Mechanism for moulding glass   ???

- Guidance Mechanism for transformation of a sliding input motion into a synchronous centric sliding output motion
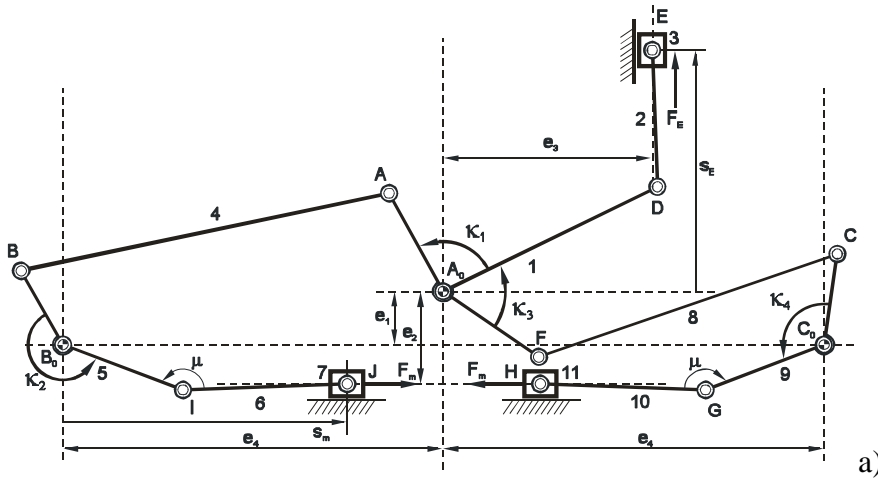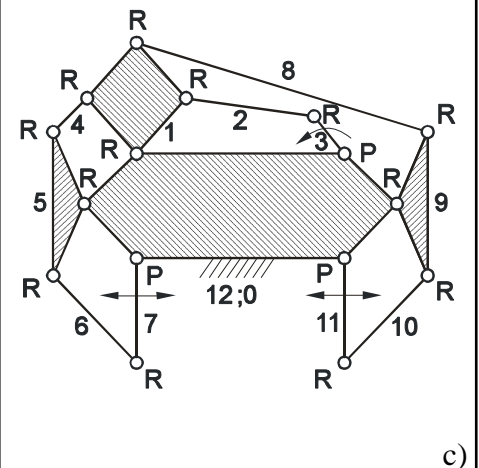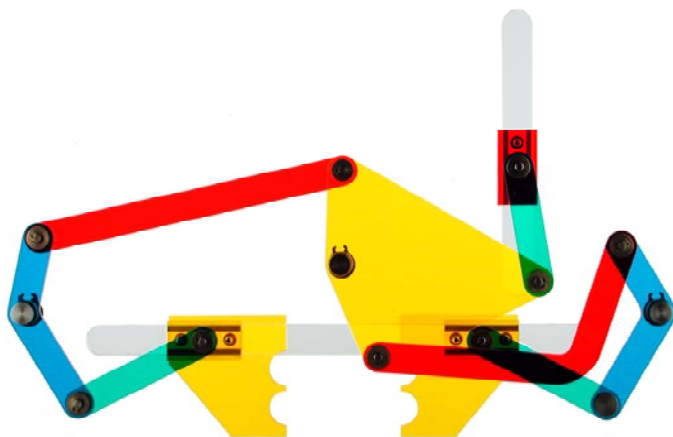- Swinging 12-bar planar mechanism with toggle position

Fig. 1. Mechanism for moulding glass

a) Kinematic Schematic Diagram
b) Mechanism Model
c) Kinematic Chain

a)

b)

c)

Symbols in Kinematic Chain:
R for Rotation   **P** for Prismatic   **S** for Screw Motion   ⤶ Input link;   ⟷ Output link
Example **R$_2$P**: Joint with 3 degrees of freedom; 2 Rotations, 1 Prismatic

Characteristics:

Number of Input Links   : 1, of which 1 at Frame
Number of Output Links   : 2, of which 2 at Frame
Number of Links   : 12, of which 8 binary, 2 ternary,
                                      1 quaternary and 1 senary
Number of Joints   : 16, of which 13 Hinges (R),
                                      and 3 Prismatic (P)

Dimensions (in Unit Lengths):

$\overline{A_0A} = \lambda_3 = 1$; $\overline{B_0B} = \overline{C_0C} = \lambda_5 = 0,82$;

$\overline{A_0F} = 1,06$; $\overline{B_0I} = \overline{C_0G} = \lambda_6 = 1,13$;

$\overline{A_0D} = \lambda_1 = 2,11$; $\overline{GH} = \overline{IJ} = \lambda_7 = 1,47$;

$\overline{AB} = \lambda_4 = 3,33$; $\overline{DE} = \lambda_2 = 1,23$; $\overline{FC} = 2,82$;

