Model Selection

1 Features and Precautions for Vacuum Adsorption

Vacuum adsorption system as a method to hold a workpiece has the following features.

- Easy construction
- Compatible with any place where adsorption is possible.
- No need for accurate positioning
- Compatible with soft and easily-deformed work pieces

However, special care is required in the following conditions.

- Workpiece may drop under certain conditions since it is transferred being adsorbed.
- Liquid or foreign matter around the workpiece may be sucked into the equipment.
- Large adsorption area is necessary to get large gripping force.
- Vacuum pad (rubber) may deteriorate.

Fully understand the features above and select the equipment that suits your operating conditions.

2 Vacuum Pad Selection

● Vacuum Pad Selection Procedures

1) Fully taking into account the balance of a workpiece, identify the adsorption positioning, number of pads and applicable pad diameter (or pad area).
2) Find the theoretical lifting force from the identified adsorption area (pad area x number of pads) and vacuum pressure, and then find the lifting force considering actual lifting and safety factor of transfer condition.
3) Determine a pad diameter (or pad area) that is sufficient to ensure the lifting force is greater than the workpiece mass.
4) Determine the pad type and materials, and the necessity of buffer based on the operating environment, and the workpiece shape and materials.

The above shows selection procedures for general vacuum pads; thus, they will not be applicable for all pads. Customers are required to conduct a test on their own and to select applicable adsorption conditions and pads based on the test results.

● Points for Selecting Vacuum Pads

A. Theoretical Lifting Force

- The theoretical lifting force is determined by vacuum pressure and contact area of the vacuum pad.
- Since the theoretical lifting force is the value measured at the static state, the safety factor responding to the actual operating conditions must be estimated in the actual operation.
- It is not necessarily true that higher vacuum pressure is better. Extremely high vacuum pressure may cause problems.
  - When the vacuum pressure is unnecessarily high, pads are likely to be worn out quickly and cracked, which makes the pad service life shorter.
    Doubling the vacuum pressure makes the theoretical lifting force double, while to doubling the pad diameter makes the theoretical lifting force quadruple.
  - When the vacuum pressure (set pressure) is high, it makes not only response time longer, but also the necessary energy to generate a vacuum larger.

Example) Theoretical lifting force = Pressure x Area

2 times

Pad diameter	Area (cm^2)	**Vacuum pressure [-40 kPa]**	Vacuum pressure [-80 kPa]
ø20	3.14	**Theoretical lifting force 12 N**	Theoretical lifting force 25 N
ø40	12.56	**Theoretical lifting force 50 N**	Theoretical lifting force 100 N

4 times

B. Shear Force and Moment Applied to Vacuum Pad

- Vacuum pads are not resistant to shear force (parallel force with adsorption surface) and moment.
- Minimize the moment applied to the vacuum pad with the position of the workpiece center of gravity in mind.
- The acceleration rate of the movement must be as small as possible, and make sure to take into consideration the wind pressure and impact. If measures to slow down the acceleration rate are introduced, safety to prevent the workpiece from dropping will improve.
- Avoid lifting the workpiece by adsorbing the vertical side with a vacuum pad (vertical lifting) if possible. When it is unavoidable, a sufficient safety factor must be secured.

Lifting Force, Moment, Horizontal Force

To lift a workpiece vertically, make sure to take into consideration the acceleration rate, wind pressure, impact, etc., in addition to the mass of the workpiece. (Refer to Fig. 1)
Because the pads are susceptible to moments, mount the pad so as not to allow the workpiece to create a moment. (Refer to Fig. 2)
When a workpiece that is suspended horizontally is moved laterally, the workpiece could shift depending on the extent of the acceleration rate or the size of the friction coefficient between the pad and the workpiece. Therefore, the acceleration rate of the lateral movement must be minimized. (Refer to Fig. 3)

