ThreeBond
TECHNICAL NEWS

Three Bond Technical News
Issued July 1, 1982
2

Pressure resistance mechanism of reaction-type liquid gaskets (Part 2)

6. Basis of evaluation method and practical performance

6-1. Factors that determine practical sealing performance

For solid gaskets used in general mechanical components, the following factors are considered during component design to determine the appropriate bolt tightening force:

(1) Tightening force required for solid gaskets (gasket factor and minimum tightening force)
(2) Elongation of bolts by heat
(3) Vibration and mechanical stress
(4) Rigidity of the component.

Total tightening force with bolts usually grows quite large, and no opening of the flange due to fluid pressure can occur, since the limition of joint pressure exceeds the internal fluid pressure.

However, during actual operation of the mechanical components, the joint spaces are changed by external factors, and complex behaviors (including the opening of flange joint) are observed. Flange opening caused by pressure greater than the limition of joint pressure under the pressure resistance test is thought to correspond with the changes in inner spaces or clearances under the real use.

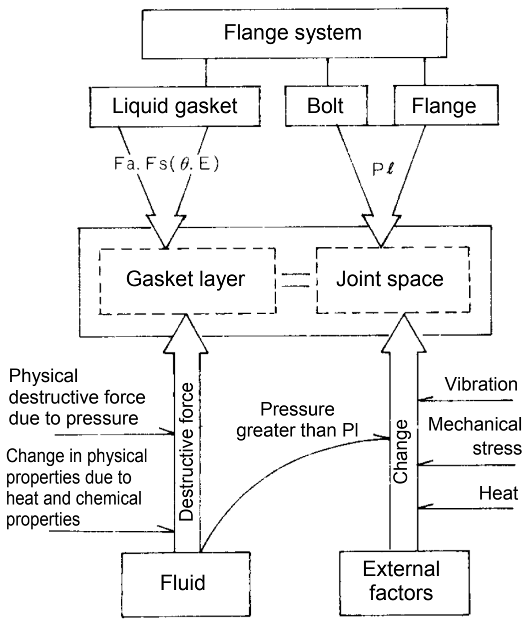


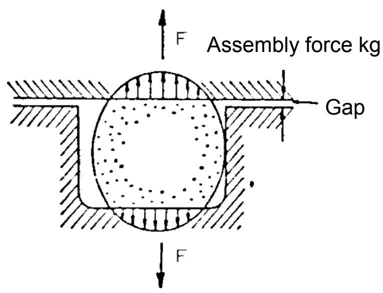
Figure 31.Factors that determine sealing performance

Contents

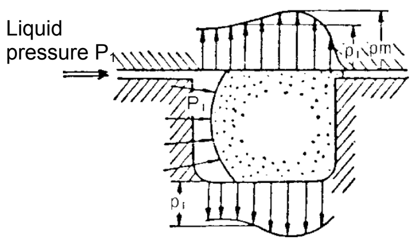
The material failure equation represents the relationship between the physical destructive force due to fluid pressure in use and the properties of liquid gaskets. Therefore, the effects of heat and the chemical properties of the fluid must be considered as variables that affect adhesive force and cohesive force (including elastic modulus and tensile strength).

6-2. Self-sealing action and extrusion effect

Solid gaskets require large contact surface pressure due to their pressure resistance mechanism, and leakage will occur if fluid pressure exceeds contact surface pressure. In the case of O-rings, the contact surface pressure deriving from assembly is not so large and the pressure is maximum at the center as shown in Figure 32-a. However, when fluid pressure is applied, the pressure is added to the original contact surface pressure, as shown in Figure 32-b, resulting in larger contact surface pressure because the O-ring is confined in the groove. This means that the maximum value of contact surface pressure is Pm, which is larger than the value of fluid pressure P1, and no leakage occurs. The remarkably useful sealing action, in which fluid pressure is added to the contact surface pressure, is called self-sealing action.



(a) O-ring (No fluid pressure is applied.)



(b) Condition that prevents leakage from O-ring

Figure 32. Distribution of contact surface pressure for O-ring

In cases in which reaction-type liquid gaskets may be destroyed, such a self-sealing mechanism is expected to function in the case of elastic materials. In Figure 33, when fluid pressure is applied and state (a) is quickly reached, force Psinθ (which remains below destructive levels) given by the material failure equation is generated. As pressure increases, destruction states (b) and (c) are initiated, followed by state (d), initiating self-sealing.

