Whitepaper

Smooth movements despite complex requirements

Tribological solutions for single-lever mixer taps

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Briefly summarised

Water taps and valves are complex mechanisms. Behind their simple visual appearance they usually conceal sophisticated kinematics coupled with a large variety of different materials. Lubricants for valves must be able to cope with the resulting complex requirements. They are used in the individual components and surfaces that are in relative motion to one another to enable their functionality, but also to achieve the desired ease of movement as part of a defined touch-feel coupled with a long service life. Lubricants must do all this under complex requirements such as usability with cold and or hot water, or tightness under a wide range of water pressures applied in different countries, and at the same time comply with regulatory frameworks.

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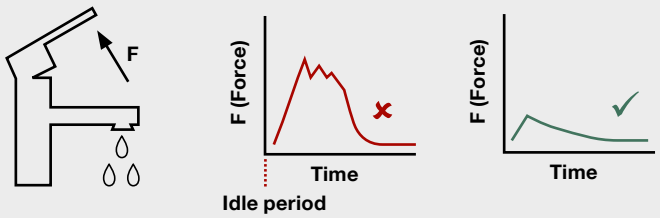
Requirements for a sanitary lubricant

Sanitary valves and fittings are subject to a wide range of requirements. Users of sanitary valves expect a jerk-free, smooth movement at all times, in order to maintain the desired temperature or to prevent excessive, abrupt water discharge (so-called Monday-morning effect). This is key right after installation of the water tap as well as after several years of operation. Since such valves are lubricated during manufacture for their entire life, the correct selection of the design element lubricant plays an essential role. The lubricant is applied to the cartridge in minimum quantities at the relevant points and is intended to ensure a long service life of the valve. To simulate the service life, the minimum actuations or load changes must be achieved as specified by the OEM on practice-oriented test rigs. These can be, for example, significantly more than 200,000 load cycles as in EN 200 for spindle tops or movement profiles or as in EN 817 for cartridges and single-lever mixing systems. By applying these requirements to the selected lubricant, one can derive mechanical-dynamic, chemical-physical, physiological as well as toxicological and microbiological requirements. These may differ depending on the design of the cartridge.

The Monday-morning effect



The feel of the lever must remain the same even after a long period of inactivity. (Operating comfort must not be impaired by prolonged downtime.)

The major tribological requirement is a reduction of friction and wear at the material pairings used. In addition to the effects of water and cleaning substances, exposure to lime and possible deposits require very good corrosion resistance of the materials during the component's life. The prevailing temperature range is 0-90 °C, for boiler systems also up to 120-130 °C. Furthermore tests at various temperatures must be passed as part of the certification process.

How are sanitary valves and fittings designed?

While there are fixed fittings like non-adjustable showers or shower heads, adjustable shower heads and water taps contain valves. In the case of water taps, a distinction is made between those with spindles and ceramic head parts on the one hand, and cartridge or ceramic disk valves on the other. In spindle taps, hot and cold water are supplied individually and their flow rates are adjusted manually. Both flows then meet. These designs can be found in applications where the external appearance is not important. Tribologically much more challenging are so-called single-lever mixer taps, which are particularly widespread in Europe. Here, the flow rate and temperature are set directly by a lever. Hot and cold water come together in a mixer tap. The choice of the right lubricant ensures not only the desired feel when opening and adjusting the water flow, but it also enables technically flawless functionality over decades.

What makes a single-lever mixer tap so special?

The movement of the lever is transmitted via a complex kinematic system to the heart of the mixer tap, the cartridge, which is also referred to as motor. Here, the motion is split up into a vertical and a horizontal component, which leads to the specific adjustment of the temperature and flow rate. This is made possible by ceramic disks moving relative to each other. These ceramic disks have holes that are connected to hot and cold water. In all design types, both streams are mixed in a chamber and flow to the outlet.

[1] Tribology is a field of science dealing with friction, wear and in this context also with the lubrication of surfaces moving under load.

