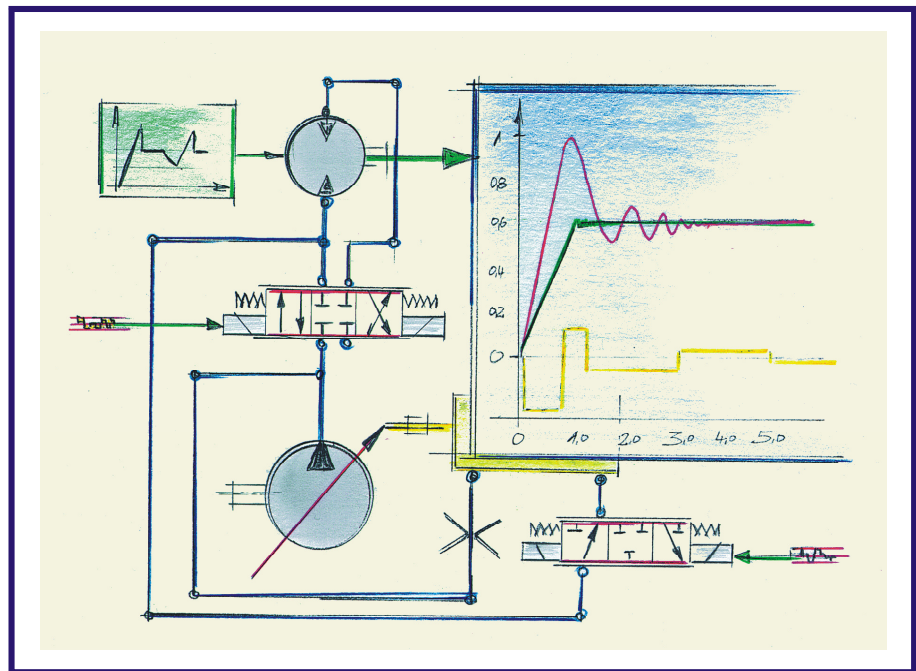


Component Manual

Steering Components



DSH^{plus}

Copyright © 1995-2008 by
FLUIDON® Gesellschaft für Fluidtechnik mbH
Jülicher Straße 336
52070 Aachen
Germany

Tel. +49 (0) 241 - 9 60 92 60
Fax +49 (0) 241 - 9 60 92 62

www.fluidon.com
e-mail info@fluidon.com

No part of the manuals may be reproduced, duplicated or distributed in any form (printing, photo print etc.) without permission of the FLUIDON GmbH.

The soft and hardware names mentioned in this manual are in the most cases registered trademarks and are subject to the legal determination as such ones.

In the course of further development of the software, parts of this manual can lose their validity.

Introduction

The component manual describes the components of the library. In accordance with the component categories in the library, the manual subdivides itself into several parts:

- Component library Hydraulics
- Component library Pneumatics
- Component library Control,
- Component library Mechanics
- Component library Thermal Hydraulics
- Component library Modules
- Component library Miscellaneous

The **HYDRAULICS** part contains all hydraulic components of the library. This includes pumps and motors, flow valves, pressure valves, check valves, and directional valves as well as accumulators and pipes.

The **PNEUMATICS** part of the library includes many components for pneumatic systems. The components range from cylinders and resistors to directional valves and sensors.

In the manual part **MECHANICS** the mechanical components are described. These are the masses and the spring damper components as well as other mechanical components.

The component library of *DSHplus* includes analog and digital components for control tasks that are explained in the chapter **CONTROL**.

The **THERMAL HYDRAULICS** part contains thermal hydraulic components of the library. This includes pumps and motors and directional valves as well as accumulators and pipes.

The component manual should help to select the right component for a model and to parameterize it. Furthermore, there is information about the kind of modeling of the components, e. g. whether they were modeled in accordance with the physical qualities of the real components or whether only their dynamic characteristics were taken.

The **MODULES** contains the components for the *DSHplus*-STC and for the sub model prepare. The part **MISCELLANEOUS** contains other components to which the nodes in particular belong.

All components are described according to the same scheme. The following page shows an example component with which the scheme is explained.

ComponentName

Symbol of the component

Symbol

Sketch

Drawing of the component

Connectors and Variables

Name	Type	Unit	Description
<i>Hydraulic connector</i>	Hydr	Unit	<i>short description</i>
<i>Hydraulic volume less connector</i>	Hvol	Unit	<i>short description</i>
<i>Thermal hydraulic connector</i>	THydr	Unit	<i>short description</i>
<i>Pneumatic connector</i>	Pneu	Unit	<i>short description</i>
<i>Signal input</i>	In		<i>short description</i>
<i>Signal output</i>	Out		<i>short description</i>
<i>Mechanical connector</i>	Mech		<i>short description</i>
<i>Internal variable</i>	V		<i>short description</i>

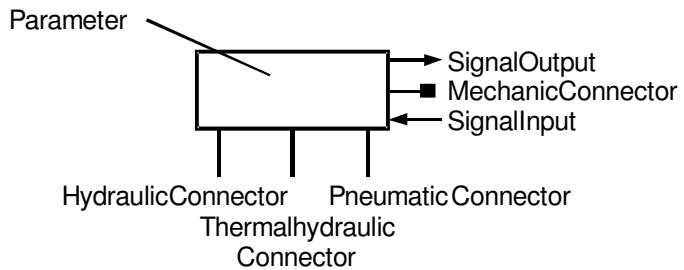
Parameters

Name	Value	Unit	Description
<i>Parameter name</i>	<i>Value</i>	<i>Unit</i>	<i>short description</i>

Notes

Remarks about function and application

Comments to the example component:

	The component symbol is the symbol with which a component appears in the library and in the model.														
	The component with its parameters and its connectors is represented in the component drawing according to the following figure:  The arrows at the component specify whether the connector is an input, an output or a mechanical connection. The direction of state variables is defined by a coordinate system.														
	In the table Connectors and Variables , all connectors and variables of a component are listed.														
	The connectors and variables of a component can be subdivided into different types. They are characterized in the column Type in accordance with: <table> <tbody> <tr> <td>Hydr:</td><td>hydraulic connector</td></tr> <tr> <td>Pneu:</td><td>pneumatic connector</td></tr> <tr> <td>Thydr:</td><td>thermal hydraulic connector</td></tr> <tr> <td>In:</td><td>input of a signal</td></tr> <tr> <td>Out:</td><td>output of a signal</td></tr> <tr> <td>Mech:</td><td>mechanical connector</td></tr> <tr> <td>V:</td><td>internal variable (state variable)</td></tr> </tbody> </table>	Hydr:	hydraulic connector	Pneu:	pneumatic connector	Thydr:	thermal hydraulic connector	In:	input of a signal	Out:	output of a signal	Mech:	mechanical connector	V:	internal variable (state variable)
Hydr:	hydraulic connector														
Pneu:	pneumatic connector														
Thydr:	thermal hydraulic connector														
In:	input of a signal														
Out:	output of a signal														
Mech:	mechanical connector														
V:	internal variable (state variable)														
	Units (column Unit) were assigned to the variables. In so far as the customer does not change the Units, the graphic or numeric edition of the variables occurs with these Units. The units for the values of the other connectors are listed only for better understanding.														
	In the parameter list, all parameters are listed with its Values and Units with which a component is described.														
	The Notes give further remarks to the function and the application of the component.														
	The following spelling is used: COMPONENTNAME <i>Parameters, Connectors and Variables</i>														