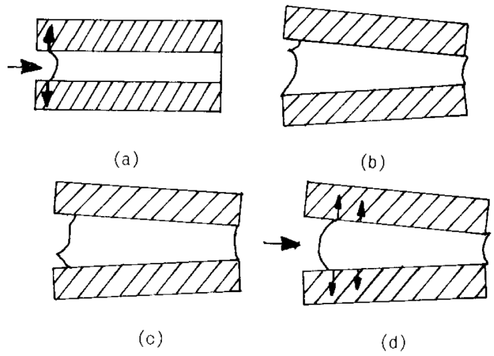


Figure 33. Self-sealing action of high modulus liquid gaskets

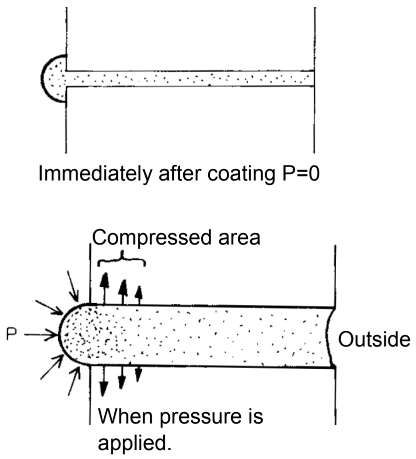


Figure 34. Extrusion effect of liquid gaskets

Although most liquid gaskets will exhibit extrusion in general use, the extrusion generated by high modulus liquid gaskets results in self-sealing action, as shown in Figure 34. Table 6 shows the results of tests on Three Bond 1215.

Table 6. Extrusion effects associated with TB 1215

Testing condition		Leakage pressure (kg/cm^2)	
Average surface pressure kg/cm^2	Pl value kg/cm^2	With extrusion	Extrusion is removed.
50	22.5	68	53
20	7.5	55	33

* The test flange shown in Figure 6 was used.

6-3. Shrinkage stress

In solvent-type liquid gaskets, volume decreases when the solvent volatilizes. In reaction-type liquid gaskets, shrinkage will occur when polymerization or condensation reaction takes place and intermolecular distance decreases. Due to such shrinkage of liquid gaskets, shear stress acts upon the gasket layer. If the shear stress exceeds the adhesive force during the curing process, the joint surface and gasket will separate, even if no external force is applied.

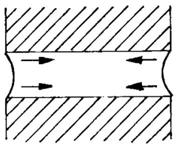


Figure 35. Shear stress in gasket layer

Assuming that the coefficient of linear contraction is C, Young's modulus is E, and the length of joint section is ℓ, average shrinkage stress $P=E\ell C$ acts in parallel to the joint surface. Furthermore, at the both ends of gasket layer and gaps of boundary surface, the stress distribution becomes non-uniform causing stress concentration.

Since the results of adhesive strength tests incorporate such internal stresses, no additional steps to take this phenomenon into account are required.

6-4. Evaluation items

1) Evaluation items for sealing performance

In conventional sealing performance tests, leakage pressure is measured by the pressure resistance test. However, this method simultaneously tests both the physical properties of the flange system and gasket, and evaluation results can vary significantly, depending on flange system conditions.

The sealing performance of liquid gaskets must be evaluated based on results obtained from tests on material properties corresponding to each term of the material failure equation. Table 7 gives the physical properties to be evaluated.

Table 7. Evaluation items for sealing performance

	Conventional evaluation	Physical property evaluation	Remarks
Basic properties	Pressure resistance test	Viscosity before curing	Viscosity is one of the evaluation items for sealing performance because the performance of reaction-type gasket before curing is evaluated by assuming the gasket to be a non-drying material. (Measurement using a pressure-type apparent viscosity meter is more feasible than measurement with a rotating viscosity meter.)
		Elongation	Determination of limit value of Δh.
		Hardness	Since θ varies depending on the conditions of the joint section space, it must be estimated from hardness or E. When the length of gasket layer (width of the flange) is sufficiently long relative to thickness (not shorter than A1-A4 shown in Figure 21), θ of the used gasket is given by $\Delta h/h$ and P, and can be measured.
		Tensile strength	For the determination of Fs. However, measurement of tensile strength must also account for testing speed.
		Shear or tensile adhesive strength	Since the true value of Fa cannot be measured, common adhesive strength is measured instead.
Resistance to liquid	Weight change due to immersion	Changes in physical properties after immersion	Changes in E and Fa are observed.

2) Items for comprehensive evaluation

In actual use, the time required to develop gasket sealing performance (curing rate) becomes an issue, and the durability of a gasket relative to the life of the corresponding mechanical component is another major evaluation item. Aspects such as workability, cost-effectiveness, and handling qualities must also be evaluated.