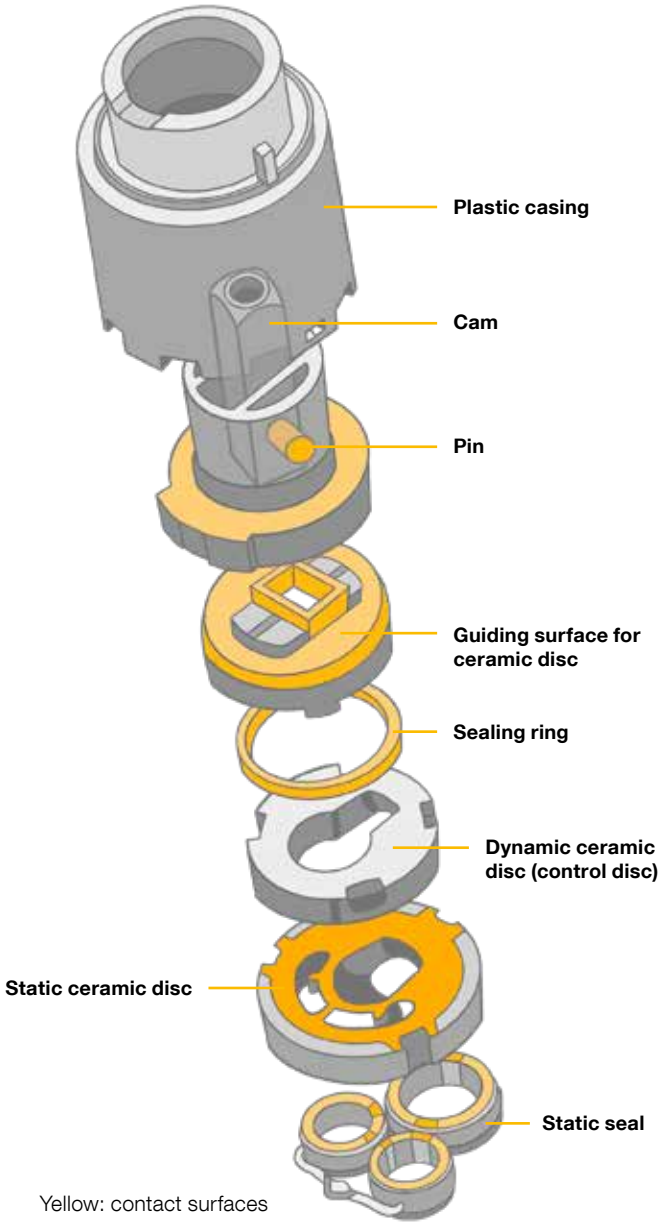
Other requirements are:

- Low friction and wear values with different material pairings
- Enable a damping, uniform and smooth movement, even after a long period of inactivity (= feel/ haptics of the single-lever mixer tap)
- No stick-slip movements that are perceived as jerking
- Uniform motion over the entire temperature range and lifetime
- No washout by cold or hot water
- Chemical neutrality to elastomers (e.g. EPDM, NBR, HNBR, silicone rubber) and plastics (e.g. ABS, POM, PPE, PS, PSU, PBT, PA, PP)
- No corrosion or discoloration
- Very good sealing behaviour for various geometries and surfaces
- No breeding ground for microorganisms
- No change in drinking water in terms of appearance, odour, taste
- Approvals according to BWGL- KTW (UBA guideline, formerly DVGW-KTW), NSF 61, ACS (and others on request) allow the use of the design element sanitary valve lubricant for all water-flushed friction points including those permanently in contact with drinking water.
- In addition, global lubricant availability plays an essential role.

Friction points and lubrication points

At the heart of the single-lever mixer tap are the ceramic disks. Their manufacture, geometry, but also their roughness and flatness are important influencing factors. Numerous components are moved in relation to each other to act on the ceramic disk and make the water flow. Between these components friction and also wear can occur, reinforced by the different materials. Immediately upon movement of the lever, the effect of the lubricant can be felt, for example in the way of its jerk-free opening or simple adjustment by turning. Here, special lubricants are used which, due to their chemical structure, enable the tap to be opened smoothly. Depending on the design, about 0.5 to 1.5 grams of lubricant is applied per cartridge.