Contents

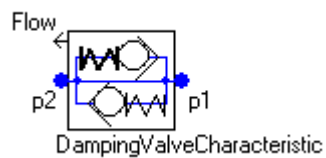
DampingValveCharacteristic.....	3
TorsionBar	5
SteeringValve	7
SteeringValveMp	10
SteeringCylinder.....	15
LenkzylinderVariableVerzahnung	18
PumpeDrehzahlKennfeld_n_p.....	22
PumpeQRegel	24

Steering Components



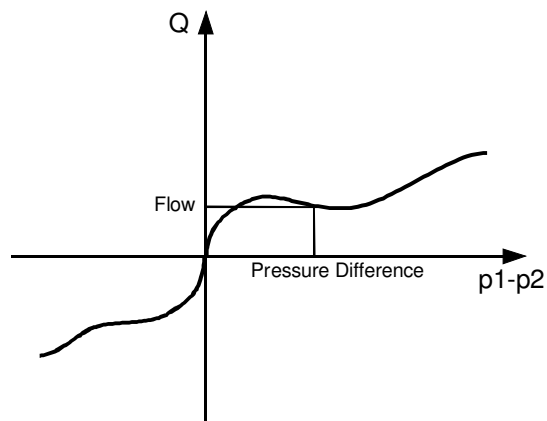
*The Steering components are not finished in the English version yet,
but we work hard on it!*

DampingValveCharacteristic



Symbol

Sketch



Connectors and Variables

Name	Type	Unit	Description
p1	Hydr	bar	pressure at side 1
p2	Hydr	bar	pressure at side 2
VolumeFlow	Out		flow through the component

Parameters

Name	Value	Unit	Description
pQCharacteristic	-1	-	look-up table of the volume-flow-pressure-function
Factor	1	-	stretch- or compress factor for the output values of the look-up table

Notes

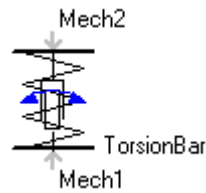
With the component RESISTORPQCHARACTERISTIC arbitrary dependences of the pressure difference $p1 - p2$ and the flow can be described. Flow values and pressure differences are stored into an one-dimensional look-up table and assigned to the parameter PQCHARACTERISTIC.

The component RESISTORPQCHARACTERISTIC allows to integrate e. g. a pressure flow curve which is measured on a test bench into the simulation.

The parameter FACTOR stretches or compresses the flow values of the look-up table.

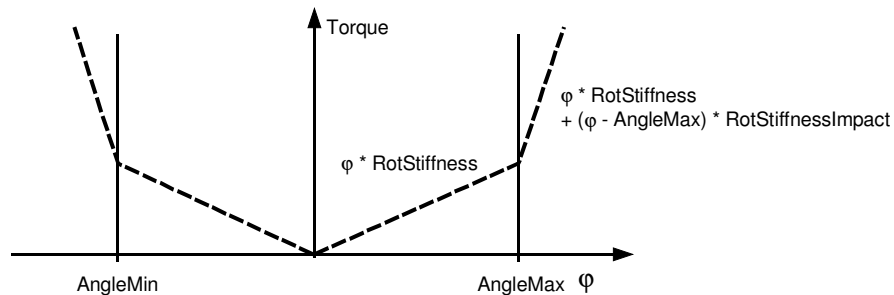
If the pressure difference at the component is greater than the maximum- resp. minimum value of the look-up table, the defined flow value of the edge of the look-up table is constant. There is no extrapolation.

TorsionBar



Symbol

Sketch



Connectors and Variables

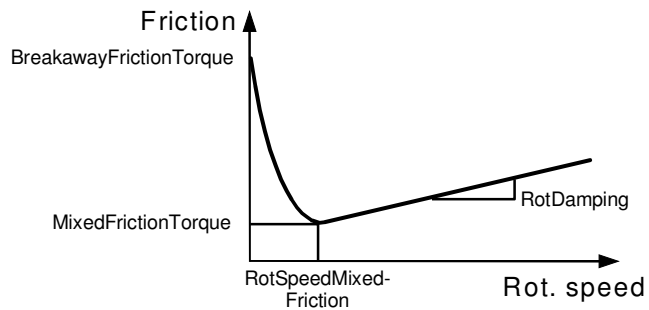
Name	Type	Unit	Description
Mech1	Mech	-	mechanical connector 1
Mech1phi	In	°	angle 1
Mech1omega	In	°/s	angular velocity 1
Mech1M	Out	Nm	torque 1
Mech2	Mech	-	mechanical connector 2
Mech2phi	In	°	angle 2
Mech2omega	In	°/s	angular velocity 2
Mech2M	Out	Nm	torque 2

Parameters

Name	Standard value/ standard unit	Description
RotStiffness	2 Nm/°	
RotDamping	1 Nms/°	
RotStiffnessImpact	20 Nm/°	
RotDampingImpact	1 Nms/°	
PretensioningAngle	0 °	
BreakawayFrictionTorque	0.05 Nm	
MixedFrictionTorque	0.01 Nm	
RotSpeedMixedFriction	1 °/s	
AngleMax	5 °	
AngleMin	-5 °	

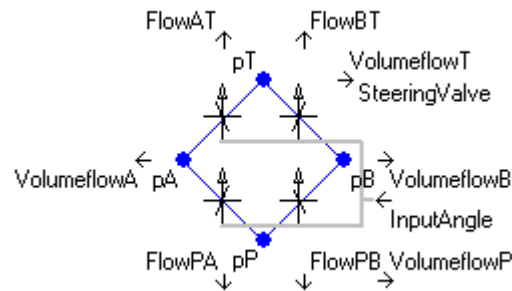
Notes

The torsion bar has been modeled with velocity-dependent friction according to the Stribeck-curve. The characteristics BreakawayFrictionTorque, MixedFrictionTorque, RotSpeedMixedFriction and RotDamping determine the points on the friction curve shown in the figure below.



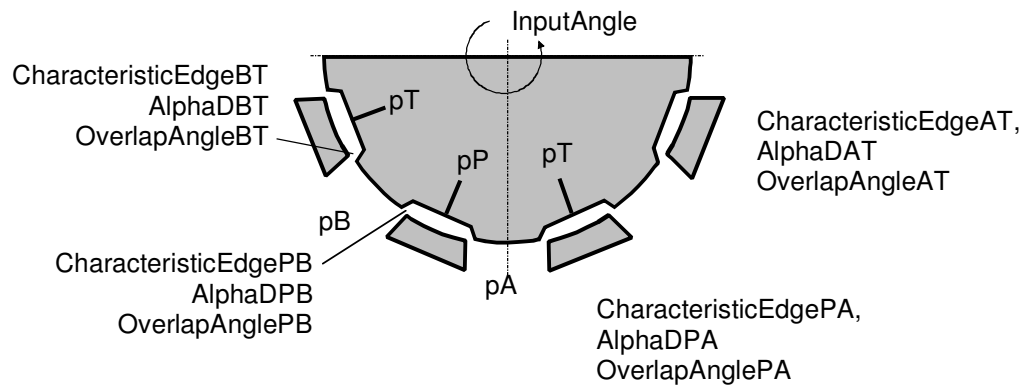
The input connectors *Mech1phi* and *Mech2phi*, the output connectors *Mech1omega* and *Mech2omega* as well as the force connectors *Mech1M* and *Mech2M* are summarized in the mechanical connectors *Mech1* and *Mech2*.