Fig. 1

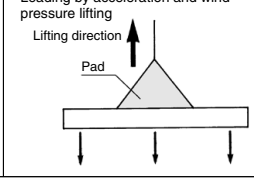


Fig. 2

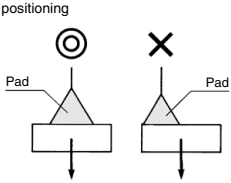
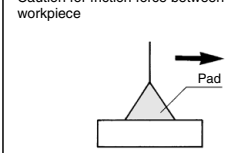
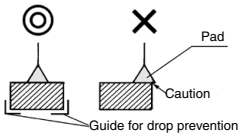


Fig. 3

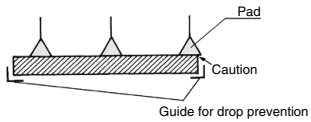


Balance of Pad and Workpiece

Make sure that the pad's suction surface is not larger than the surface of the workpiece to prevent vacuum leakage and unstable picking.



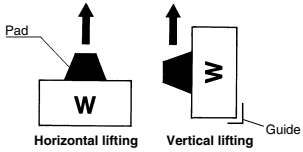
If multiple pads are used for transferring a flat object with a large surface area, properly allocate the pads to maintain balance. Also make sure that the pads are aligned properly to prevent them from becoming disengaged along the edges.



Provide an auxiliary device (example: a guide for preventing the workpieces from dropping) as necessary.

Mounting Position

As a rule, the unit must be installed horizontally. Although a diagonal or a vertical installation should be avoided whenever possible, if the unit must be installed in such a manner, be certain to guarantee guide and absolute safety.



Model Selection

● Lifting Force and Vacuum Pad Diameter

1. Theoretical Lifting Force

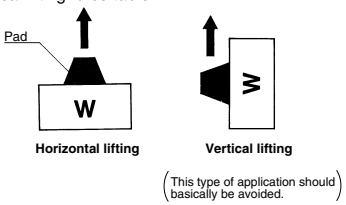
- Set the vacuum pressure below the pressure that has been stabilized after adsorption.
- However, when a workpiece is permeable or has a rough surface, note that the vacuum pressure drops since the workpiece takes air in. In such a case, carry out an adsorption test for confirmation.
- The vacuum pressure when using an ejector is approximately –60 kPa as a guide.

The theoretical lifting force of a pad can be found by calculation or from the theoretical lifting force table.

Calculation

$$W = P \times S \times 0.1 \times \frac{1}{t}$$

W : Lifting force (N)
P : Vacuum pressure (kPa)
S : Pad area (cm²)
t : Safety factor Horizontal lifting: 4 or more
Vertical lifting: 8 or more



Horizontal lifting **Vertical lifting**

(This type of application should basically be avoided.)

Theoretical Lifting Force

The theoretical lifting force (not including the safety factor) is found from the pad diameter and vacuum pressure.
The required lifting force is then found by dividing the theoretical lifting force by the safety factor **t**.

Lifting force = **Theoretical lifting force** ÷ **t**

(1) Theoretical Lifting Force (Theoretical lifting force = P x S x 0.1)

Pad Diameter (ø1.5 to ø50) (N)

Pad diameter (mm)		ø1.5	ø2	ø3.5	ø4	ø6	ø8	ø10	ø13	ø16	ø20	ø25	ø32	ø40	ø50
Pad area S (cm²)		0.02	0.03	0.10	0.13	0.28	0.50	0.79	1.33	2.01	3.14	4.91	8.04	12.6	19.6
Vacuum pressure (kPa)	–85	0.15	0.27	0.82	1.07	2.40	4.2	6.6	11	17	26	41	68	106	166
	–80	0.14	0.25	0.77	1.00	2.26	4.0	6.2	10	16	25	39	64	100	157
	–75	0.13	0.24	0.72	0.94	2.12	3.7	5.8	10	15	23	36	60	94	147
	–70	0.12	0.22	0.67	0.88	1.98	3.5	5.5	9.3	14	22	34	56	87	137
	–65	0.11	0.20	0.63	0.82	1.84	3.2	5.1	8.6	13	20	31	52	81	127
	–60	0.11	0.19	0.58	0.75	1.70	3.0	4.7	8.0	12	18	29	48	75	117
	–55	0.10	0.17	0.53	0.69	1.55	2.7	4.3	7.3	11	17	27	44	69	107
	–50	0.09	0.16	0.48	0.63	1.41	2.5	3.9	6.7	10	15	24	40	62	98
	–45	0.08	0.14	0.43	0.57	1.27	2.2	3.5	6.0	9.0	14	22	36	56	88
	–40	0.07	0.13	0.38	0.50	1.13	2.0	3.1	5.3	8.0	12	19	32	50	78

