdot v_s^2 \qquad \text{ENERGY BALANCE}$$

$$A_u + A_{yr} = \frac{1}{2} m_1 v_1^2 \left\{ 1 - (m_1 + m_c) \cdot \frac{m_1}{(m_1 + m_c)^2} \right\}$$

$$A_u + A_{yr} = \frac{1}{2} m_1 v_1^2 \cdot \frac{m_c}{m_1 + m_c}$$

IDEAL PLASTICITY

$$F = F_o = k \cdot S \quad ; F = m_1 \cdot a_1 = m_c \cdot a_2 \quad . \quad a_1 = \frac{v_1 - v_s}{t} \text{ deceleration}$$

$$a_2 = \frac{v_s}{t} \text{ acceleration}$$

STRIKING TIME

$$t = \frac{v_1}{a_1 + a_2} = v_1 \cdot \frac{m_1 \cdot m_c}{(m_1 + m_c)} \cdot \frac{1}{k \cdot S}$$

REAL CASE

$$A_u + A_{yr} = \frac{1}{2} m_1 \cdot v_1^2 (1 - k_r^2) \cdot \frac{m_c}{m_1 + m_c}$$

k_r = RESTITUTION COEFFICIENT $\quad 0 < k_r < 1$

- $k_r = 0$ - IDEAL PLASTICITY
- $k_r = 1$ - IDEAL ELASTICITY
- $k_r \Rightarrow 0{,}3$ - HOT FORGING
- $k_r \Rightarrow 0{,}7$ - COLD FORGING

EFFICIENCY

$$\eta = \frac{2 A_u}{m_1 v_1^2} = (1 - k_r^2) \cdot \frac{m_c}{m_1 + m_c} \cdot \frac{A_u}{A_u + A_{yr}}$$