Table 8 provides a comprehensive list of evaluation items. The importance of each item is determined by the user, location of use, and operating conditions.

Table 8. Comprehensive evaluation of reaction-type gaskets

Sealing performance	Basic properties	According to Table 7.	Durability	Long-term evaluations based on service conditions are required.
	Resistance to liquid	According to Table 7.		
	Low-temperature and high-temperature resistance	Should be evaluated together with resistance to liquid.		
	Developing time (curing rate)	The time required to develop sealing performance under service conditions (variation of viscosity over time from start to end of curing)		
Workability	When coating	For assembly lines, workability is evaluated together with the performance of coating equipment.		
	When separating	Although workability depends on adhesive strength and elasticity, it is actually evaluated by manipulation.		
Cost-effectiveness	Cost	Unit price of the product		
	Total cost	The various pros and cons of sealing performance, workability, handling quality and merits on designing are considered.		
Management	Safety	In consideration of "Occupational Health and Safety Law" and "Fire Defense Law."		
	Storage stability	Stability of material quality and safety in storage		

7. Precautions for joint section design

The design of a flange system must take into account the interrelationships between operating conditions and physical properties of the liquid gasket, the total tightening force of the bolts, flange shape, and external factors. (See Figure 31.)

7-1. Difference from solid gaskets

1) Bolt tightening force and external factors

The bolt tightening force determines the initial thickness of the gasket and affects the extent of change in the joint section space in relation to external factors. Since the liquid gasket layer elastically follows changes in the joint section space, the large initial surface pressure required in the case of solid gaskets is not necessary.

To identify the appropriate diameter, number, and initial tightening force of bolts, it is sufficient to consider the force required to hold the component so long as the displacement of both flange faces does not cause deformation exceeding the elastic limit of the gasket material.

Table 9 shows the results obtained from a test of a flange system using reaction-type liquid gaskets in which bolts are removed when measuring the leakage pressure.

Table 9. Leakage pressure of a flange measured without fixing bolts (kg/cm^2)

Type of gasket	TB 1215	Low-modulus-type silicone	Anaerobic flexible type
Surface pressure at coating: 50 kg/cm^2	3.0	0.2	11
Surface pressure at coating: 20 kg/cm^2	3.0	0.3	16
Clearance: 100 μ	3.0	0.3	16

2) Extent of joint surface finishing

Solid gaskets require meticulous attention to the finish of joint surfaces.

Spiral finishing marks and parallel streaks resulting from shaping or planing impair the performance of metal gaskets. Table 10 shows the extent of finishing required for solid gaskets.

Table 10. Extent of finishing required for flange joint surface (solid gaskets)

Gasket material	Extent of finishing (S)
Leather gasket	50 - 100
Paper gasket	50 - 100
Rubber gasket	50 - 100
Compressed asbestos sheet	25
Semi-metallic gasket	6.4 - 35
Metal gasket	3.2 - 6.4

Liquid gaskets require no such consideration due to their conforming ability. The only factors that need to be considered are those that affect the adhesiveness of the joint surface, such as oil stains. If the liquid gasket has adhesive strength corresponding to the elasticity of the material, it is possible to use a flange face that has not been machine-finished.

3) Flange surface width

Although the minimum width required for solid gaskets depends on the gasket thickness and material, solid gaskets are generally said to be a minimum of 5 mm. In the case of liquid gaskets, the length of the gasket (flange width) is adequate if it is greater than the distance available to relieve the compressive force exerted by liquid pressure (not less than A1 - A4 in Figure 21). Tests for OLG show that 3 mm is sufficient. (See Figure 11.)

7-2. Selection of liquid gaskets

For flange systems for which conditions are known, the limit pressure resistance obtained by applying the physical properties of the liquid gasket to the material failure equation must exceed fluid pressure. In fact, reaction-type gaskets that have been completely cured may be used in virtually all cases in which no dynamic conditions (such as opening of the joint section) exist.

When the evaluation must consider dynamic conditions, the limit pressure resistance can be determined by obtaining the maximum value of the opening of the flange caused by beating or mechanical stress due to vibration, and substituting it for Δh (equation in 4.18) in the material failure equation. However, since the pressure resistance of high-elasticity materials varies significantly with the value of θ, the relationship between pressure and θ must be considered (particularly relating to Δh).

7-3. Shape of joint section

Reaction-type liquid gaskets clearly reduce component costs, and they can be used at even joint sections with large flange displacements and high pressure. Table 11 shows the effects of the shape of the joint section by changing the shape of the joint section to take full advantage of the characteristics of liquid gaskets.

