Comment in the course of the public consultation on the restrictions report on “Per- and polyfluoroalkyl substances (PFAS)”

Submitted by:

KS Gleitlager GmbH
Am Bahnhof 14

68789 St. Leon Rot

Submitted: 26.05.2023

Table of Content

1 Abbreviations

COF	Coefficient of friction
ETFE	Ethylene tetrafluoroethylene
FEP	Fluorinated ethylene propylene
PA	Polyamide
PBT	Polybutylene terephthalate
PE	Polyethylene
PEEK	Polyether ether ketone
PFA	Perfluoroalkoxy polymer
PLC	polymers of low concern (according to the OECD definition)
PP	Polypropylene
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene fluoride
UHMWPE	Ultra-high-molecular-weight polyethylene

2 Introduction KS Gleitlager GmbH

KS Gleitlager GmbH is part of the Rheinmetall Group and specialises primarily in sliding element applications. In addition to metallic sliding elements, these are mainly polymer-coated sliding elements, which usually contains fluoropolymers. The major amount of these sliding elements is for plain bearings. Therefore, in the following plain bearings are often used to explain the essential properties of our materials. Nevertheless, as these properties are also relevant for other sliding elements, these argumentations are usually valid for sliding elements in general.

Our products, which are designed for high-performance applications, are typically built up as follows: A steel basis is coated with a porous bronze. This bronze is filled with a polymer compound, usually based on PTFE, which also forms the top layer as a thin running-in layer for initial lubrication. Having very good tribological properties, this structure enables a high load capacity and very good thermal dissipation, especially compared to full plastic bearings. In addition, this structure means that only comparatively small quantities of fluorocarbons are needed.

While we also have subsidiaries outside of Europe, the presented data, unless otherwise specified, relates to our European production, which is for polymer-based products at our plant in Rot (Germany).

3 Overview Sectors

We supply to different sectors and our products are subject to different (sub-)uses.

Table 1 gives an overview of the share of fluoropolymer containing products produced by KS Gleitlager in Europe for the different sectors as defined in the Annex XV restriction report.

Table 1: Turnover shares by sectors.

Sectors	Share related to turnover	Main applications
Transportation (sub-use according to restriction proposal: coatings and finishes)	75%	Transmissions Brakes Shock absorbers Seat adjusters Steering Systems
Non-transportation (Medical devices, energy sector, construction products, defence, and others)	25%	(Solenoid) Valves Compressors Turbines Pumps Pneumatics Hydraulics Tools

It must be mentioned that the assignment to sectors and sub-uses as defined by the restriction proposal is not trivial and not always possible in our case. For example, a pump that is supplied with one of our parts can end up in different final applications and therefore sectors, while we do not get the information of the final application. But in general, our products are used in industrial applications and not in consumer goods.

In total, fluoropolymer-coated sliding elements account for more than 50% of the turnover generated at the KS Gleitlager plant in Rot.

4 Fluoropolymers Usage

We use different fluoropolymers in our plain bearing and other sliding element applications. The following table shows the consumption of these fluoropolymers by KS Gleitlager in 2022. As can be seen, PTFE and PVDF as base polymers in these applications make up by far the largest share (Table 2).

Table 2: Usage of fluoropolymers by KS Gleitlager in 2022.

Fluoropolymer	Yearly usage 2022 (tons)
PTFE	45
PVDF	13
PFA	2
FEP	0.003
Total	**60**

It should be emphasized that more than 240 million parts have been produced from these relatively low amounts of fluoropolymers.

As mentioned before, these products are high-performance sliding elements. Our market share for these kind of products in Europe is about 30%. It should be noted that also simple PTFE bearings exist and that this market is even several times larger. For example, the company Igus is a large manufacturer of such bearings.

5 Emissions during Life Cycle

In the following, we provide data on possible emissions from these fluoropolymers during their life cycle. Since a clear assignment to sectors is, as mentioned before, not always possible, the following estimations on emissions during the life cycle are not broken down accordingly but are estimated in total. Overall, the emissions during life cycle of our products are estimated to be low and uncritical.

5.1 Manufacturing Phase

In this section we estimate potential emissions of PFAS during the manufacturing phase. Due to the high thermal stability of fluoropolymers, degradation during processing can be considered as minor. We estimate that emissions caused by degradation during the manufacturing phase should be **well below 1 kg / year**.

