

Fluidic muscle DMSP

FESTO



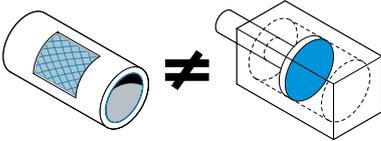
Key features

Mode of operation

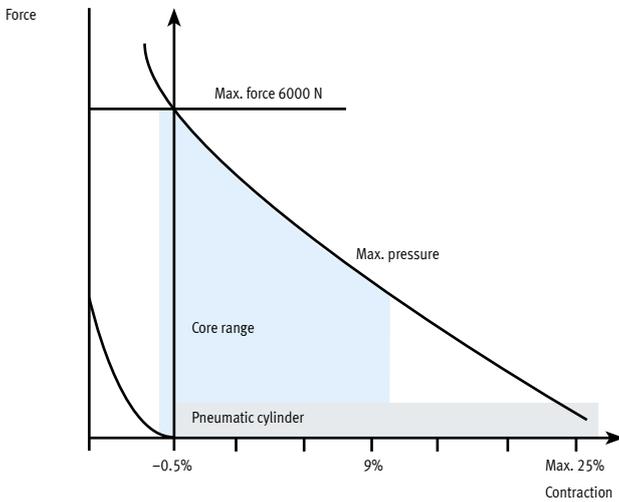


The fluidic muscle is a tensile actuator which mimics the natural movement of a muscle. It consists of contractible tubing and appropriate connectors. The contractible tubing is made up of a rubber sheath with a non-crimped fabric made of aramid fibres on the inside. The sheath hermetically seals the operating medium, while the fibres provide reinforcement and power transmission.

When internal pressure is applied, the tubular sheath extends in circumferential direction. This creates a tensile force and contracts the tubing lengthwise. The maximum usable tensile force is available at the start of the contraction and then decreases with the stroke.



Force profile and operating range



The muscle expands lengthways when it is pretensioned by an external force. When pressurised, on the other hand, the muscle contracts, i.e. its length decreases.

Areas of application

Clamping

- High force combined with a small diameter
- Insensitive to dirt
- Frictionless movement
- Hermetically sealed

Vibrating and shaking

- Frequency up to 150 Hz
- Amplitude/frequency can be adjusted independently of each other
- Insensitive to dirt

Pneumatic spring

- Adjustable spring force
- Frictionless movement
- Hermetically sealed
- Easy to handle

Other

- Positioning using pressure
- High acceleration of a load

Key features

Fluidic muscle DMSP, with press-fitted connection



In the DMSP, the sheath is crimped using a sleeve and the adapters are integrated.

Nominal length

The nominal length of the fluidic muscle is defined in the non-pressurised, load-free state. It corresponds to the visible length of the sheath between the connections (→ page 16).

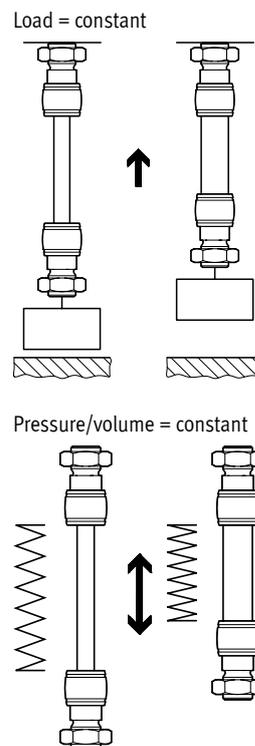
Single-acting actuator

Sizing examples → page 20

In the simplest case, the fluidic muscle operates as a single-acting actuator against a mechanical spring or a load. The mechanical spring pretensions the muscle so it leaves its normal, expanded and non-pressurised state. The ideal operating status is 0.5% of its nominal length, as in the unpressurised state, the diaphragm is not compressed. When pressurised, a pretensioned muscle develops maximum force with optimum dynamic characteristics and minimum air consumption.

The most effective operating range is when the contraction is less than 9%. The smaller the degree of contraction, the more effective it is.

The muscle behaves like a spring when the external force changes as it follows the application of force. With the fluidic muscle, both the pretensioning force of this "pneumatic spring" and its spring stiffness can be varied. The fluidic muscle can be operated as a spring with constant pressure or constant volume. This produces different spring characteristics that enable the spring effect to be matched perfectly to a particular application.



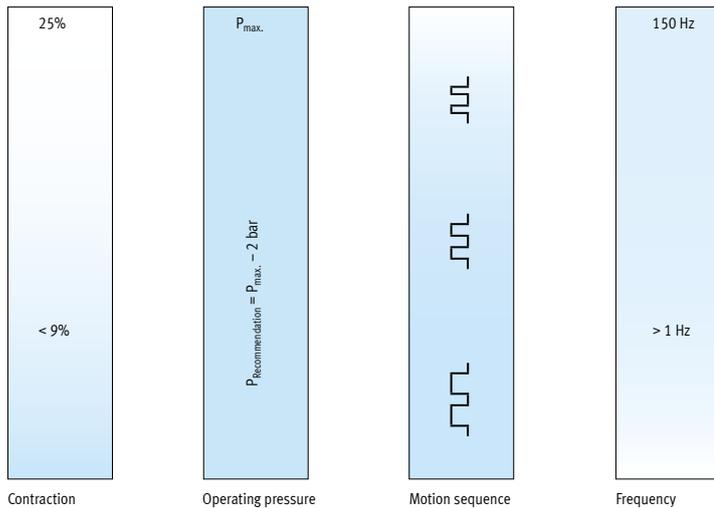
Note
If the muscle is supplied with compressed air and the volume blocked, the pressure in the muscle can increase significantly when the external force varies.

Key features

Design

The simplest and most reliable way to ensure correct sizing is by contacting the specialist department "Membrane Technologies" at Festo. Otherwise, calculation software is available to help you size the fluidic muscle. You can also use the force/displacement graphs to make a rough estimate.