Table 11. Effects of the shape of joint section

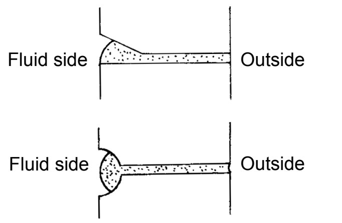
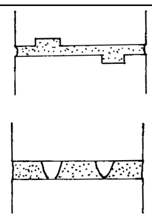
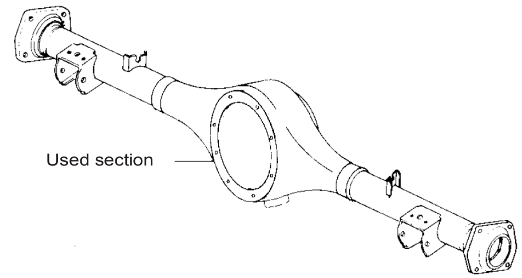
<table>
<tr><th>Countermeasures</th><th>Major effects</th></tr>
<tr><td></td><td>Extrusion effects (Self-sealing action)</td></tr>
<tr><td>Partial projections on the flange face</td><td>Improvement of Δh due to greater maximum thickness of the joint section space (vibration resistance)</td></tr>
</table>

Table of comprehensive comparative evaluations between OLG and solid gaskets
When OLGS is applied to automobile differential carrier

	Item	Description	
1.	Industry sector	Automotive	
2.	Equipment and component	Differential carrier (large truck)	
3.	Production scale	1,500/month	
4.	Dimensions/surface area/weight	Circumference of differential carrier: 140 cm; face width: 25 mm	
5.	Material	Steel × cast iron; mating surface: 12S	
6.	Trade name/grade	Three Bond 1215	Paper gasket+liquid gasket
7.	Amount used	15 g/unit	A sheet/unit, coating on both sides
8.	Used product price	¥6,000/kg	¥170/sheet + ¥30/10 g
9.	Unit cost	¥6/g, ¥90/unit	¥200/unit
10.	Production quantity/total amount used	22.5 kg	1,500 sheets, 15 kg
11.	Total cost	¥135,000	¥300,000
12.	Cost of equipment/component		
13.	Purpose of use/details	Improved sealing performance (improved oil tightness) and subsequent cost savings	
14.	Use conditions	Subjected to splashing gear oil; max. temperature: 120°C Internal pressure: 0.1 kg/cm^2 or less; load is applied at startup and in the event of reserve motion.	

	Item	Description
15.	Problems and countermeasures	The trend is toward liquid gaskets, since the constant strain of solid gaskets reduces torque.
16.	Problems that arise when sealing fails	No problems arise, since the sealing is perfect.
17.	Reason and purpose of adoption	To improve performance and prevent claims
18.	Schematic diagram	

	Functional evaluation				Comparative evaluation				Details of comparative evaluation
	Item	Three Bond Products	Conventional products	Reason	Description	Disadvantages	Three Bond Products	Conventional products	
Material costs	1. Material or processing costs 1-1 Material costs 1-2 Auxiliary material costs 1-3 Labor costs	◎	×	Cost differences	1-1 Material costs (gasket)		¥90	¥170 ¥30	● Conventional products use a solid gasket after coating both sides with a liquid gasket.
Appearance	2. Operation instructions, labeling, design 3. Service (URC, technology)	○	○						
Handling quality	4. Inventory management (including outsourcing) 4-1 Ordering and inventory costs 4-2 Storage conditions and period	○	△	Labor cost	No gasket management according to the type of automobile is required.		¥14.40	¥28.80	● Conventional products: one person, three days (8 hours/day) ● OLG: one person, 1.5 days (8 hours/day) ● Labor costs: ¥1,800/hour÷1,500 units
Handling quality	5. Workability 5-1 Facilities, tools, conditions 5-2 Time 5-3 Operational performance (level of skill required) 5-4 Human factors affecting willingness to undertake related tasks (extent to which the task is disagreeable)	○	△	Labor cost	5-1 Semi-automatic coating equipment is used. 5-2 No significant skill is required. (No training is required; training represents 10% of labor costs) 5-3 No dispersion. 5-4 Good working environment, without odors (Improvements in the working environment and employee morale reduce labor costs by 50%.)		¥3.30 ¥7.50	¥15 ¥1.50 ¥7.50	● Semi-automatic coating equipment: ¥300,000/unit, ¥5,000/month based on 5-year depreciation ¥5,000÷1,500 units=¥3.30/unit ● Setting of conventional solid gaskets: 10 seconds Coating of liquid gasket: 10 seconds x 2 (coating of both sides) ● Coating of OLG: 15 seconds ● Labor cost: @¥0.50/second
Major factor	6. Process control (duplication)	◎	×	Labor cost				α	
Major factor	7. Sealing efficiency 7-1 Sealing efficiency (prevention of problems resulting from leakage) ● Pressure resistance ● Air tightness ● Coefficient of volume shrinkage ● Heat resistance cycle (change over time) 7-2 Chemical strength ● Water, oil, gas, chemicals ● Damage to base material	◎	×	Material cost Labor cost Quality assurance cost	OLG provides perfect sealing for oil tightness. Conventional gaskets result in frequent claims.			¥198.20	●Rate of failure during use (completed car): 484 cases/year ●Overhaul costs: component cost: ¥170; labor cost: ¥7,200 (for 4 hours) 484 cars x (¥170+¥7,200)=¥3,567,080 ¥3,567,080÷12 months÷1,500 units=¥1,980.20
Adverse effects	8. Reliability and safety	◎	△					α	Total cost reductions 1. Per unit: ¥451 - ¥115.20 = ¥335.80 2. Per month: ¥503,700+α 3. Per year: ¥6,044,400+α
Adverse effects	9. Reuse	×	△						
Adverse effects	10. Model change (change in design)	◎	×		OLG is usable after change in design.			α	
					Total		¥115.20	¥451	