SteeringValve



Symbol

Sketch



Connectors and Variables

Name	Type	Unit	Description
pP	Hydr	bar	supply pressure
pT	Hydr	bar	reservoir pressure
pA	Hydr	bar	working pressure A
pB	Hydr	bar	working pressure B
InputAngle	In	°	input signal
VolumeflowP	Out	l/min	flow rate P
VolumeflowT	Out	l/min	flow rate T
VolumeflowA	Out	l/min	flow rate A
VolumeflowB	Out	l/min	flow rate B
FlowPA	Out	l/min	flow rate PA
FlowPB	Out	l/min	flow rate PB
FlowAT	Out	l/min	flow rate AT
FlowBT	Out	l/min	flow rate BT

Parameters

Name	Standard value/ standard unit	Description
AlphaDPA	0.7 -	flow coefficient for the metering edge from P to A
AlphaDAT	0.7 -	flow coefficient for the metering edge from A to T
AlphaDPB	0.7 -	flow coefficient for the metering edge from P to B
AlphaDBT	0.7 -	flow coefficient for the metering edge from B to T
OverlapAnglePA	0 °	Overlap angle for the metering edge from P to A
OverlapAnglePB	0 °	Overlap angle for the metering edge from P to B
OverlapAngleAT	0 °	Overlap angle for the metering edge from A to T
OverlapAngleBT	0 °	Overlap angle for the metering edge from B to AT
TDifference	0	Difference between local and system Temperature
CharacteristicEdgePA	- area over angle	field of characteristics for the aperture cross-section area of the metering edge from P to A
CharacteristicEdgePB	- area over angle	field of characteristics for the aperture cross-section area of the metering edge from P to B
CharacteristicEdgeAT	- area over angle	field of characteristics for the aperture cross-section area of the metering edge from A to T
CharacteristicEdgeBT	- area over angle	field of characteristics for the aperture cross-section of the metering edge from B to T

Notes

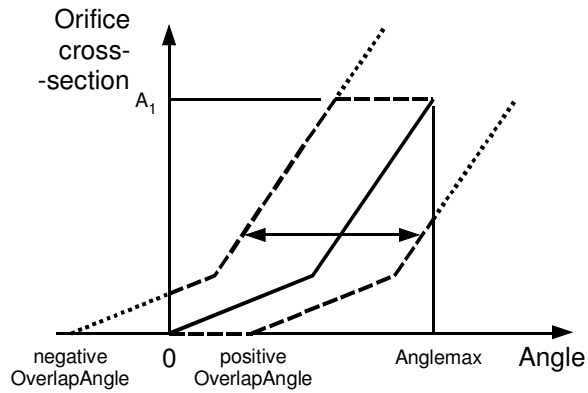
The component **STEERINGVALVE** is a simplified, look-up table based model of a symmetrical 6- or 8-land valve. The valve opening angle is proportional to the **INPUTANGLE** signal. Usually this signal represents the twisting angle of the torsion bar.

Look-up tables describe the orifice cross-section areas of the valve in dependence of the **INPUTANGLE**. Independent of the direction in which the valve opens, it is assumed for each field of characteristics that a positive **INPUTANGLE** is opening the metering edge.

For each metering edge the starting point of a look-up table is displaced with the parameter *OverlapAngle* (see figure).

It applies:

- $OverlapAngle < 0$: valve opened in resting position
- $OverlapAngle = 0$: valve just closed in resting position
- $OverlapAngle > 0$: valve closed in resting position



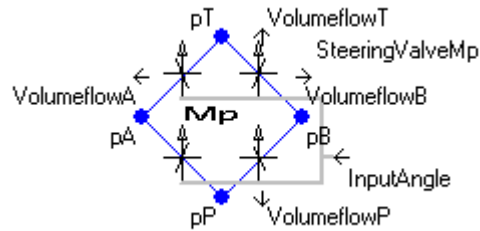
If the look-up table is defined in the range $Angle = 0..Anglemax$ the orifice cross-section does not exceed A_1 in case of a negative overlap. If the look-up table is defined beyond $Anglemax$ the orifice cross-section follows the look-up table.

The metering edges of steering valves can be considered as turbulent hydraulic resistances. The volume flow Q_i through the metering edges with the cross section area $A_{V,i}$ is calculated with

$$Q_i = \alpha_D \cdot \sqrt{\frac{2}{\rho}} \cdot A_{V,i} \cdot \sqrt{\Delta p_i}$$

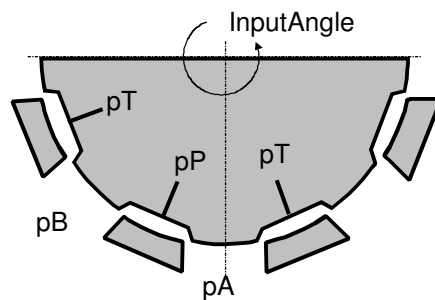
at which the flow coefficient α_D is regarded as constant. The pressure difference is Δp_i at the cross section area. All metering edges are connected together in a hydraulic full bridge. The cross sectional area A of a single edge is defined through the look-up tables *CharacteristicEdge*.

SteeringValveMp



Symbol

Sketch



Connectors and Variables

Name	Type	Unit	Description
pP	Hydr	bar	Supply pressure
pT	Hydr	bar	Reservoir pressure
pA	Hydr	bar	Working pressure A
pB	Hydr	bar	Working pressure B
InputAngle	In	°	Input signal
VolumeflowP	Out	l/min	VolumeflowP
VolumeflowT	Aus	l/min	VolumeflowT
VolumeflowA	Aus	l/min	VolumeflowA
VolumeflowB	Aus	l/min	VolumeflowB

Parameter

Name	Standard value/ standard unit		Description
Q Valve	6	l/min	Volume flow through the valve
p max	100	bar	Maximum pressure
p Sys0	0.5	bar	System pressure in middle position

Name	Standard value/ standard unit		Description
Q Leakage	0.05	l/min	Leakage volume flow at maximum pressure
c T-Bar	1.7	Nm/°	t-bar stiffness
alpha D	0.6		Flow coefficient
PhiMax	6	°	Maximum valve twist angle
TDifference	0	K	Temperature difference from global to system temperature
M-Dp-Specification			Look-up table steering moment about pressure difference

Notes

The STEERINGVALVEMP is based on the STEERINGVALVE component. It is also a simplified, look-up table based model of a symmetrical 6- or 8-land valve. However, the modeling approach is different.

The STEERINGVALVEMP is used if the look-up tables for the cross sectional areas of the metering edges **are not available**. The component parameterization is done by means of a look-up table (M(Δp) specification) that describes either a measured or a desired boost curve and some auxiliary system parameters.

The dialog to parameterize the valve is as follows.