Sizing of the fluidic muscle is explained using examples → page 20



Note

Do you need technical support?
We will be happy to help!

Membrane Technologies
→ membrantechnologie@festo.com

Note

- Kinking, compression and torsion are not permissible
→ lead to failure of the sheath
- Pretensioning by up to 0.5% will prevent kinking and compression
- Avoid unpressurised state
→ residual pressure up to 0.5 bar

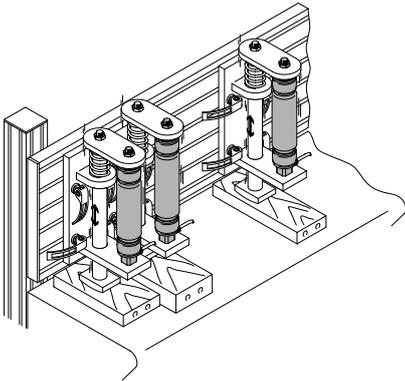
Application examples

Successful areas of application

Clamping

- High force combined with a small diameter
- Insensitive to dirt
- Frictionless movement
- Hermetically sealed

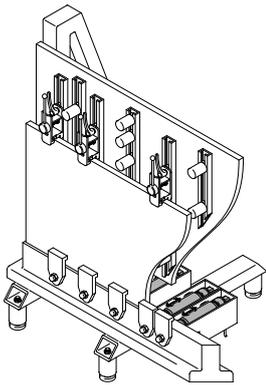
Clamping workpieces



When you need to combine high forces with a small diameter, that is not a problem for the fluidic muscle.

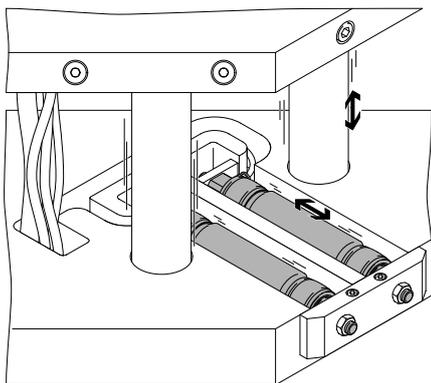
Thanks to its small diameter, it can be integrated and used in the smallest of spaces, e.g. when clamping workpieces. Its initial force is 10 times higher than that of a conventional pneumatic cylinder.

Clamping metal sheets



With the fluidic muscle large and unwieldy workpieces, such as plates, walls and side covers, can be easily clamped and machined (turning, drilling, milling). This shows the muscle's outstanding characteristics, such as high force combined with a small diameter, frictionless and thus jerk-free movement, insensitivity to dirt (swarf, abraded particles) and hermetically sealed design.

Clamping parts to be joined



When joining components, such as during welding processes, the components to be welded are held in place by the fluidic muscle. Here too, the muscle excels thanks to its high force and small diameter.

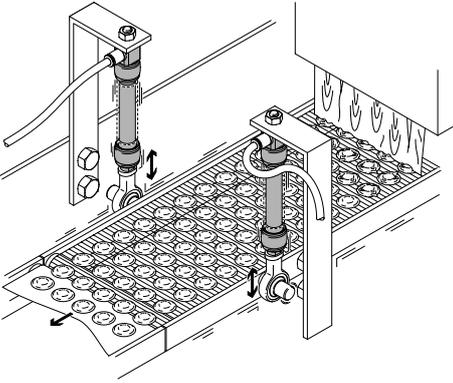
Application examples

Successful areas of application

Vibrating and shaking

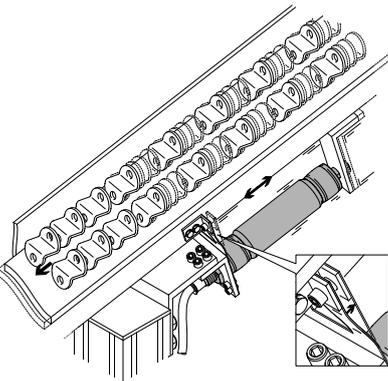
- Frequency up to 150 Hz
- Amplitude/frequency can be adjusted independently of each other
- Insensitive to dirt

Distributing



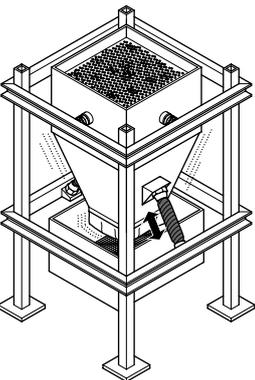
When applying a viscous coating agent to a fixed carrier substance, a vibrating support is required to ensure even distribution over the surface. In applications with strokes of less than 1 mm, the fluidic muscle can achieve cycle rates of up to 150 Hz.

Conveying



The fluidic muscle is exceptionally well suited to transporting or aligning parts. Amplitude and cycle rate can be adjusted simply and independently of each other. This flexibility makes it possible to set the optimum conveyor speed in any conveying process.

Releasing



Hoppers and silos are susceptible to the problem of a "jamming arch" forming during feeding. In practice, discharging aids such as vibrators or knockers are used to prevent jamming. This function can be achieved with the fluidic muscle. The frequency is infinitely variable up to 150 Hz, independently of the amplitude. This guarantees a continuous conveying process.