Detailed estimation:

- As the major amount of fluoropolymers used at our company is PTFE, an exemplary estimation of degradation during processing is performed for this material.

- Typical processing temperatures for sintering PTFE is around 380 °C [1]. This is also the typical temperature that is used in our company. Based on [1] the degradation at this temperature should be approx. in the range of 0.01%.
- As we are processing thin layers of PTFE containing compounds, in our process the average time at these temperatures is below 2 min.
- These assumptions lead to the calculated amounts as shown in table 3.

Table 3: Estimation on yearly emission caused by PTFE degradation.

Degradation rate at 380 °C [1]	0.01% / h
Processing time	2 min
Degradation during processing	$3.33 * 10^{-4}$ %
Yearly emission caused by degradation (based on 44.5 tons PTFE)	**0.148 kg**

- Converted to a single bearing, this corresponds to an emission of only approx. 0.6 µg.
- It can be assumed that the degradation of the other fluoropolymers is in a similar relative range under the respective processing conditions. Therefore, it can be estimated, that the total amount of (volatile) degradation products that are generated by processing should be well below 1 kg per year.

It can be assumed that the majority of these decomposition products are the monomers of the polymers used and that these are to be considered less critical than low molecular weight PFAS.

Even if only low amounts of degradation products are generated during processing of the fluoropolymers, workers are additionally protected as all processing steps at elevated temperatures are performed in closed systems with sufficient ventilation.

5.2 Use Phase

In this section we try to estimate potential emissions during use phase. Because of the various kinds of plain bearings, we can only make an estimation based on average values.

We calculate that during use phase approx. 4.5 tons of fluoropolymers are removed from our plain bearings produced in a year. Nevertheless, only a small fraction of this amount is supposed to enter the environment as the majority stays in the systems as transfer film over the whole use-phase.

Detailed estimation:

- A typical structure of a running layer consists of a porous bronze filled with a fluoropolymer compound and a run-in layer over the bronze with the same fluoropolymer compound. This run-in layer, which corresponds approximately to the proportion of material removed, is on average 15 µm.

- In 2022 we produced fluoropolymer containing sliding elements with a total area of about 200000 m^2.

- From this, a volume of 3 m^3 can be determined, which is removed from the plain bearings during the use phase. Considering approx. 25% fillers in these layers and an average density of the fluoropolymers used of approx. 2 g/cm^3, a value of 4.5 t results.

- The stated amount of fluoropolymer, which corresponds to approximately 10% of the total amount of fluoropolymer used that is likely to be removed from a bearing bushing during its life cycle, represents a worst-case amount of fluoropolymer that may enter the environment during its life cycle. Realistically, the fluoropolymers remain as transfer films on the surfaces of shafts, remain elsewhere in the relevant application or end up in lubricants that are treated and disposed of separately. Thus, it can be assumed that only a small fraction of this amount enters the environment during the use phase.

It should be emphasised that even if any input of foreign substances into the environment should be avoided as far as possible, due to the low quantity and PLC properties of fluoropolymers [2,3] compared to the total inputs of (non-fluorinated) polymers and other substances to the environment, a ban does not appear to be proportionate, especially when considering the benefit profile.

5.3 End-of-Life Phase

The remaining fluoropolymers remain in the bronze until the end of its life. Usually, they will be disposed of properly and will thus largely energetically recycled. Here, reference should be made to the requirements in the automotive industry (accounting for approx. 80% of our products) which prescribes appropriate recycling. For other industries, too, it can be assumed that machinery and equipment are disposed of and recycled accordingly at the end of their life cycle. Plain bearings are part of metallic construction and are following the metallic recycling route. That means, temperature treatment higher than 800 °C for more than 3 min are guaranteed. Fluoropolymers under these conditions are completely mineralized (non-toxic).

A study on this topic by Gujarat Fluorochemicals (GFL) is expected to be published in June 2023.

In case of landfilling, however, due to the properties of the fluoropolymers, it can be assumed that they will not decompose into critical substances and will also not leach to the environment.

As we do not supply our products to consumers goods, improper disposal should be negligible.