The screenshot shows a software dialog box titled "SteeringValveMpSpec1". It contains several parameter input fields, each with a numerical value and a unit dropdown menu. The parameters and their values are: Q Valve (6, l/min), p max (100, bar), p Sys0 (0.5, bar), Q Leakage (0.05, l/min), c T-Bar (1.7, Nm/°), alpha D (0.6), PhiMax (6, °), TDifference (0, K), and M-Dp-Specification (empty). At the bottom of the dialog are three buttons: OK, Cancel, and Help.

The look-up table that contains the valve angle dependent cross sectional areas of the control edges is computed internally.

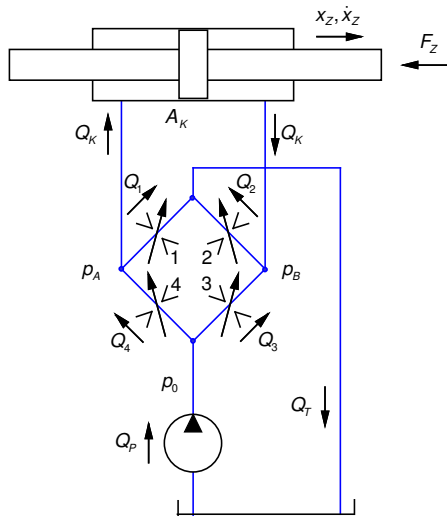
Attention: If the look-up tables for the metering edges are available the STEERINGVALVE is always to prefer, because there is no single solution by computing the look-up tables from the M(Δp) specification.

The metering edges of steering valves can be considered as turbulent hydraulic resistances. The volume flow Q_i through the metering edges with the cross section area $A_{V,i}$ is calculated with

$$Q_i = \alpha_D \cdot \sqrt{\frac{2}{\rho}} \cdot A_{V,i} \cdot \sqrt{\Delta p_i}$$

at which the flow coefficient α_D is regarded as constant. The pressure difference is Δp_i at the cross section area. All metering edges are connected together in a hydraulic full bridge.

The cross section area is a function of the input angle of the valve and is not always known. But it is possible to estimate the opening area from the boost curve. This procedure is described in the following. The boost curve describes the relationship between the possible pressure difference and hence the hydraulic assistance by the valve and the torque to actuate. The torque is directly promotional to the input angle because of the torsion spring.



Boost Curve

$$\Delta p = \frac{1}{4} \cdot \left[\frac{(Q_P - Q_K)^2}{B_1^2} - \frac{(Q_P + Q_K)^2}{B_2^2} \right]$$

$$\Delta p|_{Q_K=0} = \frac{1}{4} \cdot Q_P^2 \cdot \left[\frac{1}{B_1^2} - \frac{1}{B_2^2} \right]$$

A_K	Piston area
$A_{V,i}$	Cross section areas of the metering edges $A_{V,1} = A_{V,3}$, $A_{V,2} = A_{V,4}$
B_i	Flow coefficients of the metering edges $B_i = \alpha_D \cdot A_{V,i} \cdot \sqrt{2/\rho}$
F_Z	Rod Force
p_0	System pressure
p_A, p_B	Working pressure
Δp	Pressure difference $\Delta p = p_A - p_B$
Q_i	Cross section volume flow
Q_K	Piston volume flow $Q_K = A_K \cdot \dot{x}_Z$
Q_P	Pump volume flow
$\dot{x}_Z, \ddot{x}_Z$	Rod stroke, - velocity
α_D	Flow coefficient
ρ	Oil density
1 - 4	Metering edge indices

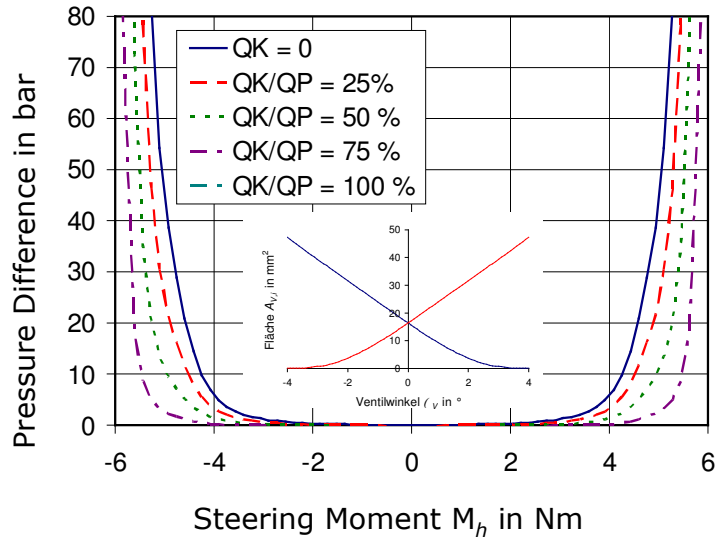
The boost curve can be calculated from the volume flow balance and the flow equations, if the cross section areas are well known. The equation looks as follows for a symmetric valve.

$$\Delta p = \frac{F_Z}{A_K} = \frac{1}{4} \cdot \left[\frac{(Q_P - Q_K)^2}{B_1^2} - \frac{(Q_P + Q_K)^2}{B_2^2} \right]$$

If the steering velocity is 0, $Q_K = 0$, the pressure difference Δp is calculated with:

$$\Delta p|_{Q_K=0} = \frac{1}{4} \cdot Q_P^2 \cdot \left[\frac{1}{B_1^2} - \frac{1}{B_2^2} \right]$$

The result curve is normally called the "Boost curve".



Calculated Boost curves at known metering edges

The equations and graphics show the decreasing hydraulic assistance at increasing steering velocity hence increasing piston volume flow. Or, in other words, a higher steering wheel torque is necessary at higher steering velocity and with a default load. The required torque is proportional to the steering velocity. If the steering velocity is extremely high, so that the piston volume flow is higher than the pump volume flow or equal there is no hydraulic assistance and the steering wheel torque is increasing abruptly.

The equations show also that it is not quite clear to predict the cross section areas from the pressure difference. Even if B_1 and B_2 and the corresponding areas are mirror inverted, only the ratio of the pressure difference is important, not the absolute values. Because of this, it is possible to create the same boost curve with many cross section area geometries, which have the same ratio of B_1 and B_2 .

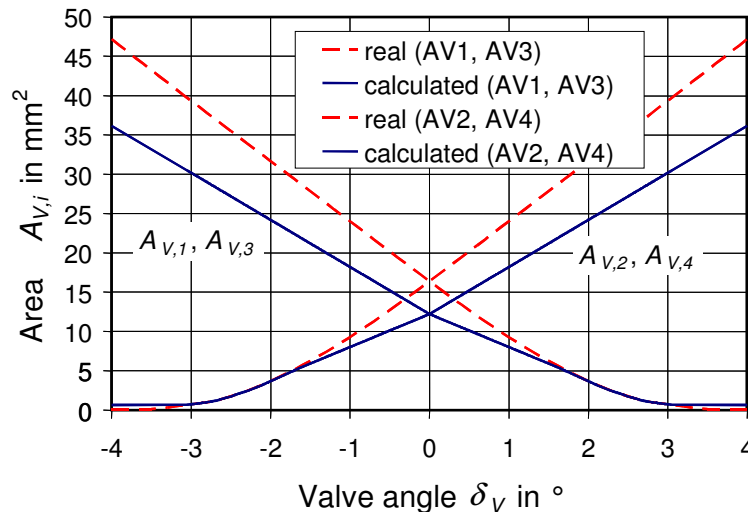
Therefore, the parameterization of the metering edges can not be done directly, it has to be used an approximation procedure, which is based on the following estimations. The estimations are standards in the nowadays used steering valves:

- The valve is designed symmetrical
- The curve of the opening area about the Angle is strictly monotone.