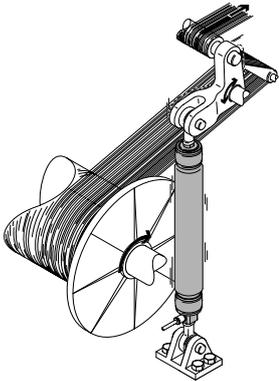
Application examples

Successful areas of application

Pneumatic spring

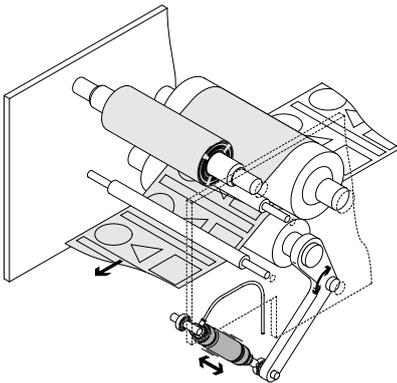
- Adjustable spring force
- Frictionless movement
- Hermetically sealed
- Easy to handle

Tension compensation



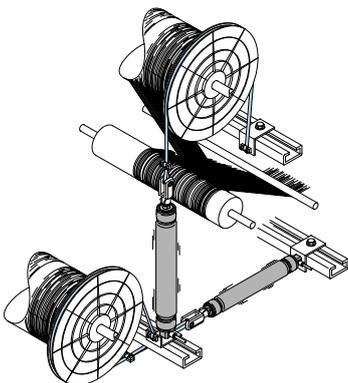
In all applications in which threads, films, paper or tapes are transported or wound and unwound using rollers, high stresses (peak stresses) can develop and potentially tear the material. Thanks to its adjustable spring force and frictionless movement, the fluidic muscle can absorb these stresses. The muscle's spring strength is easy to adjust through pressure and is thus easy to use. When making any changes to the process, the mechanical spring and weights need to be changed too. The fluidic muscle is an excellent alternative to existing solutions using loads and mechanical springs.

Adjustable contact pressure



The fluidic muscle is exceptionally well suited to clamping rollers. The contact pressure can be varied using the operating pressure. The design means that components do not get stuck and there are thus no peak forces. As the fluidic muscle is hermetically sealed it can be disconnected from the compressed air supply, but it will continue to perform its function.

Brake for tension regulation

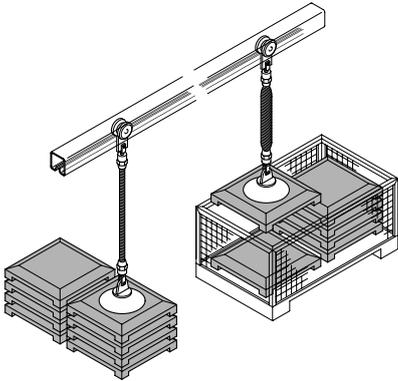


The spring properties of the fluidic muscle make it exceptionally well suited to regulating the thread tension when winding threads. It ensures that the tension in the threads is always as high as it needs to be for the applications and the optimum thread tension is always available. This protects the threads and prevents wear of all components.

Application examples

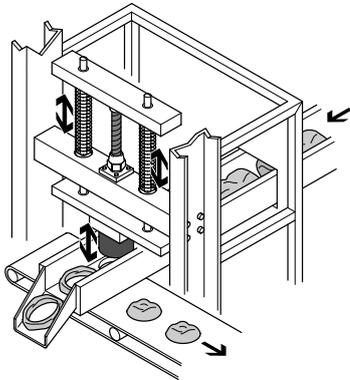
Other possible applications

Lifting aid



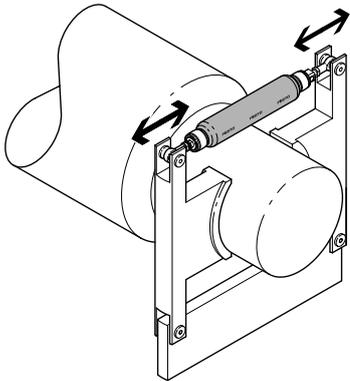
Intermediate positions can be easily achieved using pressure regulation. This raises or lowers the workpieces as required by pressurising or exhausting the muscle via a hand lever valve. Muscle lengths up to 9 m are available to suit different applications.

Punching



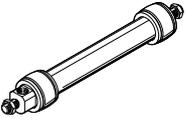
Very high cycle rates can be achieved with the muscle, on the one hand because of its low weight and on the other because it has no additional moving parts (e.g. piston). The simple construction – one muscle pretensioned using two springs – replaces a complicated toggle lever clamping system using cylinders.

Emergency stop



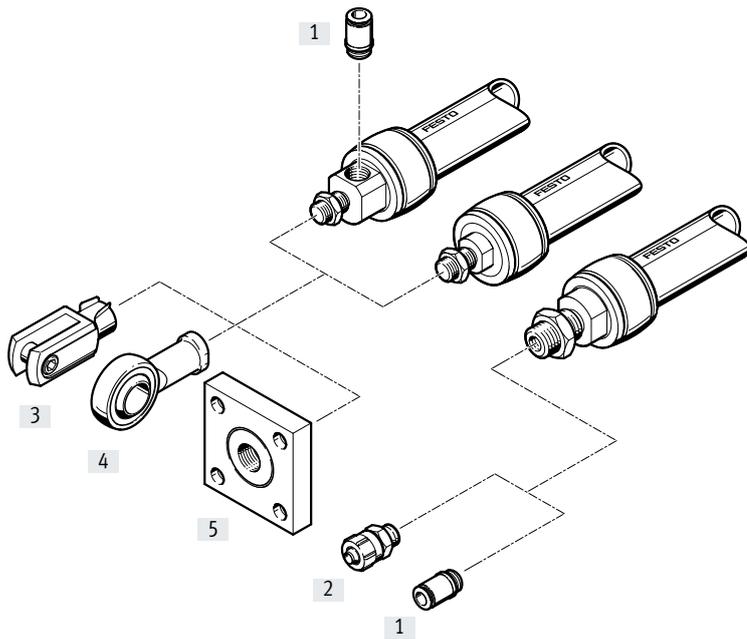
The fluidic muscle is setting benchmarks in applications that require fast response times. An emergency stop for rollers demands both speed and a high initial force. This can prevent risks to the operator in the event of malfunctions.