Conclusion

With solid gaskets, the behavior of joint section is affected by vibration, loosening of bolts, and decrease in face pressure due to stress relaxation of the gasket. The factors can cause leaks, since sealing performance depends on contact surface pressure at the joint section. In reaction-type liquid gaskets, adhesion to the contact surface is maintained by the adhesive force of the gasket itself. Changes in inner boundary spaces or in clearances resulting from lower face pressure are offset by elastic deformation of the gasket, maintaining sealing performance.

The destruction of the gasket layer of reaction-type liquid gaskets is caused by fluid pressure and flange opening. The mechanism of destruction is elastic deformation. The internal stress upon a gasket layer is determined by the extent of deformation (strain), and the material failure equation is derived from the relationship between the adhesive force and cohesive force (including the elasticity term) of the material.

As typical reaction-type gaskets, RTV silicone and anaerobic acryl represent suitable OLG (F.I.P.) materials. As this report indicates, a proper design of joint sections that takes full advantage of the properties of these materials (e.g., application to non-finished joint surface of castings) can result in significant cost savings for mechanical components.

Very little real use research on reaction-type gaskets has been performed. Progress will depend on the concerted study of flange systems design methods by manufacturers and end users. With candidate materials for reaction-type gaskets extending beyond RTV silicone and anaerobic acryl, the development of alternate materials is another direction being pursued by liquid gasket manufacturers.

Contents of the next issue

Introduction of Group Company

Three Bond Riken, Ltd.
2-7-1 Nishishinjuku, Shinjuku-ku, Tokyo 160
Tel: 03-342-3911

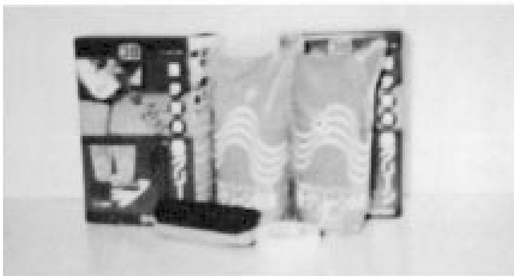
Although the major products of the Three Bond Group are industrial materials, Three Bond Riken also develops and sells consumer goods for the general public.

Three Bond Riken's "Care and Cleaning in Daily Life" series has been augmented by significant new product additions.

Tatami Green, a newly-developed tatami mat cleaner that extends the life of tatami mats, has won great popularity. With a light surface coating, Tatami Green transforms a sun-stained or soiled tatami mat into a lush green.

The coating can be performed with the tatami mat facing up, revitalizing old tatami mats and prolonging service life at a cost one-third of that required for re-covering or reversing. Preserves the original characteristics of new tatami mats, including air permeability.

Three Bond Riken is devoted to the development of useful products based on careful observations of daily life from varying perspectives. It is this approach that allows it to meet consumer demand.



ThreeBond
TECHNICAL NEWS
THREE BOND CO., LTD.
1456 Hazama-cho, Hachioji-shi, Tokyo 193-8533, Japan
Tel: 81-426-61-1333