The motor at the heart of the mixer tap



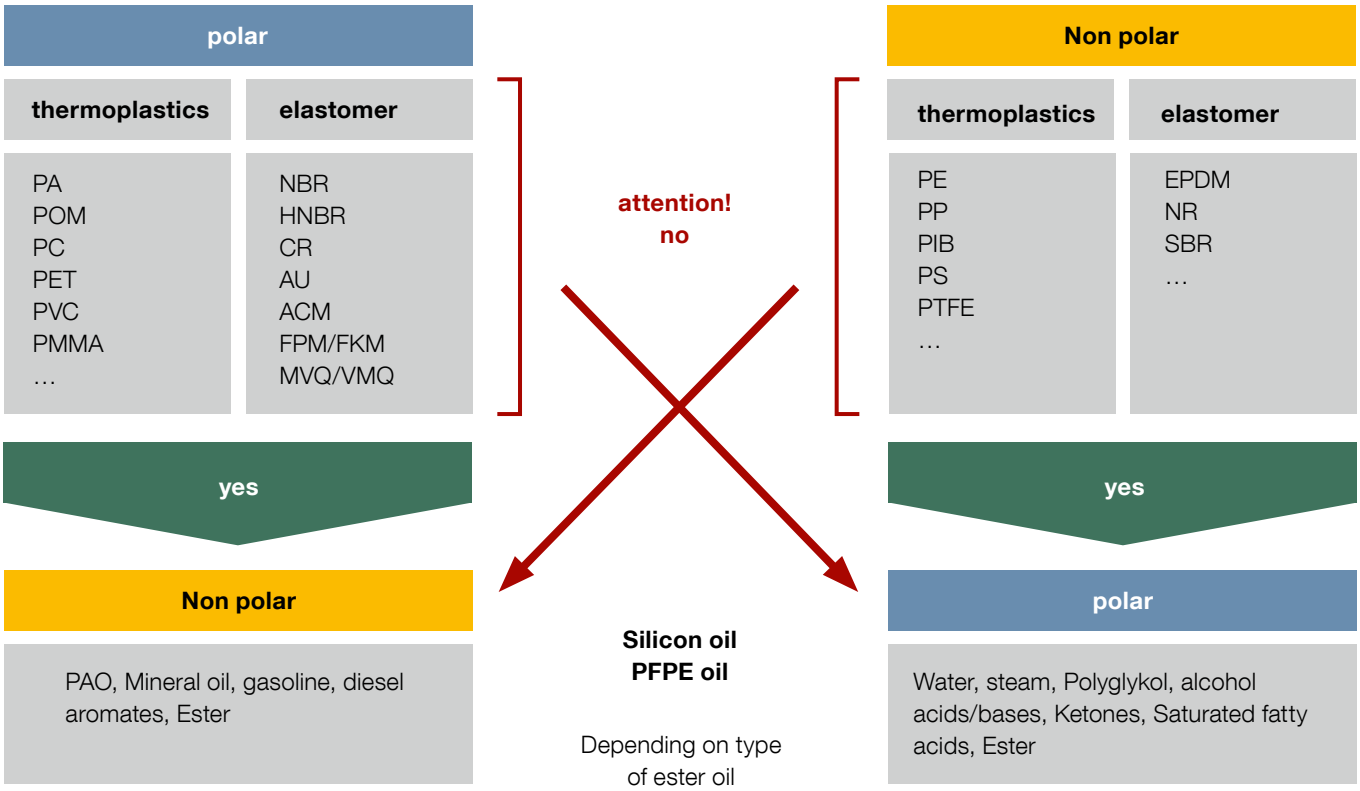
Yellow: contact surfaces to be lubricated

Material pairings

For the sake of a cost-effective, but also durable design, a wide variety of materials are used. Typically components made of brass or steel are used, but coated functional surfaces can also be found. The cartridge itself is made of plastic and contains other plastic components, ceramic disks, and elastomer seals. In some cases metal pistons or metal balls are used. This variety requires chemical neutrality to elastomers (e.g. EPDM, NBR, HNBR, silicone rubber) and plastics (e.g. ABS, POM, PPE, PS, PSU, PBT, PA, PP). The lubricant has the important function of reducing friction and wear between all the materials, geometries, movements and forces used, without chemically attacking them and causing a functional impairment. The use of different plastics and elastomers has repercussions for the lubricant formulation. For this purpose, the polarities between the materials and the lubricant must be taken into account.