Product range overview

Function	Version	Inside \varnothing [mm]	Nominal length [mm]	Lifting force [N]
Single-acting, pulling	Fluidic muscle with press-fitted connection			
		5	30 ... 1000	0 ... 140
		10	40 ... 9000	0 ... 630
		20	60 ... 9000	0 ... 1500
40		120 ... 9000	0 ... 6000	

Inside \varnothing [mm]	Max. permissible pretensioning	Max. permissible contraction	Operating pressure [bar]	→ Page/Internet
Fluidic muscle with press-fitted connection				
5	1% of nominal length	20% of nominal length	0 ... 6	10
10	3% of nominal length	25% of nominal length	0 ... 8	
20	4% of nominal length	25% of nominal length	0 ... 6	
40	5% of nominal length	25% of nominal length	0 ... 6	

Peripherals overview



Accessories	Description	Size				→ Page/Internet
		5	10	20	40	
[1] Push-in fittings QSM/QS	For connecting compressed air tubing with standard O.D.	■	■	■	■	qs
[2] Quick connectors CK	For connecting compressed air tubing with standard I.D.	–	■	■	■	ck
[3] Rod clevis SG	Permits swivel motion of the fluidic muscle in one plane	■	■	■	■	19
[4] Rod eye SGS	With spherical bearing	■	■	■	■	19
[5] Coupling pieces KSZ	For compensating radial deviations	■	■	■	■	19
Coupling pieces KSG	For compensating radial deviations	–	■	■	■	19

Type codes

001	Series
DMSP	Fluidic muscle, single-acting, pulling

002	Size [mm]
5	5
10	10
20	20
40	40

003	Nominal length [mm]
30	30
40	40
60	60
120	120
1000	1000
9000	9000

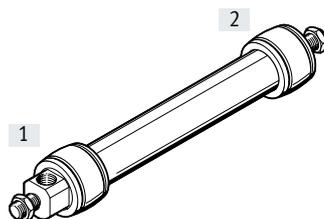
004	Pneumatic connection/mounting 1
RM	Radial/male thread
AM	Axial/male thread

005	Pneumatic connection/mounting 2
RM	Radial/male thread
AM	Axial/male thread
CF	None/female thread
CM	None/male thread

Variants

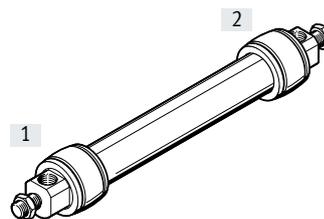
DMSP-...-RM-CM

- [1] Radial connection
- [2] No connection, with male thread



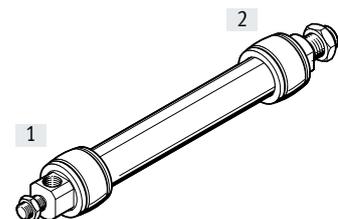
DMSP-...-RM-RM

- [1] Radial connection
- [2] Radial connection



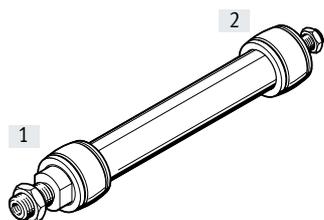
DMSP-...-RM-AM

- [1] Radial connection
- [2] Axial connection



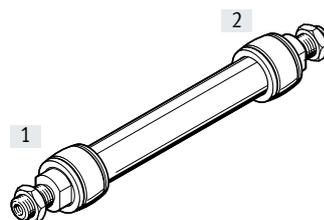
DMSP-...-AM-CM

- [1] Axial connection
- [2] No connection, with male thread



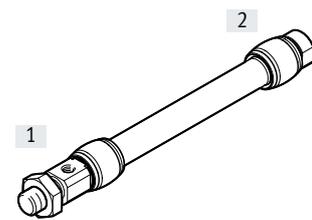
DMSP-...-AM-AM

- [1] Axial connection
- [2] Axial connection



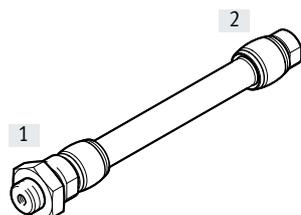
DMSP-...-RM-CF (DMSP-5)

- [1] Radial connection
- [2] No connection, with female thread

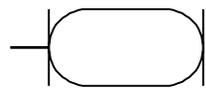


DMSP-...-AM-CF (DMSP-5)

- [1] Axial connection
- [2] No connection, with female thread



Data sheet



Size
5 ... 40

Nominal length
30 ... 9000 mm

Stroke force
0 ... 6000 N



General technical data				
Size	5	10	20	40
Pneumatic connection	M3	G1/8	G1/4	G3/8
Design	Contracting sheath			
Mode of operation	Single-acting, pulling			
Inside \varnothing [mm]	5	10	20	40
Nominal length [mm]	30 ... 1000	40 ... 9000	60 ... 9000	120 ... 9000
Stroke [mm]	0 ... 200	0 ... 2250	0 ... 2250	0 ... 2250
Max. additional load, freely suspended [kg]	5	30	80	250
Max. permissible pretensioning ¹⁾	1% of nominal length	3% of nominal length	4% of nominal length	5% of nominal length
Max. permissible contraction	20% of nominal length	25% of nominal length		
Max. perm. offset of connections	Angle tolerance: $\leq 1.0^\circ$ Parallelism tolerance: $\pm 0.5\%$ (up to 400 mm nominal length), ≤ 2 mm (from 400 mm nominal length)			
Type of mounting	With accessories			
Mounting position	Any (an external guide is required if lateral forces occur)			

1) Max. pretensioning is achieved when the max. permissible freely suspended payload is attached.

