The flow characteristic on the position of the drive

To determine the water shock or to determine the flow in the valve, we need to know the flow characteristic, which depends on the stroke of the drive. The flow characteristic of the valve, which is not dependent on the stroke of the actuator, must be recalculated, because there may be a member between the actuator that is not linear (crank mechanism). Or the drive itself may be non-linear due to its arrangement (hydraulic cylinder that controls the lever). These differences can be in the order of tens of percent. And they have a significant effect on the flow characteristics. To determine the flow characteristics that depend on the drive, the findings contained in see below.

The flow characteristic (crank mechanism):
It is designed to convert the horizontal displacement (stroke) of the flow characteristic into a rocking motion.

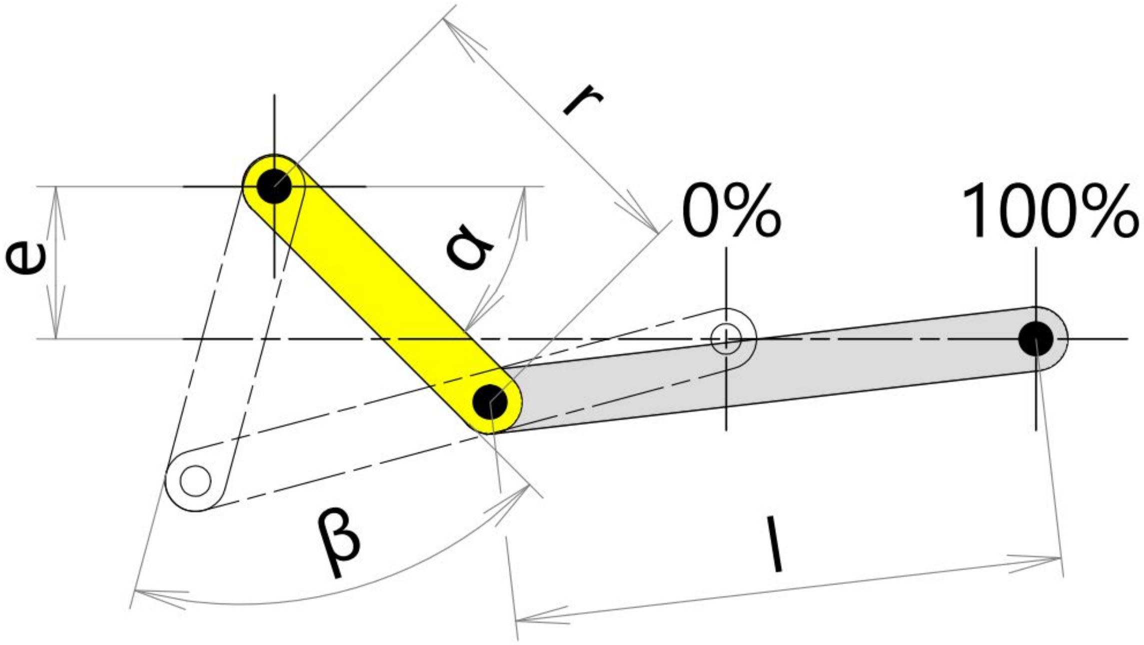

Fig. 1 Crank mechanism

Stroke:

$$S_{max} = \sqrt{l^2 - (r\,sin \propto - e)^2} + r\,cos \propto - \sqrt{l^2 - (r\,sin(\propto + \beta) - e)^2} - r\,cos(\propto + \beta)$$

S_{max}	stroke	[mm]
l	rod length	[mm]
r	lever arm length	[mm]
α	lever angle in closed position	[°]
e	eccentricity	[mm]
β	swing angle	[°]

Angle rotation of the rocking motion:

$$\beta_S = \frac{\beta}{100} * S$$

β_s	angle rotation of the rocking motion	[°]
β	swing angle	[°]
S	percent rotation of the rocking motion	[%]