Pad Diameter (ø63 to ø340) (N)

Pad diameter (mm)		ø63	ø80	ø100	ø125	ø150	ø200	ø250	ø300	ø340
Pad area S (cm²)		31.2	50.2	78.5	122.7	176.6	314.0	490.6	706.5	907.5
Vacuum pressure (kPa)	–85	265	427	667	1043	1501	2669	4170	6005	7714
	–80	250	402	628	982	1413	2512	3925	5652	7260
	–75	234	377	589	920	1325	2355	3680	5299	6806
	–70	218	351	550	859	1236	2198	3434	4946	6353
	–65	203	326	510	798	1148	2041	3189	4592	5899
	–60	187	301	471	736	1060	1884	2944	4239	5445
	–55	172	276	432	675	971	1727	2698	3886	4991
	–50	156	251	393	614	883	1570	2453	3533	4538
	–45	140	226	353	552	795	1413	2208	3179	4084
	–40	125	201	314	491	706	1256	1962	2826	3630

Oval Pad (2 x 4 to 8 x 30, 30 x 50) (N)

Pad diameter (mm)		2 x 4	3.5 x 7	4 x 10	5 x 10	6 x 10	4 x 20	5 x 20	6 x 20	8 x 20	4 x 30	5 x 30	6 x 30	8 x 30	30 x 50
Pad area S (cm²)		0.07	0.21	0.36	0.44	0.52	0.76	0.94	1.12	1.46	1.16	1.44	1.72	2.26	13.07
Vacuum pressure (kPa)	–85	0.60	1.79	3.0	3.7	4.4	6.4	7.9	9.5	12.4	9.8	12.2	14.6	19.2	112
	–80	0.56	1.68	2.8	3.5	4.1	6.0	7.5	8.9	11.6	9.2	11.5	13.7	18.0	105
	–75	0.53	1.58	2.7	3.3	3.9	5.7	7.0	8.4	10.9	8.7	10.8	12.9	16.9	98
	–70	0.49	1.47	2.5	3.0	3.6	5.3	6.5	7.8	10.2	8.1	10.0	12.0	15.8	92
	–65	0.46	1.37	2.3	2.8	3.3	4.9	6.1	7.2	9.4	7.5	9.3	11.1	14.6	85
	–60	0.42	1.26	2.1	2.6	3.1	4.5	5.6	6.7	8.7	6.9	8.6	10.3	13.5	79
	–55	0.39	1.16	1.9	2.4	2.8	4.1	5.1	6.1	8.0	6.3	7.9	9.4	12.4	72
	–50	0.35	1.05	1.8	2.2	2.6	3.8	4.7	5.6	7.3	5.8	7.2	8.6	11.3	66
	–45	0.32	0.95	1.6	1.9	2.3	3.4	4.2	5.0	6.5	5.2	6.4	7.7	10.1	59
	–40	0.28	0.84	1.4	1.7	2.0	3.0	3.7	4.4	5.8	4.6	5.7	6.8	9.0	53

● Vacuum Pad Type

• Vacuum pads are available in flat, deep, bellows, thin flat, with rib, and oval types, etc. Select the optimal shape in accordance with the workpiece and operating environment. Please contact SMC for shapes not included in this catalog.