Operating and environmental conditions				
Size	5	10	20	40
Operating pressure [bar]	0 ... 6	0 ... 8	0 ... 6	0 ... 6
Operating medium	Compressed air to ISO 8573-1:2010 [7:-:-]			
Note on the operating/pilot medium	Lubricated operation possible (in which case lubricated operation will always be required)			
Ambient temperature [°C]	-5 ... +60			
Corrosion resistance CRC ¹⁾	2			
Certification	TÜV			

1) Corrosion resistance class CRC 2 to Festo standard FN 940070
Moderate corrosion stress. Internal applications in which condensation can occur. External visible parts with primarily decorative surface requirements which are in direct contact with a normal industrial environment.

Forces [N] at max. permissible operating pressure				
Size	5	10	20	40
Theoretical force ¹⁾	140	630	1500	6000

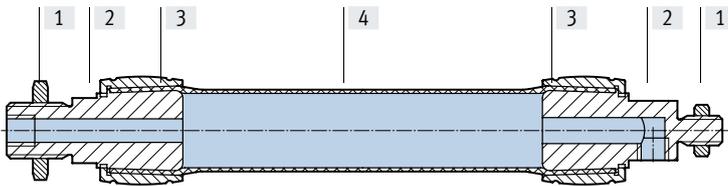
1) For minimum nominal length, the force is reduced by approx. 10%.

Data sheet

Weights [g]				
Size	5	10	20	40
Product weight for 0 m length				
DMSP...-RM-CM	10	58	169	675
DMSP...-RM-RM	11	66	182	707
DMSP...-RM-AM	12	75	202	767
DMSP...-AM-CM	12	66	189	735
DMSP...-AM-AM	14	83	222	827
DMSP...-RM-CF	7	–	–	–
DMSP...-AM-CF	9	–	–	–
Additional weight per 1 m length	27	94	178	340

Materials

Sectional view



Fluidic muscle	
[1] Nut	Galvanised steel
[2] Flange	Colourless anodised wrought aluminium alloy
[3] Sleeve	Colourless anodised wrought aluminium alloy
[4] Sheath	AR, CR
Note on materials	RoHS-compliant
	Free of copper and PTFE
	Contains paint-wetting impairment substances

Data sheet

Permissible force F [N] as a function of the contraction h [%] in the nominal length

Force/displacement graphs and sizing ranges

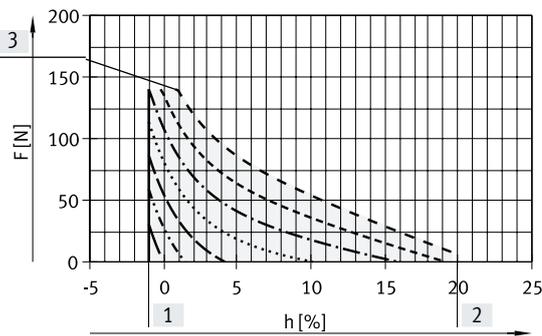
The limits specified in the technical data must be complied with when using the fluidic muscle. The graphs below illustrate the operating range of the fluidic muscle as a function of the diameter, within the limits shown below.

Using the graphs

1. The upper limit of the grey area indicates the maximum permissible force.
2. The right limiting curve of the grey area indicates the maximum permissible operating pressure.
3. The right vertical limit of the grey area indicates the maximum permissible contraction.
4. The left limit of the grey area indicates the load limit of the muscle in terms of the maximum permissible pretensioning.

Operating range DMSP-5-100N-...

Sizing examples → page 20

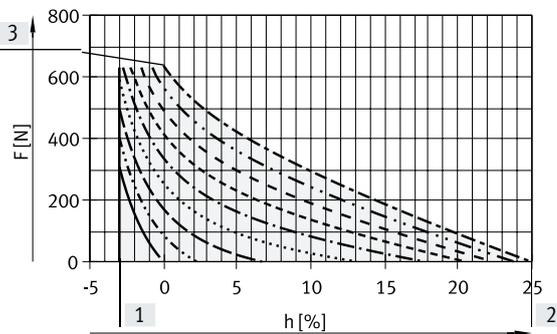


- [1] Max. permissible pretensioning
- [2] Max. permissible contraction
- [3] Theoretical force (140 N) at max. operating pressure

■ Permissible operating range

Operating range DMSP-10-100N-...

Sizing examples → page 20



- [1] Max. permissible pretensioning
- [2] Max. permissible contraction
- [3] Theoretical force (630 N) at max. operating pressure

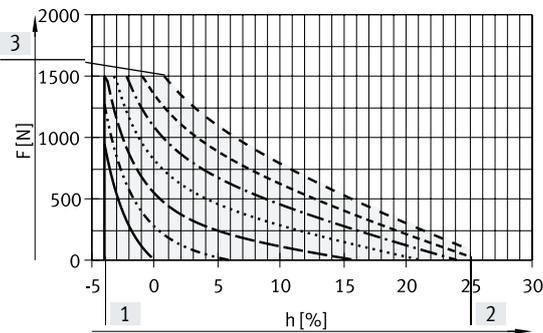
■ Permissible operating range

Data sheet

Permissible force F [N] as a function of the contraction h [%] in the nominal length

Operating range DMSP-20-200N-...

Sizing examples → page 20



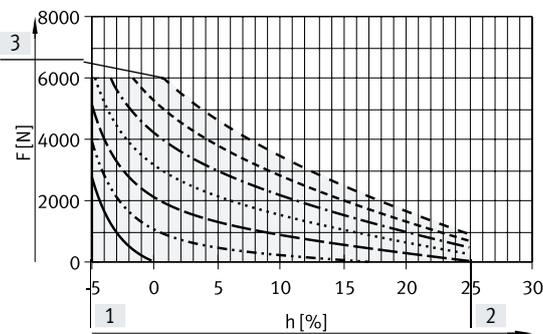
- 0 bar
- ⋯ 1 bar
- - - 2 bar
- ⋯⋯⋯ 3 bar
- · - · 4 bar
- - - - 5 bar
- - - - 6 bar

- [1] Max. permissible pretensioning
- [2] Max. permissible contraction
- [3] Theoretical force (1500 N) at max. operating pressure

Permissible operating range

Operating range DMSP-40-400N-...