Stroke in the pivot position:

$$S_s = S_{max} - \sqrt{l^2 - (r\,sin \propto - e)^2} - r\,cos \propto + \sqrt{l^2 - (r\,sin(\propto + \beta - \beta_s) - e)^2} + r\,cos(\propto + \beta - \beta_s)$$

S_s	stroke in the pivot position	[mm]
S_{max}	stroke	[mm]
l	rod length	[mm]
r	lever arm length	[mm]
α	lever angle in closed position	[°]
e	eccentricity	[mm]
β	swing angle	[°]
β_s	angle rotation of the rocking motion	[°]

Stroke percentage:

$$S_{s\%} = \frac{100}{S_{max}} * S_s$$

$S_{s\%}$	stroke percentage	[mm]
S_s	stroke in the pivot position	[mm]
S_{max}	stroke	[mm]

The flow characteristic (crank mechanism):

$$Q_c = Q_o - \frac{(Q_o - Q_{o+10})}{10}(S_{s\%} - S)$$

Q_c	value of flow characteristic (crank mechanism)	[]
Q_0	the value of the flow characteristic of the horizontal movement	[]
Q_{0+10}	10% higher value of the flow characteristic of horizontal movement	[]
$S_{s\%}$	stroke percentage	[mm]
S	percent rotation of the rocking motion	[%]

The flow characteristic (gearbox):
It is designed to convert the oscillating motion of the flow characteristic, which is in degrees of rotation, to the oscillating motion, which is in percent of rotation.

Angle rotation of the rocking motion:

$$\beta_S = \frac{\beta}{100} * S$$

β_s	angle rotation of the rocking motion	[°]
β	swing angle	[°]
S	percent rotation of the rocking motion	[%]

The flow characteristic (gearbox):

$$Q_c = Q_o - \frac{(Q_o - Q_{o+n})}{\beta_{+n} - \beta}(\beta_s - \beta)$$

Q_c	value of flow characteristic (gearbox)	[]
Q_0	the value of the flow characteristic of the oscillating motion	[]
Q_{0+n}	one value higher value of the flow characteristic of the oscillating motion	[]
β_{+n}	one value higher lever angle in the closed position	[°]
β_s	angle rotation of the rocking motion	[°]
β	swing angle	[°]

The flow characteristic (hydraulic cylinder):
It is designed to convert the oscillating motion of the flow characteristic, which is in percent of rotation per stroke of the hydraulic cylinder.