With the use of the well known steering gear parameters:

- Valve curve specification
- Pump volume flow
- Torsion bar stiffness
- System pressure
- Leakage

it is possible to approximate the metering edge geometry with an iteration method by optimizing the values of the gradient and/or the curve. The calculation results area shown in the following graph.

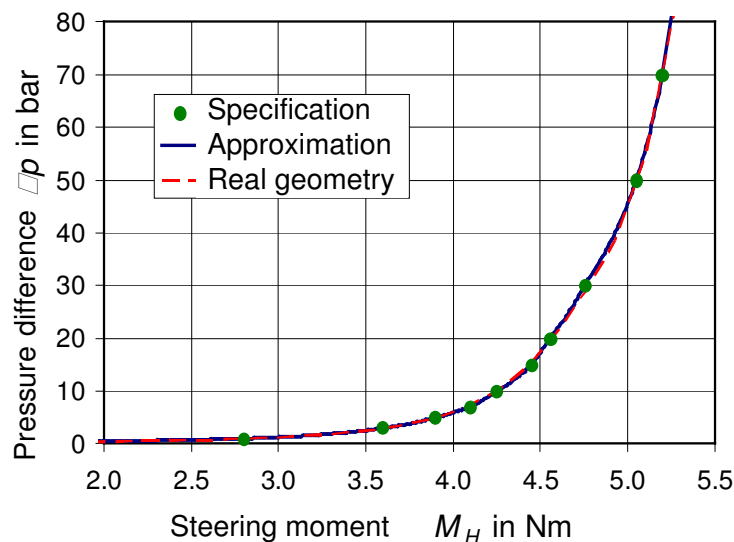


The graphic shows the real curve of the valve opening area. The boost curve had been calculated with this geometry. Some typical specification points had been calculated also. They are shown in the next graphic.

Based on these specifications and the further boundary conditions the metering edge geometry is calculated approximately backwards.

This calculation is shown as dashed line. The two curves are identical, when the valve is closing the metering edges, the most important function of the valve.

The congruence is not quite so good in the area, when the valve is quite open, a less important operating point.



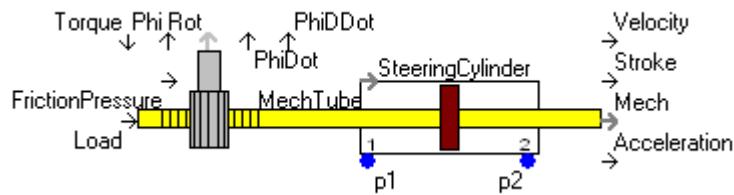
The boost curves are almost identical, only at the specification points there is a little difference. With this method it is possible to define the metering edge geometries from existing and measured values.

Thus it is a suitable tool to parameterize steering valves for the simulation even in an early design stage. For more information please have a look at:

Prof. Dr.-Ing. H. Ulrich, Dr.-Ing. H. Baum
„Digitale Simulation bei der Entwicklung fluidtechnischer Fahrzeugsysteme“

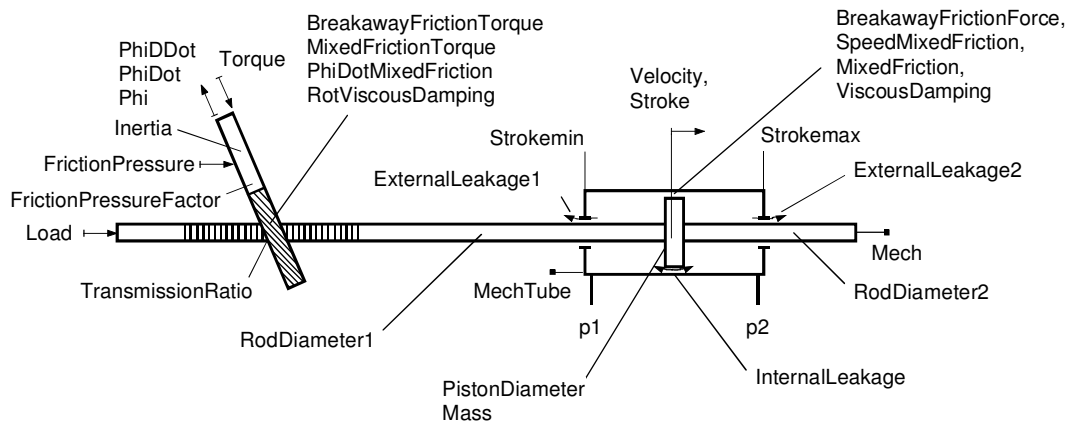
Tagung „Hydraulik im Kraftfahrzeug – Systeme und Komponente“; Haus der Technik
e.V.; 11.2003

SteeringCylinder



Symbol

Sketch



Connectors and Variables

Name	Type	Unit	Description
p1	Hydr	bar	Pressure in piston chamber 1
p2	Hydr	bar	Pressure in piston chamber 2
velocity	V	m/s	Velocity of the piston
stroke	V	mm	Displacement of the piston
Load	In	N	External load
FrictionPressure	In	bar	Pressure for the calculation of friction depending on pressure
Torque	In	Nm	External torque
Velocity	Out	m/s	Velocity of the piston
Stroke	Out	mm	Displacement of the piston
Acceleration	Out	m/s ²	Acceleration of the piston
Phi	Out	°	Input shaft angle
PhiDot	Out	°/s	Input shaft speed
PhiDDot	Out	°/s ²	Input shaft rotational acceleration

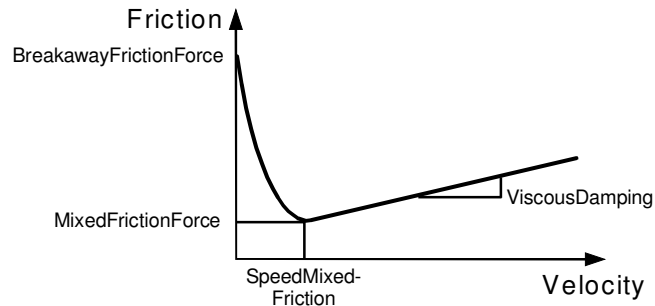
Name	Type	Unit	Description
Mech	Mech		Mechanical connection
MechF	In	N	force at the piston
Mechx	Out	mm	absolute displacement of the piston
Mechv	Out	m/s	absolute velocity of the piston
MechTube	Mech	-	Mechanical connection
MechF	Out	N	force of the tube
Mechx	In	mm	displacement of the tube
Mechv	In	m/s	velocity of the tube