$e_1 = 0,51$; $e_2 = 0,82$; $e_3 = 1,89$;

$e_4 = 3,38$; $\kappa_1 = 93,3°$; $\kappa_2 = 223,3°$;

$\kappa_3 = 62,3°$; $\kappa_4 = 119,1°$;

Description:
The in **figure 1** presented mould mechanism is a swinging

12-bar linkage that is used in glass industry where it is build into Individual Section (IS) machines for the production of glass containers [1]. The mostly pneumatically driven input link is slider 3 which moves eccentrically along a vertical line having an offset e_3 with respect to A_0 (fig.1a). Coupler 2 transforms the sliding motion of link 3 into a rocking motion of the quaternary element 1 which drives by use of couplers 4 and 8 the elements 5 and 9 respectively into a rocking motion. These rockers are mounted by revolute pairs to the senary frame link 12 at a horizontal offset e_1 and a vertical offset e_4 with respect to A_0 as shown in figure 1a. Sliders 7 and 11 represent the left and right mould respectively (fig.1b) and move along the horizontal line having an offset e_2 with respect to A_0. Their motion is nearly synchronous and centric with respect to the vertical through A_0 and is driven by the identical couplers 6 and 10. By pressing the moulds together, the angle

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μ between the rockers 5 and 9 and the couplers 6 and 10 respectively reaches almost 180° which is a toggle position in which the mechanical advantage is relatively high.

Fig. 2a. 1st four-bar mechanism

Fig. 2b. 2nd four-bar mechanism

Fig. 2c. 3rd four-bar mechanism

The easiest way to calculate the transfer function of s_M depending on the displacement of point E, s_E, is by first splitting up the model into three 4-bar mechanisms as shown in **figure 2**. From figure 2a the transfer angle φ can be found by the relation $\varphi = \kappa_1 + \varphi_s - \varphi_t$. Here κ_1 is the constant angle of λ_1 relative to λ_3 and φ_s and φ_t are obtained by

$$\sin \varphi_s = \frac{s_E}{f_1}, \quad \cos \varphi_s = \frac{e_3}{f_1}, \quad \cos \varphi_t = \left(\frac{\lambda_1^2 - \lambda_2^2 + f_1^2}{2\lambda_1 f_1} \right),$$

in which $f_1 = \sqrt{s_E^2 + e_3^2}$ and for φ_t the cosine rule was applied. From figure 2b the transfer function $\psi(\varphi)$ is defined as $\psi = \kappa_2 + \psi_s + \psi_t$ with constant κ_2 being the greatest relative angle between λ_5 and λ_6 and ψ_s and ψ_t being calculated by

$$\sin \psi_s = \frac{e_1 + \lambda_3 \sin \varphi}{f_2}, \quad \cos \psi_s = \frac{e_4 + \lambda_3 \cos \varphi}{f_2},$$

$$\cos \psi_t = \frac{\lambda_5^2 - \lambda_4^2 + f_2^2}{2\lambda_5 f_2}$$

with $f_2 = \sqrt{(e_4 + \lambda_3 \cos \varphi)^2 + (e_1 + \lambda_3 \sin \varphi)^2}$. Finally from figure 2c the mould displacement s_M can be calculated by

$$s_M = \sqrt{\lambda_7^2 - (e_1 - e_2 - \lambda_6 \sin \psi)^2} + \lambda_6 \cdot \cos \psi .$$

The graph of the 0th order transfer function $s_M(s_E)$ is shown in **figure 3**. The dashed vertical lines represent the maxima of the input displacement s_E within the model. The 1st order transfer function, presented in **figure 4**, can be calculated by differentiating s_M with respect to s_E as follows:

$$s_M' = \frac{ds_M}{ds_E} = \frac{ds_M}{d\psi} \cdot \frac{d\psi}{d\varphi} \cdot \frac{d\varphi}{ds_E}$$

The relative mechanical advantage of the whole mechanism can be calculated by use of the principle of virtual work [2]. This writes $F_E \cdot ds_E = 2F_M \cdot ds_M$, with F_E and F_M being the driven force in point E and the press force respectively. Rearranging the virtual work relation results into

$$\frac{F_M}{F_E} = \frac{1}{2} \frac{ds_E}{ds_M} = \frac{1}{2s_M'} .$$

In **figure 5** the mechanical advantage with respect to the input displacement s_E is shown. Indeed the mechanical advantage increases strongly by reaching the toggle position.

Fig. 3. 0th order transformation

Fig. 4. 1st order transformation

Fig. 5. Mechanical Advantage

References:

[1] Corves, B.: Mechatronic in Container Glass Forming, Mechatronic 2006 - 4th IFAC-Symposium on Mechatronic Systems, 2006, Heidelberg.

[2] Dittrich, G., Müller, J.: Geradenparallelgreifer. Der Konstrukteur 22, 1991, Nr. 10, p 15/16.