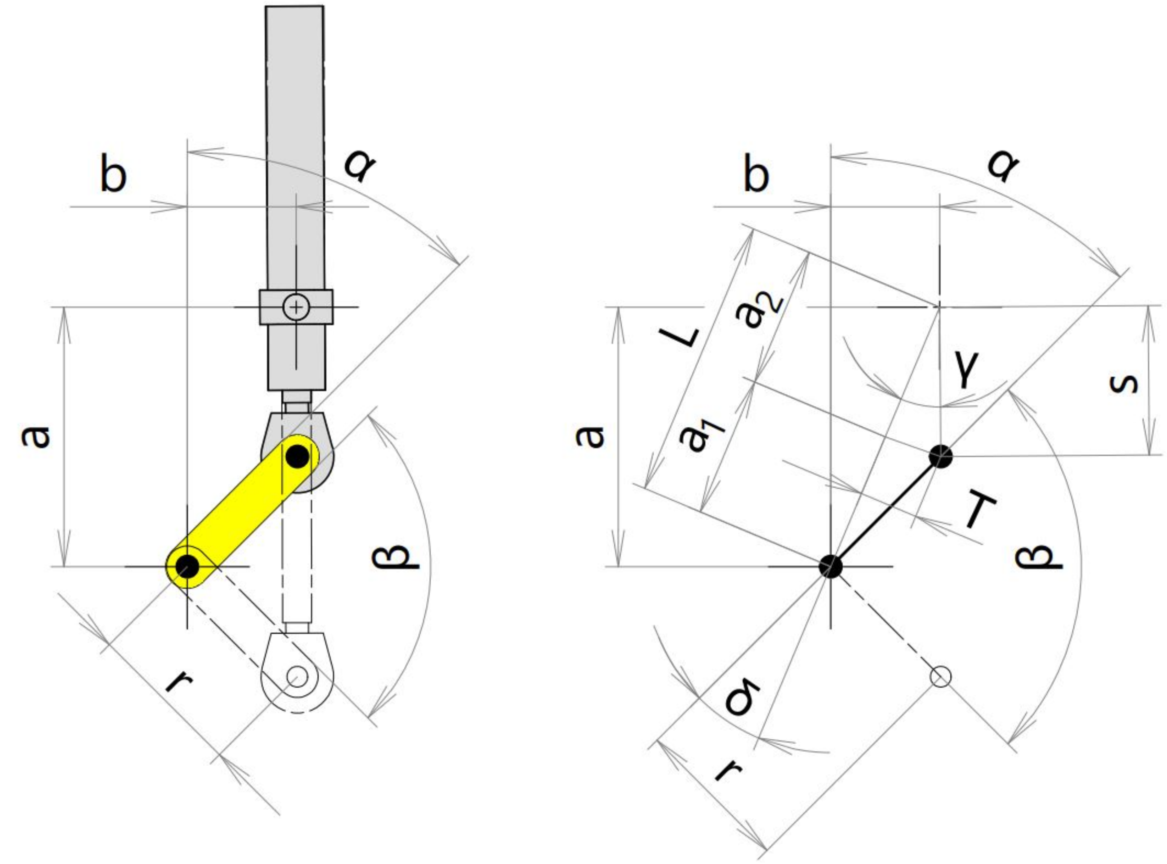

Fig. 2 Hydraulic cylinder

$$\alpha \geq tan^{-1}\frac{b}{a}$$
$$\alpha + \beta - 180 \leq tan^{-1}\frac{b}{a}$$
$$L_d < 100$$
$$T_c > T_d$$
$$T_d > 0 \rightarrow 0{,}8T_c \geq T_d \geq 0{,}1T_c$$

α	lever angle in closed position	[°]
β	swing angle	[°]
a	distance to hydraulic cylinder	[mm]
b	distance to hydraulic cylinder	[mm]
L_d	damping phase	[%]
T_c	total closing time	[s]
T_d	damping time	[s]

Distance between the axis of rotation of the valve and the axis of the hydraulic cylinder:

$$L = \sqrt{a^2 + b^2}$$

L	Distance between the axis of rotation of the valve and the axis of the Hydraulic cylinder	[mm]
a	distance to hydraulic cylinder	[mm]
b	distance to hydraulic cylinder	[mm]

Stroke:

$$\begin{aligned} S_{max} = {} & \sqrt{(b - r\,sin(\propto + \beta))^2 + (a - r\,cos(\propto + \beta))^2} \\ & - \sqrt{(b - r\,sin(\propto))^2 + (a - r\,cos(\propto))^2} \end{aligned}$$

S_{max}	stroke	[mm]
α	lever angle in closed position	[°]
β	swing angle	[°]
a	distance to hydraulic cylinder	[mm]
b	distance to hydraulic cylinder	[mm]
r	lever arm length	[mm]

The distance between the axis of the hydraulic cylinder and the axis of the eye of the hydraulic cylinder:

$$s = S_{max} - \frac{S_{max}}{100} * S + \sqrt{(b - r\,sin(\propto))^2 + (a - r\,cos(\propto))^2}$$

s	the distance between the axis of the hydraulic cylinder and the axis of the eye of the hydraulic cylinder	[mm]
S_{max}	stroke	[mm]
S	percentage of hydraulic cylinder stroke	[%]
α	lever angle in closed position	[°]
a	distance to hydraulic cylinder	[mm]
b	distance to hydraulic cylinder	[mm]
r	lever arm length	[mm]