Sizing examples → page 20



- 0 bar
- ⋯ 1 bar
- - - 2 bar
- ⋯⋯⋯ 3 bar
- · - · 4 bar
- - - - 5 bar
- - - - 6 bar

- [1] Max. permissible pretensioning
- [2] Max. permissible contraction
- [3] Theoretical force (6000 N) at max. operating pressure

Permissible operating range

Note

The actual value of the force as a function of the contraction can vary according to the product characteristics and the ambient conditions. The deviation can be compensated if the pressure is adapted up to the maximum permissible operating pressure.

The simplest and most reliable way to ensure correct sizing is by contacting the specialist department "Membrane Technologies" at Festo. We can take all the crucial parameters for your application into consideration.

We will be happy to help!

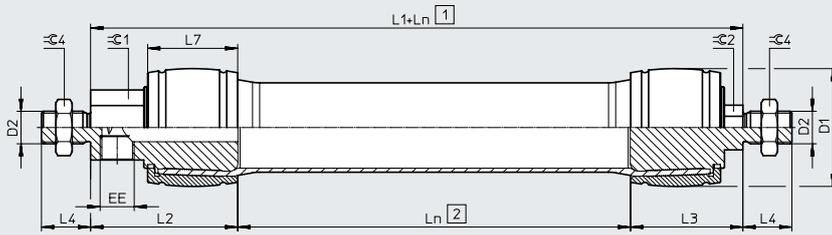
Membrane Technologies
→ membrantechnologie@festo.com

Data sheet

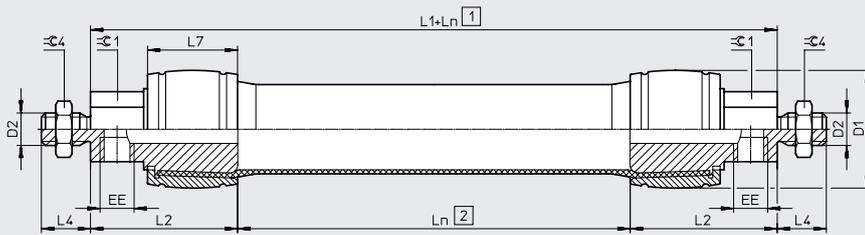
Abmessungen

Download CAD data → www.festo.com

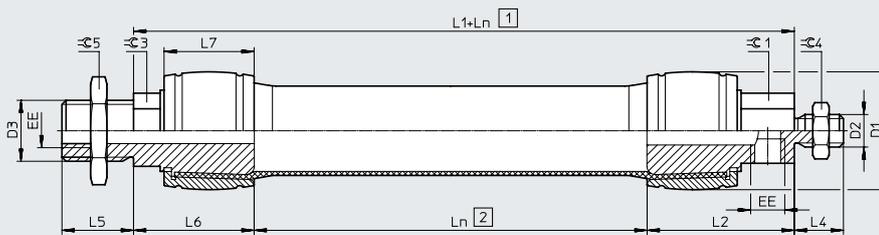
DMSP-...-RM-CM – pneumatic connection, radial – no connection, with male thread



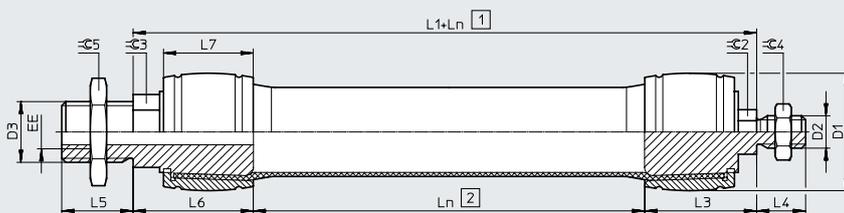
DMSP-...-RM-RM – pneumatic connection, radial – pneumatic connection, radial



DMSP-...-AM-RM – pneumatic connection, axial – pneumatic connection, radial



DMSP-...-AM-CM – pneumatic connection, axial – no connection, with male thread



[1] Installed length
[2] Nominal length

Size	D1 max.	D2	D3	EE ²⁾	Ln ¹⁾		L1				L2
					min.	max.	RM-CM	RM-RM	AM-RM	AM-CM	
5	11	M6	M8	M3	30	1000	33	37	33	29	18.5
10	22	M8	M16x1.5	G1/8	40	9000	62	72	63	53	36
20	35	M10x1.25	M20x1.5	G1/4	60		95	113	97	79	56.5
40	57	M16x1.5	M30x1.5	G3/8	120		127	144	131	114	72

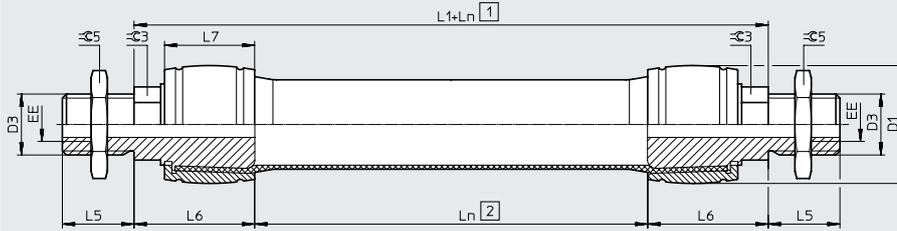
Size	L3	L4	L5	L6	L7	≙C1 ²⁾	≙C2 ²⁾	≙C3 ²⁾	≙C4	≙C5
5	14.5	10	10	14.5	10	8	8	10	13	13
10	26	15	16	27	19	17	10	17	13	24
20	38.5	20	18	40.5	30	19	12	20	17	30
40	55	24	35	59	44	30	19	30	24	46

1) Tolerance < 100 mm ±1 mm, 100 ... 400 mm ±1%, > 400 mm ±4 mm.
2) Parallel orientation of the spanner flats on the left and right connection side can lead to deviations (for production reasons).