Parameters

Name	Standard value/ standard unit	Description
PistonDiameter	50. mm	
RodDiameter1	30. mm	
RodDiameter2	30. mm	
strokemax	75. mm	
strokemin	-75. Mm	
Mass	1. kg	Mass of the piston and rack
BreakawayFrictionForce	100 N	
MixedFrictionForce	10. N	
SpeedMixedFriction	0.1 m/s	
ViscousDamping	10. Ns/m	
ExternalLeakage1	0. l/min/bar	
ExternalLeakage2	0. l/min/bar	
InternalLeakage	0.001 l/min/bar	
Inertia	0. kgm ²	Inertia of the sleeve
TransmissionRatio	50. mm/rev	Transmission ratio between the piston stroke and the angle of the pinion
BreakawayFrictionTorque	0. Nm	
MixedFrictionTorque	0. Nm	
PhiDotMixedFriction	1. °/s	
RotViscousDamping	1. Nms/°	
FrictionPressureFactor	0. Nm/bar	

Notes

The cylinder has been modeled with velocity-dependent friction according to the Stribeck-curve. The characteristics *BreakawayFrictionForce*, *MixedFrictionForce*, *SpeedMixedFriction* and *ViscousDamping* determine the points on the friction curve shown in the illustration below.



The rotational friction is modeled in the same way.

The combination of linear, rotational, and pressure dependent friction is calculated as shown below.

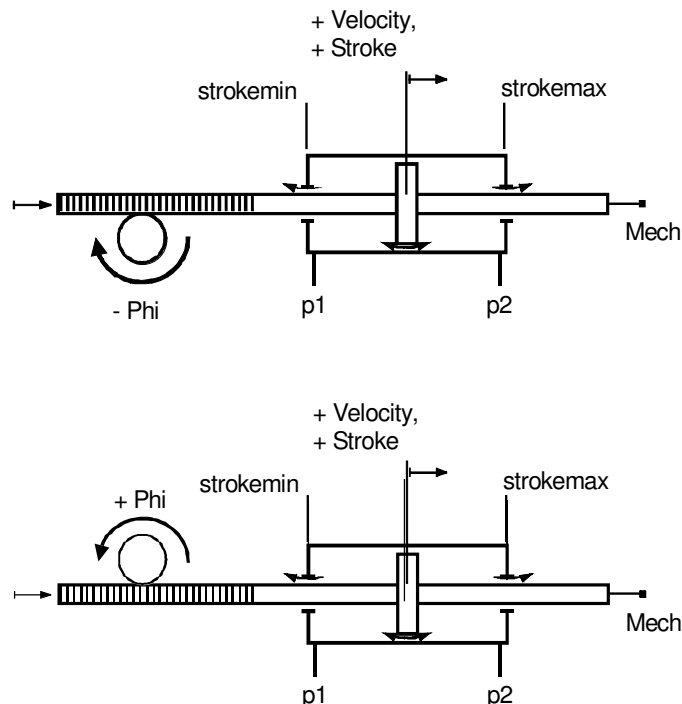
$$F_F = F(\phi) + F(\dot{x}) + F(p)$$

$$\text{if}(F_F > F_{\text{outside}})$$

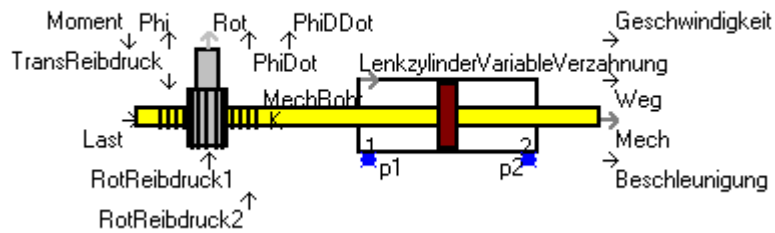
$$F_F = F_{\text{outside}}$$

The addition of the cylinder force ($A_1 \cdot p_1 - A_2 \cdot p_2$) and the external load is F_{Outside} . If the friction force is higher than F_{Outside} , F_{Outside} is equal to the friction force. Thus the acceleration of the piston is zero.

The mechanical connector *MechTube* defines the movement of the tube of the steering ram referring to the environment. In combination with a mass and a spring-damper the elasticity of the fixing can be modeled. The connector *Stroke* represents the relative displacement of the piston, the *Mech*-connector against it represents the absolute displacement referring to the environment.

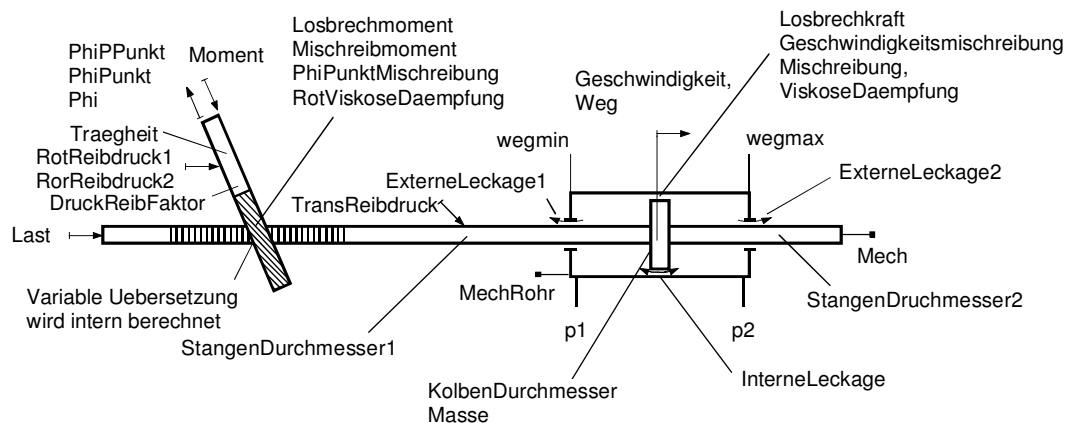


LenkzylinderVariableVerzahnung



Symbol

Skizze



Anschlüsse und Variablen

Bezeichnung	Typ	Einheit	Beschreibung
p1	Hydr	bar	Druck in Kammer 1
p2	Hydr	bar	Druck in Kammer 2
Last	Ein	N	am Kolben angreifende Kraft
Mech	Mech	-	mechanischer Anschluss
MechF	Ein	N	am Kolben angreifen- de Kraft
Mechx	Aus	mm	Weg des Kolbens
Mechv	Aus	m/s	Geschwindigkeit des Kolbens
MechRohr	Mech	-	mechanischer Anschluss
MechF	Aus	N	an Zylinderrohr an- greifende innere Kraft
Mechx	Ein	mm	Weg des Zylinder- rohrs
Mechv	Ein	m/s	Geschwindigkeit des Zylinderrohrs

Bezeichnung	Typ	Einheit	Beschreibung
Rot	Mech	-	mechanischer Anschluss
RotM	Ein	Nm	auf das Ritzel wirkendes Moment auf Seite 1
rotphi	Aus	rad	Rotationswinkel
rotomega	Aus	rad/s	Winkelgeschwindigkeit
Phi	Aus	rad	Rotationswinkel
PhiPunkt	Aus	rad/s	Winkelgeschwindigkeit
PhiPPunkt	Aus	rad/s ²	Winkelbeschleunigung
Beschleunigung	Aus	m/s ²	Beschleunigung des Kolbens
Geschwindigkeit	V-Aus	m/s	Geschwindigkeit des Kolbens
Weg	V-Aus	mm	Weg des Kolbens
RotReibdruck1	Ein	bar	Reibdruck am Ritzel
RotReibdruck1	Ein	bar	Reibdruck am Ritzel
TransReibDruck	Ein	bar	Reibdruck auf die Stange