6 Properties and Replacement Potential

6.1 Properties Related to Plain Bearings

Fluoropolymers are used in plain bearing applications due to their unique properties that are low coefficient of friction (COF), a large range of service temperature, excellent damping properties (low stiffness) and very good chemical stability. The ecological and economic advantages of these properties are discussed in more detail below. As mentioned before, we also supply other sliding elements. While the benefits here are mainly discussed for plain bearings, it should be clear that the same applies for other sliding element applications in general.

6.1.1 Low Friction

PTFE has the lowest friction coefficient of all solid materials (ref [4], p. 588). It is common sense that lower friction directly relates to lower energy demand of any application and therefore will reduce the carbon footprint. Depending on the application and potential replacement, other materials can have up to 10 times higher friction compared to a PTFE based plain bearing.

As Holmberg and Erdemir showed in their study on passenger cars [5,6], huge amounts of energy are lost due to friction. For internal combustion engine-driven passenger cars they estimate friction losses to be responsible for 33% of the energy demand.

Interestingly the authors claim that a reduction of friction losses will increase fuel efficiency by a factor of three, while at the same time exhaust and cooling losses are reduced. This should emphasize the important role of low friction plain bearings in reducing CO_2-emission.

Another important and special property of PTFE is that not only is the sliding friction very small, but the static friction is similarly low. This is particularly important where stick-slip behaviour is critical. An example of this is in control engineering, especially when very precise movements are required. In chip industry, as an important future technology sector, PTFE coated sliding guides are used for precise wafer cutting.

The low static friction also has a positive effect on the dimensioning of the actuators of systems, as these would otherwise have to be designed for the increased static friction.

Particularly at high rotational speeds, the lower friction and associated lower heat generation of PTFE-based plain bearings can prevent the seizure behaviour that would be observed with metallic bearings or the melting of other polymer-based materials.

Using PTFE plain bearings enables the production of oil free compressors, the only way to make oil free compressed air. For example, this is mandatory for all trains in Europe as compressed air in the end will directly go into the environment.

6.1.2 Maintenance-free

Due to the special properties of fluoropolymers, especially PTFE, they allow for maintenance-free plain bearings. That means they can be used during the lifetime of the respective application having only a small risk of failure. This is causing a significant reduction in costs during the operating lifetime for end-users and industry depending on the application, thus avoiding the build-up of after-markets.

6.1.3 Lubrication-free

Because of the low coefficient of friction of PTFE-based bearings, they can be used in many applications without additional lubrication. The avoidance of additional lubricants (oil or grease), that may enter the environment during the use-phase thus offers a further ecological advantage.

In addition, the complexity of drive systems is significantly lowered by avoiding external lubrication.

6.2 Other Plain Bearing Materials

Other materials, as already stated in Annex E, p. 353 of the restriction proposal, failing in at least one of the key properties of fluoropolymers. While in the restriction proposal this statement is only mentioned in the specific part for the sector transportation, we like to clarify that this is also relevant for other sectors and uses where plain bearings are used. Therefore, they cannot be seen as alternatives to fluoropolymer-based materials in many applications.

In figure 1 we made a qualitative comparison of the properties of different materials for plain bearings. The evaluation is based on relative comparison within the presented materials. It must be emphasized, that properties of the different materials are also dependent to some extent on additional factors, like lubrication and compounds added to the respective polymers. Nevertheless, the general trend should be similar.

	Service temperature (>120 °C)	Friction properties		Damping (low stiffness)	Chemical resistance
		sliding friction	stick-slip		
Fluoropolymers					
PTFE	✓	✓	✓	✓	✓
PVDF	o	✓	o	o	o
PFA	✓	✓	o	✓	✓
FEP	✓	✓	o	✓	✓
non-fluorinated polymers					
PE	×	o	×	o	×
UHMWPE	×	✓	o	✓	o
PEEK	✓	o	×	×	✓
PA (PA46)	o	o	×	o	×
PP	×	×	×	o	×
PBT	o	×	×	o	×
Silicone	×	×	×	✓	o
Metals					
Bronze	✓	×	×	×	×
Aluminium	✓	×	×	×	o
Steel	✓	×	×	×	×

Figure 1: Property overview for different plain bearing materials. (✓: good / **o** : medium / × : bad)

We would like to note, that PP, PBT and silicone are only added in this comparison as they are mentioned as non-PFAS alternatives in Annex E, p. 349. However, we do not consider them as potential materials for high performance plain bearings at all.