Pad Type

Pad shape	Application
Flat 	To be used when adsorption surface of work is flat and not deformed.
Flat with rib 	To be used when work is likely to deform or in the case of releasing work certainly.
Deep 	To be used when work is curved shape.
Bellows 	To be used when there is not enough space to install buffer or adsorption surface of work is slanted.
Oval 	To be used when work has limited adsorption surface or long in length and work is required to locate precisely.

Pad shape	Application
Ball joint 	To be used when adsorption surface of work is not horizontal.
Long stroke buffer 	To be used when work height is not even or cushioning toward work is required.
Large 	To be used when work is heavy weight.
Conductive 	As one of the countermeasures against the static electricity, rubber material with reduced resistance is used. For antistatic measures

● Vacuum Pad Material

• It is necessary to determine vacuum pad materials carefully taking into account the workpiece shape, adaptability in the operating environment, effect after being adsorbed, electrical conductivity, etc.
• Based on the workpiece transfer example for each material, select after confirming the characteristics (adaptability) of rubber.

Vacuum Pad/Example of Workpiece Transfer

Material

Material	Application
NBR	Transfer of general workpieces, Corrugated board, Veneer plate, Iron plate and others
Silicone rubber	Semiconductor, Removing from die-casting, Thin workpieces, Food processor
Urethane rubber	Corrugated board, Iron plate, Veneer plate
FKM	Chemical workpieces
Conductive NBR	General workpieces of semiconductor (Static electricity resistance)
Conductive silicone rubber	Semiconductor (Static electricity)

Model Selection

◎ = Excellent --- Not affected at all, or almost no effect
○ = Good --- Affected a little, but adequate resistance depending on conditions
△ = Better not to use if possible
× = Unsuitable for usage. Severely affected.

● Rubber Material and Properties

	General name	NBR (Nitrile rubber)	Silicone rubber	Urethane rubber	FKM (Fluoro rubber)	CR (Chloroprene rubber)	EPR (Ethylene-propylene rubber)	Conductive NBR (Nitrile rubber)	Conductive silicone rubber	Conductive silicone sponge	Conductive CR sponge (Chloroprene sponge)
	Main features	Good oil resistance, abrasion resistance, and aging resistance	Excellent heat resistance, and cold resistance	Excellent mechanical strength	Best heat resistance, and chemical resistance	Well balanced weather resistance, ozone resistance, and chemical resistance	Good aging resistance, ozone resistance, and electrical properties	Good oil resistance, abrasion resistance, and aging resistance. Conductive	Very excellent heat resistance, and cold resistance. Conductive	Excellent heat insulation, and impact resilience	Excellent impact resilience, and sound insulation. Flame retardance
	Pure gum property (specific gravity)	1.00-1.20	0.95-0.98	1.00-1.30	1.80-1.82	1.15-1.25	0.86-0.87	1.00-1.20	0.95-0.98	0.4g/cm³	0.161g/cm³
Physical properties of blended gum	Impact resilience	○	◎	◎	△	◎	○	○	◎	× to △	× to △
	Abrasion resistance	◎	× to △	◎	◎	◎	○	◎	× to △	×	×
	Tear resistance	○	× to △	◎	○	○	△	○	× to △	×	×
	Flex crack resistance	○	× to ○	◎	○	○	○	○	× to ○	×	×
	Maximum operation temperature °C	120	200	60	250	150	150	100	200	180	120
	Minimum operation temperature °C	0	−30	0	0	−40	−20	0	−10	−30	−20
	Volume resistivity (Ωcm)	—	—	—	—	—	—	10^4 or less	10^4 or less	4.8 x 10^4	3.8 x 10^4
	Heat aging	○	◎	△	◎	○	○	○	◎	△	△
	Weather resistance	○	◎	◎	◎	◎	○	○	◎	△	△
	Ozone resistance	△	◎	◎	◎	○	◎	△	◎	△	△
	Gas permeability resistance	○	× to △	× to △	× to △	○	× to △	○	× to △	×	×
Chemical resistance Oil resistance	Gasoline/Gas oil	◎	× to △	◎	◎	○	×	◎	× to △	×	×
	Benzene/Toluene	× to △	×	× to △	◎	× to △	×	× to △	×	×	×
	Alcohol	◎	◎	△	△ to ◎	◎	◎	◎	◎	△	△
	Ether	× to △	× to △	×	× to △	× to △	○	× to △	× to △	×	×
	Ketone (MEK)	×	○	×	×	△ to ○	◎	×	○	×	×
	Ethyl acetate	× to △	△	× to △	×	× to △	◎	× to △	△	×	×
Alkaline resistance Acid resistance	Water	◎	○	△	◎	◎	◎	◎	○	○	○
	Organic acid	× to △	○	×	△ to ○	× to △	×	× to △	○	×	×
	Organic acid of high concentration	△ to ○	△	×	◎	○	○	△ to ○	△	×	×
	Organic acid of low concentration	○	○	△	◎	◎	◎	○	○	×	×
	Strong alkali	○	◎	×	○	◎	◎	○	◎	△	△
	Weak alkali	○	◎	×	○	◎	◎	○	◎	△	△