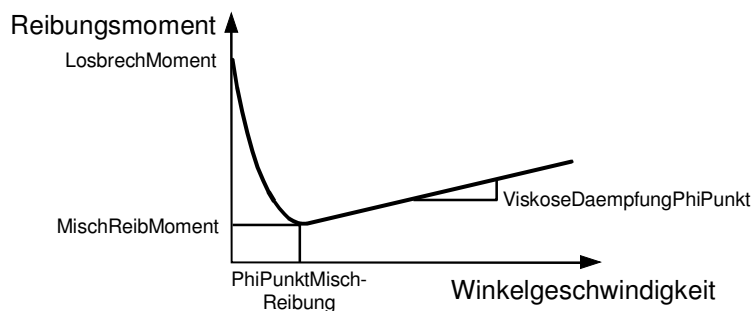
Parameter

Bezeichnung	Standardwert/ Standardeinheit		Beschreibung
KolbenDurchmesser	60	mm	Durchmesser des Kolbens
StangenDurchmesser1	40	mm	Durchmesser der Stange 1
StangenDurchmesser2	40	mm	Durchmesser der Stange 2
wegmax	100	mm	maximaler Kolbenweg in positiver Richtung
wegmin	-100	mm	maximaler Kolbenweg in negativer Richtung
Losbrechkraft	100	N	Kennwert für Stribeck-Kurve
Geschwindigkeitsmischreibung	0.1	m/s	Kennwert für Stribeck-Kurve
Mischreibkraft	10	N	Kennwert für Stribeck-Kurve
ViskoseDaempfung	10	Ns/m	Kennwert für Stribeck-Kurve
ExterneLeakage1	0	l/min/bar	aus dem Zylinder an der Kolbenstange 1 austretende Hydraulikflüssigkeit
ExterneLeakage2	0	l/min/bar	aus dem Zylinder an der Kolbenstange 2 austretende Hydraulikflüssigkeit
InterneLeakage	0.001	l/min/bar	interne Leakage

Bezeichnung	Standardwert/ Standardeinheit		Beschreibung
Masse	10	kg	Masse von Kolben und Kolbenstange
Traegheit	0.05	kgm ²	Massenträgheitsmoment der Ritzelwelle
RotViskoseDaempfung	1	Nms/°	Kennwert für Stribeck-Kurve
Losbrechmoment	0	Nm	Kennwert für Stribeck-Kurve
Mischreibmoment	0	Nm	Kennwert für Stribeck-Kurve
PhiPunktMischreibung	1	°/s	Kennwert für Stribeck-Kurve
RotDruckReibFaktor	0.	Nm/bar	Faktor für die druckabhängige rotatorische Reibung
TransDruckReibFaktor	0.	N/bar	Faktor für die druckabhängige translatorische Reibung
Uebersetzungskennfeld	-1		Kennfeld des Übersetzungsverhältnisses zwischen Zahnstange und Ritzelwelle

Bemerkungen

Der rotatorische Anteil der Reibung ist gemäß der Stribeck-Kurve mit winkelgeschwindigkeitsabhängiger Reibung modelliert. Die Parameter *Losbrechmoment*, *Mischreibmoment*, *PhiPunktMischreibung* und *RotViskoseDaempfung* beschreiben die im Bild dargestellten Punkte der Reibkurve bzw. ihre Steigung im Bereich der reinen Flüssigkeitsreibung.



Die lineare Reibung ist gleichartig modelliert.

Druckabhängige Reibung ist sowohl für den rotatorischen als auch für den translatorischen Teil des Lenkzylinders modelliert. Das rotatorische Reibmoment wird mit Hilfe des Übersetzungsverhältnisses in eine translatorische Reibkraft umgerechnet. Es gilt:

$$\text{Druck Reibmoment} = \text{Rot ReibFaktor} \cdot \text{abs}(\text{Reibdruck1} - \text{Reibdruck2})$$

$$\text{Druck ReibKraft} = i\text{TransReibFaktor} \cdot \text{TransReibDruck}$$

Die Kombination der linearen, rotatorischen und druckabhängigen Reibung wird wie folgt berechnet:

$$F_F = F(\dot{\phi}) + F(\dot{x}) + F(p)$$

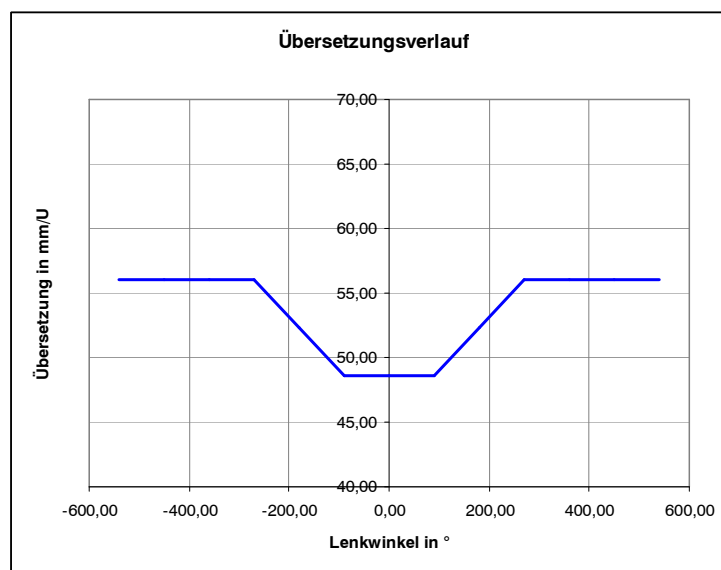
$$\text{if}(F_F > F_{\text{Aussen}})$$

$$F_F = F_{\text{Aussen}}$$

Die Addition der Zylinderkraft ($A_1 \cdot p_1 - A_2 \cdot p_2$) und der externen Last ist F_{Aussen} . Wenn die Reibkraft größer ist als F_{Aussen} , wird F_{Aussen} mit der Reibkraft gleichgesetzt. Hierdurch wird die Beschleunigung des Kolbens zu Null.

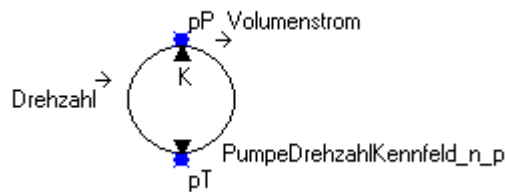
Mit dem mechanischen Anschluss *MechRohr* kann der Zylinder gegen Umgebung abgestützt werden. Da das Zylinderrohr im Modell masselos ist, muss eine externe Masse angeschlossen werden, die wiederum z. B. mit einer Feder gegen Umgebung nachgebend abgestützt werden kann.

Die variable Verzahnung wird über ein Kennfeld parametrieren, das wie in nachfolgender Grafik dargestellt, aufzubauen ist.