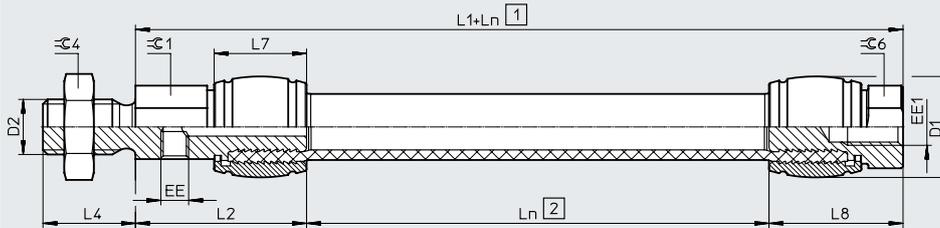
Dimensions

Download CAD data → www.festo.com

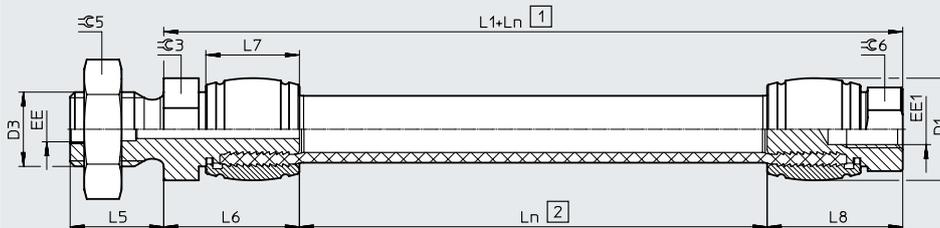
DMSP-...-AM-AM – pneumatic connection, axial – pneumatic connection, axial



DMSP-...-RM-CF – pneumatic connection, radial – no connection, with female thread



DMSP-...-AM-CF – pneumatic connection, axial – no connection, with female thread



[1] Installed length
[2] Nominal length

Size	D1 max.	D2	D3	EE	EE1	Ln ¹⁾		L1			L2
						min.	max.	AM-AM	RM-CF	AM-CF	
5	11	M6	M8	M3	M4	30	1000	29	33	29	18.5
10	22	M8	M16x1.5	G1/8	-	40	9000	54	-	-	36
20	35	M10x1.25	M20x1.5	G1/4	-	60		81	-	-	56.5
40	57	M16x1.5	M30x1.5	G3/8	-	120		118	-	-	72

Size	L4	L5	L6	L7	L8	$G1^{2)}$	$G3^{2)}$	$G4$	$G5$	$G6$
5	10	10	14.5	10	14.5	8	10	13	13	8
10	15	16	27	19	-	17	17	13	24	-
20	20	18	40.5	30	-	19	20	17	30	-
40	24	35	59	44	-	30	30	24	46	-

- 1) Tolerance < 100 mm ±1 mm, 100 ... 400 mm ±1%, > 400 mm ±4 mm.
- 2) Parallel orientation of the spanner flats on the left and right connection side can lead to deviations (for production reasons).

Diameter expansion at maximum contraction

Size	5	10	20	40
[mm]	12	24	40	80

Ordering data – Modular product system

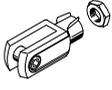
Ordering table		5	10	20	40	Conditions	Code	Enter code	
Size		5	10	20	40				
Module no.		3733012	541403	541404	541405				
Function		Fluidic muscle with press-fitted connection					DMSP	DMSP	
Size	[mm]	5	10	20	40		-... N		
Nominal length	[mm]	30 ... 1000	40 ... 9000	60 ... 9000	120 ... 9000		-... N	-... N	
First connection	Radial, male thread Mounting thread/supply port	M6 / M3	M8 / G1/8	M10x1.25 / G1/4	M16x1.5 / G3/8		-RM		
	Axial, male thread Mounting thread/supply port	M8 / M3	M16x1.5 / G1/8	M20x1.5 / G1/4	M30x1.5 / G3/8		-AM		
Second connection	Closed, male thread Mounting thread	M6	M8	M10x1.25	M16x1.5		-CM		
	Closed, female thread Mounting thread	M4					-CF		
	Radial, male thread Mounting thread/supply port	M6 / M3	M8 / G1/8	M10x1.25 / G1/4	M16x1.5 / G3/8		-RM		
	Axial, male thread Mounting thread/supply port	M8 / M3	M16x1.5 / G1/8	M20x1.5 / G1/4	M30x1.5 / G3/8		-AM		
	Operating instructions	Standard							
		Express waiver – no operating instructions to be included (already available)						-DN	

Ordering data – Standard designs

For size [mm]	Nominal length [mm]	First connection	Second connection	Part no.	Type
5	50	Male thread, radial	Male thread, closed	8114532	DMSP-5-50N-RM-CM
10	80			8114536	DMSP-10-80N-RM-CM
20	100			8114534	DMSP-20-100N-RM-CM
40	120			8114530	DMSP-40-120N-RM-CM

Accessories

Ordering data

Designation	For size	Part no.	Type
Rod eye SGS			
	5	9254	SGS-M6
	10	9255	SGS-M8
	20	9261	SGS-M10x1.25
	40	9263	SGS-M16x1.5 ¹⁾
Rod clevis SG			
	5	3110	SG-M6
	10	3111	SG-M8
	20	6144	SG-M10x1.25
	40	6146	SG-M16x1.5 ¹⁾

Data sheets → Internet: piston rod attachment

Designation	For size	Part no.	Type
Coupling piece KSG			
	5	–	
	10	–	
	20	32963	KSG-M10x1.25
	40	32965	KSG-M16x1.5
Coupling piece KSZ			
	5	36123	KSZ-M6
	10	36124	KSZ-M8
	20	36125	KSZ-M10x1.25
	40	36127	KSZ-M16x1.5

 - **Note**

- 1) If there is a dynamic load on the DMSP-40, the technical data will be subject to restrictions because of the accessories.
 Fundamentals: rated load, friction torque where $\mu = 0.2$:
 - Endurance limit at 6000 N: 1 million load cycles (higher values on request)
 - Endurance limit at 4000 N: 10 million load cycles

Design

Example 1

Lifting a constant load

The muscle needs to raise a constant load of 60 kg, free of forces, by a distance of 10 mm from a supporting surface. The compressed air supply provides a maximum of 6 bar.