Hint: Lube & Seal
By jointly considering the interaction of elastomers and lubricants, as we do in our Lube & Seal programme, the lubricant formulation can be optimised. Opposing polarities between material and lubricant are to be aimed for, while equal polarities can lead to incompatibility in the form of swelling or shrinkage, and to component failure.

Compatibility of elastomers with media



Note: We recommend testing with original components under real-life conditions prior to every series application.

What regulations must be observed?

Drinking water is the most important substance we consume and is subject to significantly stricter requirements than other foodstuffs. The positive lists for substances relevant to drinking water, which specify the substances drinking water may come into contact with, are the most heavily regulated. Country-specific regulations apply. Applicable certifications are extensive. Besides sensory analysis including odour, taste, and appearance of the water, toxicological and microbiological tests are included in the assessment. Internationally, the German and U.S. certifications as well as those of Britain and Australia are considered the most demanding. To prevent interactions between the lubricant and the materials used, carefully selected, mostly synthetic, base materials are used, sometimes supplemented by additives. Many years of experience in this field of chemistry and a large number of extensive tests enable us to draw on profound chemical know-how and use a wide variety of formulations to master an application in a relatively short time and meet the customer's specifications in every respect.

Hint: Is NSF H1 certification sufficient for drinking water applications?
No, because NSF H1 covers the occasional, unavoidable contact with foodstuffs, but not with drinking water. Drinking water requirements are much more stringent, and suitable lubricants must meet NSF Standard 61.

Regulations influence the selection of high-quality raw materials
Drinking water applications require lubricants that are certified under drinking water regulations. This is only possible with suitable raw materials. Consequently, there is a significantly smaller range of raw materials available for the production of these lubricants than for other oils and greases. Since regulations vary from country to country, only a limited number of high-quality raw materials is available for specialty lubricants to be used globally.

Regulatory influences on the lubricant formulation
Regulatory reformulations can have an effect as to which materials may be used. With the introduction of the KTW-BWGL based on the UBA guidelines, it is no longer possible to use NBR in food or drinking water applications as the composition of NBR is no longer regarded acceptable.

Overview: Some national certifications for drinking water

Country	Approvals	Approval criteria
Germany (recognised almost worldwide)	KTW- BWGL	– Until 21st of March 2021 according to the UBA (ger-man federal Environmental agency) lubricant guideline. – From 21st of March 2021 according to the UBA evalua-tion criteria document for plastics and other organic materials in contact with drinking water. – Product testing and composition evaluation
Great Britain (South East Asia, Africa, Australia)	WRAS	Product testing according to british standard BS 6920
France	ACS	Ingredients evaluation (positive list)
Australia and New Zealand	AS 4020	Product testing according to AS/NZS 4020
USA – drinking water (recognised worldwide)	NSF/ANSI/CAN 61	Product testing according to standard 61 and composition toxicological evaluation
USA – food homologation (recognised worldwide)	NSF H1	Ingredients evaluation (positive list) (not for direct contact with drinking water)

How can I recognise the right high-performance lubricant?

1. Classification based on chemical composition and suitability for applications

Lubricants for sanitary valves and fittings in the bathroom and kitchen area are available in various chemical formulations due to the complexity of requirements. The aim is to use a single lubricant for all friction points. The lubricants used consist of a base oil, a consistency-imparting thickener, and additives. Greases based on different base oil types are used, such as silicone oils, PAOs, or fatty acid-based oils.

Silicone oils are odourless, neutral in taste, non-toxic and chemically inert. They are generally neutral to most plastics and elastomers used in sanitary valves and fittings and, depending on the thickener and additives, comprehensively fulfill the most diverse regulations for drinking water applications worldwide. This predestines them for use as universally applicable design elements for valves and fittings that may come into contact with drinking water.