* The indicated physical properties, chemical resistance and other numerical values are only approximate values used for reference. They are not guaranteed values.
· The above general characteristics may change according to the working conditions and the working environment.
· When determining the material, carry out adequate confirmation and verification in advance.
· SMC will not bear responsibility concerning the accuracy of data or any damage arising from this data.

● Color and Identification (ZP/ZP2)

General name	NBR (Nitrile rubber)	Silicone rubber	Urethane rubber	FKM (Fluoro rubber)	CR (Chloroprene rubber)	EPR (Ethylene-propylene rubber)	Conductive NBR (Nitrile rubber)	Conductive silicone rubber	Conductive silicone sponge	Conductive CR sponge (Chloroprene sponge)
Color of rubber	Black	White	Brown	Black	Black	Black	Black	Black	Black	Black
Identification (Dot or stamp)	—	—	—	· Green 1 dot · Ⓕ	· Red 1 dot · Ⓒ	· Ⓔ	· Silver 1 dot	· Silver 2 dots	—	—
Rubber hardness HS (±5°)	A50/S	Other than Heavy duty A40/S Heavy duty A50/S	A60/S	A60/S	A50/S	A50/S	A50/S	A50/S	20	15

● Color and Identification (ZP3)

General name	NBR (Nitrile rubber)	Silicone rubber	Urethane rubber	FKM (Fluoro rubber)	Conductive NBR (Nitrile rubber)	Conductive silicone rubber
Color of rubber	Black	White	Brown	Black	Black	Black
Identification (Dot)	—	—	—	· Green 1 dot	· Silver 1 dot	· Pink 1 dot
Rubber hardness HS (±5°)	A60/S					

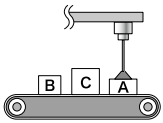
Note) The hardness of rubber shall conform to JIS K 6253. The hardness of sponge shall conform to SRIS 0101.

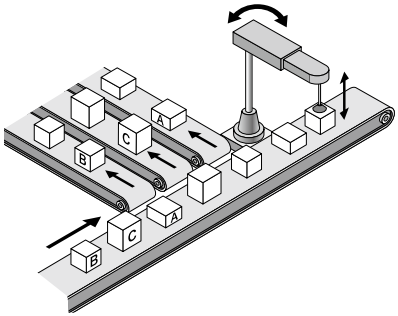
● Buffer Attachment

• Choose buffer type when the workpieces are of varying heights, the workpieces are fragile, or you need to reduce the impact to the pad. If rotation needs to be limited, use non-rotating buffer.

Unsteady Distance between Pad and Workpiece

When the workpieces are of varying heights, use the buffer type pad with built-in spring. The spring creates a cushion effect between the pad and the workpieces. If rotation needs to be limited further, use non-rotating buffer type.