The size (diameter and nominal length) of the fluidic muscle needs to be determined.



Note

The simplest and most reliable way to ensure correct sizing is by contacting the specialist department "Membrane Technologies" at Festo. We can take all the crucial parameters for your application into consideration.

We will be happy to help!

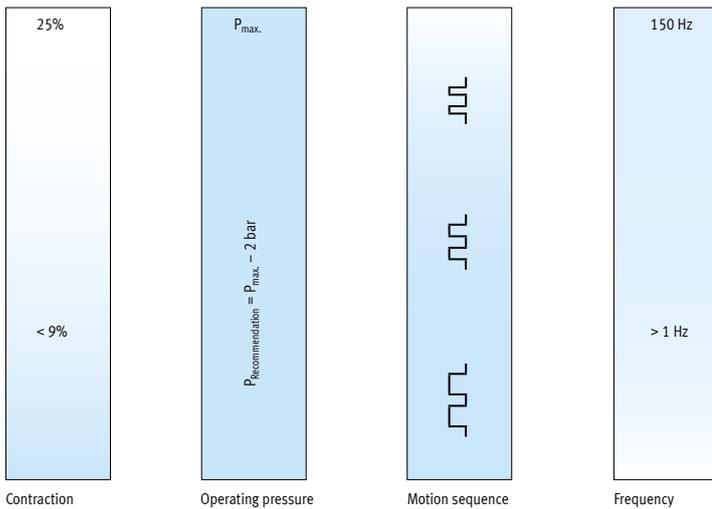
Membrane Technologies

→ membrantechnologie@festo.com

General requirements		Values
Required force at rest	[N]	0
Required stroke	[mm]	10
Required force in contracted state	[N]	Approx. 600
Max. possible operating pressure	[bar]	6

Choice of parameters

Efficient range



Solution method			
Steps	Selection	Input parameters	Result
Step 1:			
Calculating the nominal length (stroke 10 mm/contraction 5%)	200 mm		
Choice of operating pressure (p _{max.} - 2 bar)	4 bar		
Step 2:			
Entering values in the engineering tool	Nominal length:	200 mm	
	Stroke:	10 mm	
	Operating pressure:	4 bar	
Intermediate result for force	Size:	20 mm	674 N
Step 3:			
Adjusting input values	Operating pressure:	3.7 bar	
Result:			609 N

Design

Example 2

Use as a tension spring

In this example, the muscle is to be used as a tension spring.
The size (diameter and nominal length) of the fluidic muscle needs to be determined.

Note

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We can take all the crucial parameters for your application into consideration.

We will be happy to help!

Membrane Technologies

→ membrantechnologie@de.festo.com

If you are determining the size yourself, you must follow this recommendation: contraction < 9%, operating pressure $p_{\text{Recommendation}} = p_{\text{max.}} - 2$ bar, see choice of parameters

General requirements	Values
Required force in extended state [N]	2000
Required force in contracted state [N]	1000
Required stroke (spring length) [mm]	50
Operating pressure [bar]	2

Solution method

Step 1
Determine the required muscle size Determine the most suitable muscle diameter on the basis of the required force. The required force is 2000 N, therefore a DMSP-40-... is selected.

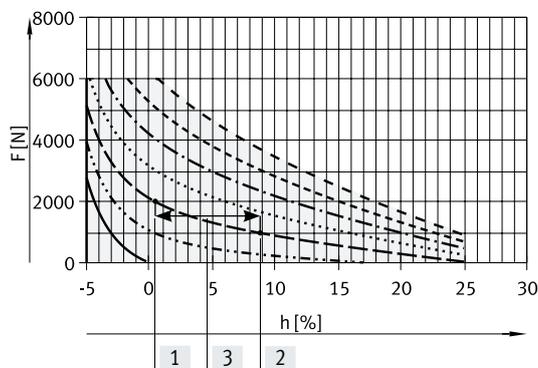
Step 2
Enter load point 1 Load point 1 is entered into the force/displacement graph for the DMSP-40-....
Force $F = 2000$ N
Pressure $p = 2$ bar

Step 3
Enter load point 2 Load point 2 is entered into the force/displacement graph.
Force $F = 1000$ N
Pressure $p = 2$ bar

Step 4
Read off the length change The change in the length of the muscle is read off between the load points on the X-axis (contraction in %).
Result: 8.7% contraction.

Step 5
Calculate the nominal length The required nominal muscle length for a stroke of 50 mm is obtained by dividing by the contraction in %.
Result: $50 \text{ mm} / 8.7\% \sim 575 \text{ mm}$.

Step 6
Result The nominal length of the muscle to be ordered is 575 mm.
For use as a tension spring with a force of 2000 N and a spring travel of 50 mm, a DMSP-40-575N-... is required.



- 0 bar
- · - · - 1 bar
- - - 2 bar
- · · · · 3 bar
- · - · - 4 bar
- - - 5 bar
- - - 6 bar

- [1] Load point 1
- [2] Load point 2
- [3] Length change = 8.7%