Polyalfaolefins or fatty acid-based oils can be a cost-effective alternative to greases based on silicone oil. These oils have a polar or non-polar character and are not compatible with all plastics or elastomers. Polyalfaolefins are not deemed suitable for use with plastics or elastomers under existing regulations. There is also a possibility of interaction with sealing materials such as EPDM.

2. Friction

Tribological characteristics are determined by means of friction tests. The examination of friction in the complex structure of a single-lever mixer tap requires special test rigs, sensor technology and handling. Tests with simple geometries in special test rigs can provide initial clues. In tests with cartridges or ceramic disk pairs, the number of cycles as well as the stroke of the lever's rotational movements relative to the ceramic disks can be illustrated, thus providing information about the friction behaviour in the system.

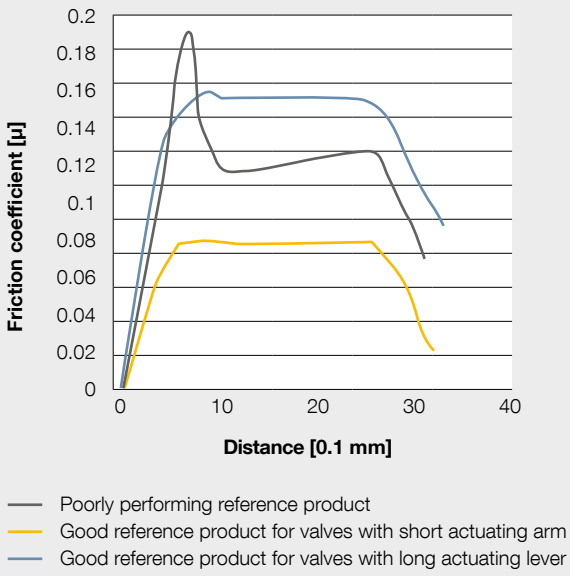
2.1 Friction measurement of a ceramic disk pair

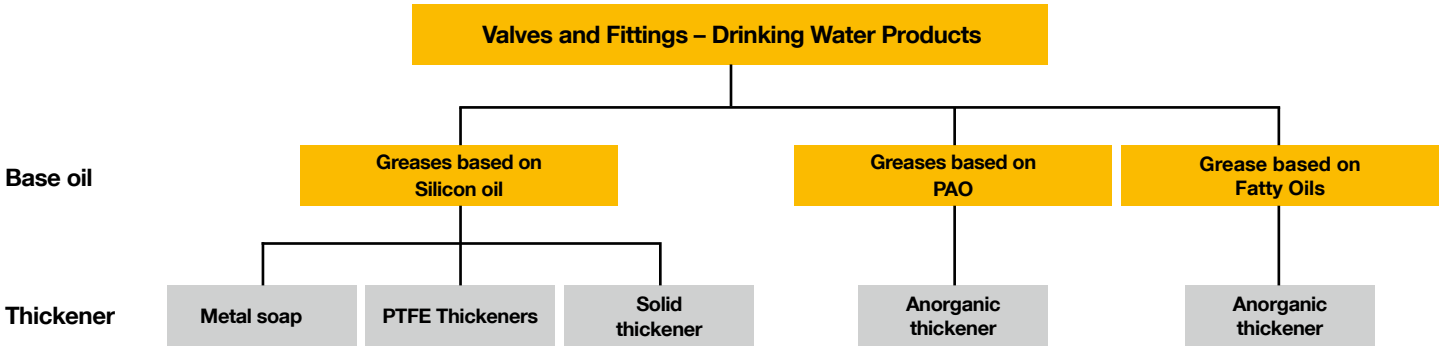
The feel/haptics and the required actuation forces depend on the lubrication conditions prevailing in the cartridge. Essential for the feel/haptics is the friction of the ceramic disk pair, which is measured in accordance with EN 817 and allows an evaluation of the first 200,000 cycles.