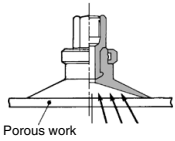


● Pad Selection by Workpiece Type

• Carefully select a pad for the following workpieces.

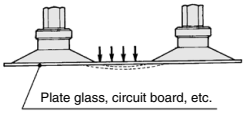
1. Porous Workpiece

To pick a permeable workpiece such as paper, select a pad with a small diameter that is sufficient to lift the workpiece. Because a large amount of air leakage could reduce the pad's suction force, it may be necessary to increase the capacity of an ejector or vacuum pump or enlarge the conductance area of the piping passage.



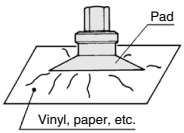
2. Flat Plate Workpiece

When a workpiece with a large surface area such as sheet glass or PCB is suspended, the workpiece could move in a wavelike motion if a large force is applied by wind pressure or by an impact. Therefore, it is necessary to ensure the proper allocation and size of pads.



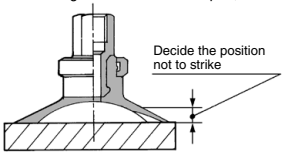
3. Soft Workpiece

If a soft workpiece such as vinyl, paper, or thin sheet is picked up, the vacuum pressure could cause the workpiece to deform or wrinkle. In such a case, it will be necessary to use a small pad or a ribbed pad and reduce the vacuum pressure.



4. Impact to Pad

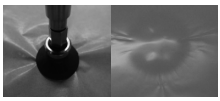
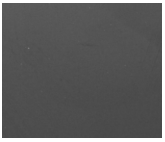
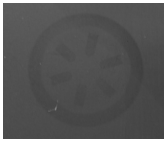
When pushing a pad to a workpiece, make sure not to apply an impact or a large force which would lead to premature deformation, cracking, or wearing of the pad. The pad should be pushed against the workpiece to the extent that its skirt portion deforms or that its ribbed portion comes into slight contact with the workpiece.
Especially, when using a smaller diameter pad, make sure to locate it correctly.



Model Selection

5. Adsorption Mark

The main adsorption marks are as follows:

	Before suction	After suction	Countermeasure
● Mark due to deformed (lined) workpiece			1) Reduce the vacuum pressure. If lifting force is inadequate, increase the number of pads. 2) Select a pad with a smaller center area.
	Suction conditions Workpiece: Vinyl Vacuum pad: ZP20CS Vacuum pressure: –40 kPa		
● Mark due to components contained in the rubber pad (material) moving to the workpiece.			Use the following products. 1) Mark-free NBR pad 2) ZP2 series • Stuck fluororesin pad • Resin attachment
	Suction conditions Workpiece: Glass Vacuum pad: ZP20CS Vacuum pressure: –40 kPa		
● A mark which remains on the rough surface of the workpiece due to wear-out of the rubber (pad material).			Use the following products. 1) ZP2 series • Stuck fluororesin pad • Resin attachment
	Suction conditions Workpiece: Resin plate (Surface roughness 2.5 μ) Vacuum pad: ZP20CS Vacuum pressure: –80 kPa		

Vacuum Pad Durability

- Need to be careful of the vacuum pad (rubber) deterioration.
- When the vacuum pad is used continuously, the following problems may occur.
  1) Wear-out of the adsorption surface.
     Shrinkage of the pad dimensions, sticking of the part where the rubber materials come into contact with each other (bellows pad)
  2) Weakening of the rubber parts (skirt of the adsorption surface, bending parts, etc.)

  ∗ It may occur at an early stage depending on the operating conditions (high vacuum pressure, suction time [vacuum holding], etc.).
- Decide when to replace the pads, referring to the signs of deterioration, such as changes in the appearance due to wear, reduction in the vacuum pressure or delay in the transport cycle time.