Height:

$$T = \sqrt{s^2 - \left(\frac{L^2 - r^2 + s^2}{2L}\right)^2}$$

T	height	[mm]
s	the distance between the axis of the hydraulic cylinder and the axis of the eye of the hydraulic cylinder	[mm]
L	Distance between the axis of rotation of the valve and the axis of the hydraulic cylinder	[mm]
r	lever arm length	[mm]

The angle between the axis of the hydraulic cylinder and the imaginary line between the axis of the closure and the pivot axis of the hydraulic cylinder:

$$\gamma = sin^{-1}\frac{T}{s}$$

γ	the angle between the axis of the hydraulic cylinder and the imaginary line between the axis of the closure and the pivot axis of the hydraulic cylinder	[°]
T	height	[mm]
s	the distance between the axis of the hydraulic cylinder and the axis of the eye of the hydraulic cylinder	[mm]

Length a_2:

$$a_2 = s\,cos\,\gamma$$

a_2	length a_2	[mm]
s	the distance between the axis of the hydraulic cylinder and the axis of the eye of the hydraulic cylinder	[mm]
γ	the angle between the axis of the hydraulic cylinder and the imaginary line between the axis of the closure and the pivot axis of the hydraulic cylinder	[°]

Length a_1:

$$a_1 = L - a_2$$

a_1	length a_1	[mm]
a_2	length a_2	[mm]
L	Distance between the axis of rotation of the cap and the axis of the hydraulic cylinder	[mm]

The angle between the lever axis and the imaginary line between the valve axis and the pivot axis of the hydraulic cylinder:

$$a_1 \leq 0 \rightarrow \delta = 90 + cos^{-1}\frac{T}{r}$$

$$a_1 > 0 \rightarrow \delta = 90 - cos^{-1}\frac{T}{r}$$

δ	the angle between the lever axis and the imaginary line between the valve axis and the pivot axis of the hydraulic cylinder	[°]
a_1	length a_1	[mm]
T	height	[mm]
r	lever arm length	[mm]

Angle rotation of the rocking motion:

$$\beta_s = \delta_0 - \delta$$

β_s	angle rotation of the rocking motion	[°]

δ_0	the angle between the axis of the lever and the imaginary line between the axis of the valve and the pivot axis of the hydraulic cylinder in the open position	[°]
δ	the angle between the lever axis and the imaginary line between the valve axis and the pivot axis of the hydraulic cylinder	[°]

Flow characteristic (hydraulic cylinder):

$$Q_H = Q_c - \frac{(Q_c - Q_{c+10})}{\beta/10}\left(\beta_s - \frac{\beta}{100} * S\right)$$

Q_H	flow characteristic (hydraulic cylinder)	[]
Q_c	flow characteristic value (crank mechanism / gearbox)	[]
Q_{c+10}	10% higher value of the flow characteristic	[]
β_s	angle rotation of the rocking motion	[°]
β	swing angle	[°]
S	percentage of hydraulic cylinder stroke	[%]

Percentage of hydraulic cylinder stroke at a given time:

$$T_s < (T_c - T_d) \rightarrow S_T = \frac{100 - L_d}{T_c - T_d} * T_s$$

$$T_s \geq (T_c - T_d) \rightarrow S_T = 100 - L_d + \frac{L_d}{T_d} * (T_s - T_c + T_d)$$

T_s	time value	[s]
T_c	total closing time	[s]
T_d	damping time	[s]
S_T	percentage of hydraulic cylinder stroke at a given time	[%]
L_d	damping phase	[%]

Flow characteristic (hydraulic cylinder at closing time):

$$Q_{Tc} = Q_H - \frac{(Q_H - Q_{H+10})}{10}(S_T - S)$$

Q_{TC}	flow characteristic (hydraulic cylinder at closing time)	[]
Q_H	value of flow characteristic (hydraulic cylinder)	[]
Q_{H+10}	10% higher value of flow characteristic (hydraulic cylinder)	[]
S_T	percentage of hydraulic cylinder stroke at a given time	[%]
S	percentage of hydraulic cylinder stroke	[%]