2.2 Friction value curves per test cycle

The figure shows the friction values of selected lubricants with characteristic curves related to the distance travelled in one motion cycle. It can be seen that, depending on the requirements, one lubricant can be used to reduce the coefficient of friction significantly. Two factors are essential for the evaluation of the curves. Besides the breakaway torque at the beginning of the

Friction coefficient curve of some lubricants





motion, the frictional torque during longer travel distances is also relevant. The friction values mentioned were determined in test rig trials with commercially available ceramic disks. For a clear evaluation, it is important to consider the surfaces of the ceramic disks. The actuating forces must be carefully selected depending on the overall system.

Curve 1 (poorly performing reference product) shows a high friction value of up to 0.19 at the start of actuation, which drops sharply during further actuation and is then 0.12-0.13. Opening and closing of the valve requires correspondingly high actuating forces, abrupt opening leads to an increased volume flow. This effect is known as the Monday-morning effect.

Curve 2 (good reference product for taps with short actuating arm) shows a very low friction coefficient curve for sanitary applications in bathrooms or kitchens. Opening is easy, the friction coefficient is low at 0.08. During further actuation, the friction coefficient is constant and the tap is easy to operate. This is achieved by mixing a base oil of suitable viscosity and an organic thickener such as PTFE. Further formulation components round off the overall performance, e.g. with regard to backflow behaviour.

When using valves with a longer actuating lever, e.g. in hospitals, a product such as the one shown with curve 3 is suggested (good reference product for valves with long actuating lever). The high friction coefficient allows a controlled opening of the valve with an extended lever arm, the coefficient of friction remains constant during further opening. A suitable lubricant here is a product with a considerably higher base oil viscosity and a medium consistency, good adhesion and thixotropic behaviour. Further components contained in the formulation result in very good damping behaviour. These properties are essential due to the larger ceramic disks and cartridge.

2.3 Endurance tests

The endurance tests over 20,000 cycles provided as examples show two characteristic curves. The "constant friction value" is that of a lubricant with excellent haptic properties. The coefficient of friction is constant over the entire number of cycles and shows only small changes. Users of sanitary valves require the same actuating force to open a valve even after years of use.

The "run-in" curve shows the friction coefficient curve with a pronounced running-in phase. This running-in process of the overall system of ceramic disks and lubricant is completed after about

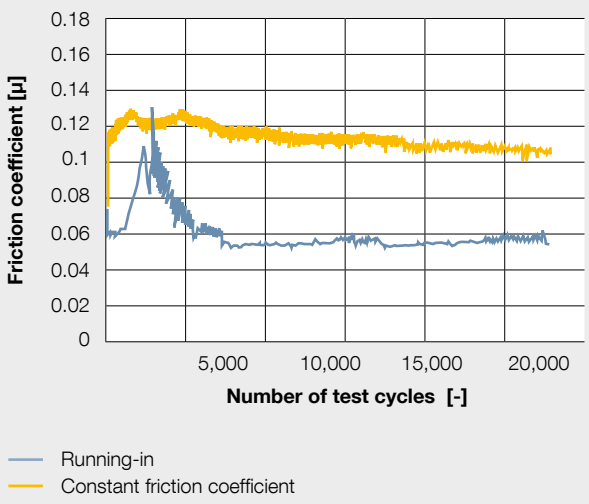
Factors influencing lubricant selection[2]

Customer requirements	Required product characteristics	Resulting product composition
Good haptic feel, also after prolonged operation	Low internal friction, good adhesion	– Silicone base oil – PTFE thickener and/or metal soap – Additives suitable for non-ferrous metals and elastomers – NLGI 3 to 00
Certification for Germany, USA, France, UK	KTW-BWGL, NSF 61, WRAS, ACS	
Use of EPDM seals	Compatibility with plastics	
More than 1 m items made, automated production	Easy application for small item numbers	

[1] Flow characteristics of lubricants with viscosity decreasing due to permanent external influences, i.e. the medium becomes more fluid with increasing pressure.