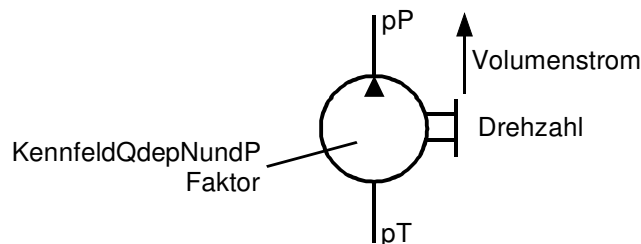
Der Lenkwinkel in der Einheit ° bildet die x-Achse und die Übersetzung in der Einheit mm/Umdrehung beschreibt die y-Achse.

PumpeDrehzahlKennfeld_n_p



Symbol

Skizze



Anschlüsse und Variablen

Bezeichnung	Typ	Einheit	Beschreibung
pP	Hydr	bar	Arbeitsdruck
pT	Hydr	bar	Tankdruck
Drehzahl	Ein	1/min	Drehzahl der Pumpe
Volumenstrom	Aus	l/min	Volumenstrom den die Pumpe in Abhängigkeit von Drehzahl und Differenzdruck fördert

Parameter

Bezeichnung	Standardwert/ Standardeinheit		Beschreibung
KennfeldQdepNundP	-	-	Kennfeld, das die Abhängigkeit der Fördermenge von der Druckdifferenz und der Pumpendrehzahl beschreibt
Uebersetzungsverhaeltnis	1	-	Übersetzung der Motordrehzahl auf die Pumpendrehzahl (> 1: Übersetzung ins Schnelle)

Bemerkungen

Das Bauteil PUMPEDREHZAHLKENNFELD_N_P ist das Modell einer Volumenstromquelle, bei der der geförderte Volumenstrom über das Kennfeld *KennfeldQDepNundP* definiert wird. Dieses Kennfeld gibt den Volumenstrom in Abhängigkeit der Motordrehzahl *Drehzahl* und der Druckdifferenz $pP - pT$ wider.

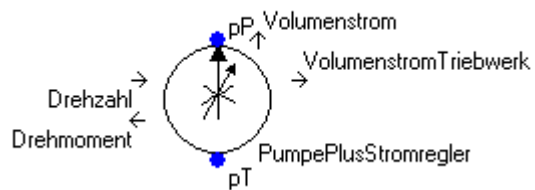
$$\text{Volumenstrom} = f_{\text{KennfeldQdepNundP}}(pP - pT, \text{Drehzahl})$$

Im Kennfeldeditor muss für das Bauteil ein zweidimensionales Kennfeld werden. Der Eingangskanal 1 repräsentiert die Druckdifferenz, der Eingangskanal 2 beinhaltet die Drehzahl. Die Einheiten der Kanäle müssen den Einheiten der Pumpe entsprechen.

Im Fall das die Drehzahl oder die Druckdifferenz die Grenzen des Kennfelds überschreitet, wird der entsprechende Randwert konstant gehalten. Das Kennfeld wird nicht extrapoliert!.

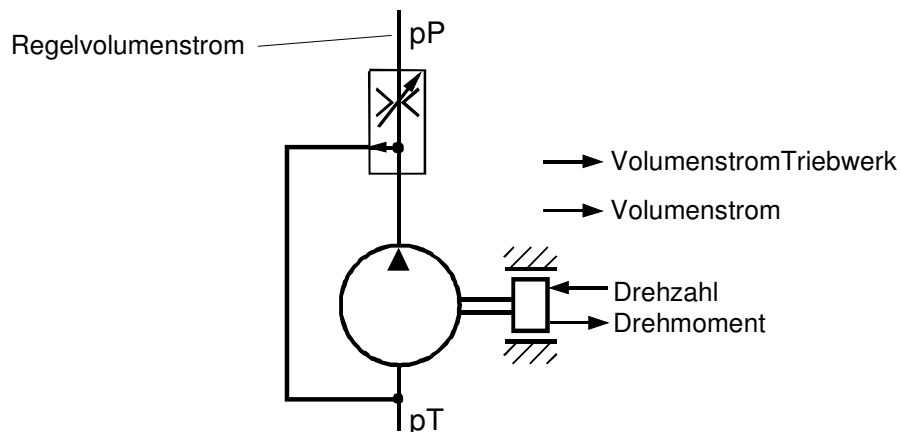
Der Volumenstrom bezieht sich immer auf den Anschluss pP .

PumpeQRegel



Symbol

Skizze



Anschlüsse und Variablen

Bezeichnung	Typ	Einheit	Beschreibung
pP	Hydr	bar	Arbeitsdruck
pT	Hydr	bar	Tankdruck
Drehzahl	Ein	1/min	vorgegebene Drehzahl
Drehmoment	Aus	Nm	Drehmomentaufnahme des Antriebs bei vorgegebener Drehzahl
Volumenstrom	Aus	l/min	Fördervolumenstrom
VolumenstromTriebwerk	Aus	l/min	Triebwerksvolumenstrom
DrehzahlPT1	V	-	Interne Hilfsgröße zur Bestimmung des Momentes

Parameter

Bezeichnung	Standardwert/ Standardeinheit	Beschreibung
Schluckvolumen	32 cm ³	Fördervolumen bei einer Umdrehung der Pumpe ohne Leckage

Bezeichnung	Standardwert/ Standardeinheit		Beschreibung
Regelvolumenstrom	30	l/min	Volumenstrom, der die Pumpe am Anschluss pP verlässt
Traegheitsmoment	0.05	kgm ²	Trägheitsmoment der rotierenden Pumpenteile
DifferenzierZeit	1	ms	Interne Hilfsgröße zur Bestimmung des Momentes
VorzeichenMoment	-1	-	Vorzeichen für die Ausgabe des Momentes
Kavitationsdruck	-0.5	bar	Kavitation setzt ein

Bemerkungen

Das Bauteil PUMPEQREGEL ist ein Modell einer Pumpe, bei dem die *Drehzahl* vorgegeben und das dafür notwendige *Drehmoment* des Antriebs berechnet wird. Trägheits- und Reibmomente werden berücksichtigt.

Das *Drehmoment* wird aus der Drallgleichung differenziert. Dafür wird der Parameter *DifferenzierZeit* benötigt.

Mit dem Parameter *VorzeichenMoment* kann das Vorzeichen des *Drehmoments* so angepasst werden, wie es für den Anschluss an weitere Bauteile notwendig ist.

Mit dem Parameter *Regelvolumenstrom* wird der maximale Fördervolumenstrom eingestellt, der ins System fließen soll. Ist der Triebwerksvolumenstrom, der sich aus der Drehzahl und dem Fördervolumen ergibt, größer als der *Regelvolumenstrom*, wird der Differenzvolumenstrom auf die Saugseite der Pumpe abgedrosselt; ist der Triebwerksvolumenstrom kleiner bzw. gleich dem *Regelvolumenstrom*, gelangt der Triebwerksvolumenstrom ins System.

Die PUMPEQREGEL fördert nur von pT nach pP. Der *Volumenstrom* bezieht sich (unabhängig von der Förderrichtung) grundsätzlich auf den Anschluss pP.