[2] Exemplary diagram

Friction values in long-term tests



5,000 cycles and then remains constant. Overall, the coefficient of friction is lower than in the "constant coefficient of friction" process, which means that opening can be perceived as too smooth. The tests shown were carried out with identical ceramic disks. The curves show the maximum coefficients of friction in each case when opening the disks. For all tests, a motion profile was carried out in accordance with DIN EN 817.

3. Material compatibility

A further factor influencing lubricant selection are material compatibilities. The interaction between lubricants and plastics/elastomers in particular has been subject of research in recent years. Due to the different compositions of these materials, individual testing of compatibility is recommended before series application is recommended.

Hint: Few lubricants are suitable for EPDM

Contact between seals and lubricants may occur and may lead to interactions. Few lubricants are suitable for use with EPDM, in which case a formulation with a silicone base oil or one containing fatty acids can be used.

Application examples

Numerous influencing variables play a role in the correct choice of lubricant. Making a general recommendation is difficult due to the large number of influencing variables. Technical consulting is therefore highly recommended. On the basis of application examples we would like to give a small selection of typical applications, which could be verified by corresponding tests. We will be pleased to support you.

Application example 1: Mixer tap with special haptic requirements to be produced and sold worldwide

A typical application of sanitary valves: A water tap manufacturer plans to sell a single-lever mixer tap with good feel/haptics, i.e., with low resistance to opening and adjusting of the tap. The tap is to be used in various countries and to be produced fully automatically at several production sites. The materials used are NBR and EPDM seals, in addition to steel and brass.

The following criteria and aspects apply to the selection of lubricants: Suitable for this application is, for example, a product based on a silicone base oil not thickened with PTFE. PTFE causes low coefficients of friction, and the silicone base oil creates permanent separation of the surfaces due to creep. Due to the temperature-independent creep behaviour of silicone, a user-friendly feel is possible in cold and hot water. The suitability of the product was confirmed in customer tests.

Application example 2: High surface stressing of the ceramic disks and simultaneous good wetting for sanitary and household applications

The component surfaces have a significant influence on the service life of the ceramic disks and feel/haptics in the form of low breakaway and actuation torques. Good wetting of surfaces influences the production of valves as well as their operation at the end customer throughout their entire lifetime.

This enables targeted lubrication of the complex components of a valve during production without the lubricant flowing away from the contact. In operation, the good wetting effect by silicone oils in combination with calcium soaps results in good lubricating properties in narrow lubrication gaps or hard-to-reach friction points. A further improvement in operating comfort is achieved by a low dependence of viscosity on temperature.

Application example 3: Use of special seals and silicone-free lubricant

In certain manufacturing processes, silicone is undesirable because of its creep properties, especially where paints and coatings come into play. In the application case described, a silicone-free lubricant is required for a painted or coated valve with EPDM seals. The feel/haptics should be smooth both with cold and hot water. As an alternative to silicone base oils, fatty acid-based base oils have proven their worth. Thickened with a metal-based soap or PTFE, low coefficients of friction and thus low actuating forces are possible. Such concepts entail easy application to the components.

Hint: Lubricants not just for drinking water – approvals for beer and milk

Besides water, there are also other sensitive beverages that make special demands on lubricants. For example a lubricant for beer dispensers must not impair the froth formation of the beer. For perishable beverages such as milk, food regulations and certifications apply, such as H1. Specially developed lubricants that meet both requirements for drinking water and food contact are available worldwide.

The complexity of a single-lever mixer tap requires lubricants that can cope with this complexity and meet the different requirements. Developing such lubricants requires decades of intensive worldwide market observation and fundamental research. Based on extensive experience in the valve industry combined with new intelligent product concepts, technically unique lubricants matching all regulations are developed.

The complexity of single-lever mixer taps require lubricants that can function under these conditions and meet the various requirements. The development of such lubricants requires thorough market knowledge gained over many decades and fundamental research. Based on ample experience in the field of valves and fittings and innovative, smart product concepts, lubricants with unique technical characteristics can be created to work under different regulatory regimes.

Edition 11.21
Publisher and copyright:
Klüber Lubrication Deutschland SE & Co. KG
Geisenhausenerstraße 7, 81379 München, Germany, HRA 84883
www.klueber.de