6.3 Advantages Compared to Rolling Bearings

Rolling bearing may be also considered as a replacement for plain bearing application where low friction is necessary. Nevertheless, in many cases technical and economic reasons speak against such a replacement, such as significantly higher weight and space requirements as well as higher costs compared to plain bearings. In addition, rolling bearings cannot be used in maintenance-free applications. Also in use-cases where excellent stick-slip behaviour is necessary or in case of certain types of motions rolling bearings are no suitable replacements.

6.4 Results of Internal Comparison Experiments

The following figures 2 and 3 show exemplary results of internal results on friction properties for different plain bearing materials. In both comparisons friction of the PTFE-based materials is set to 100%.

As shown, both under dry running conditions as well as under oil lubrication, PTFE-based systems show by far the lowest friction.

In case of a lubricated systems using VG 46 hydraulic oil (figure 2), a PVDF based bushing showed five times higher frictions compared to PTFE, which is still lower than that of a PEEK-based bushing (8x higher friction compared to PTFE).

An aluminium-based bushing showed under these conditions a friction which is 12 times higher compared to PTFE-based. Aluminium was used for this comparison as it is expected to show the best friction properties of metallic based systems. Alternative metallic materials like copper or bronze can be expected to be even worse.

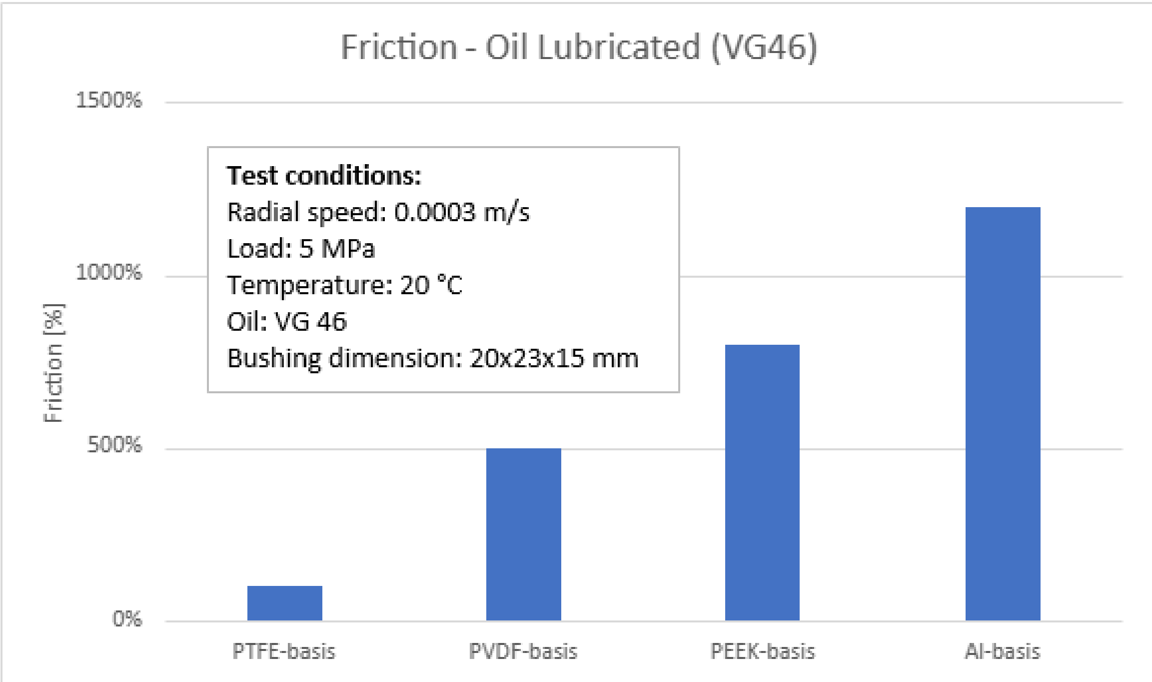

Figure 2: Comparison of friction for different base material under oil lubrication.

In case of dry running (no lubrication) the trends remain unchanged, with a PEEK-based systems as non-fluorinated replacement shows seven times higher friction compared to PTFE (figure 3). Under these conditions, it was not even possible to determine a value for an aluminium-based system, as seizure of the bearing was observed. Also, here the same is expected for copper or bronze based metallic bushings.

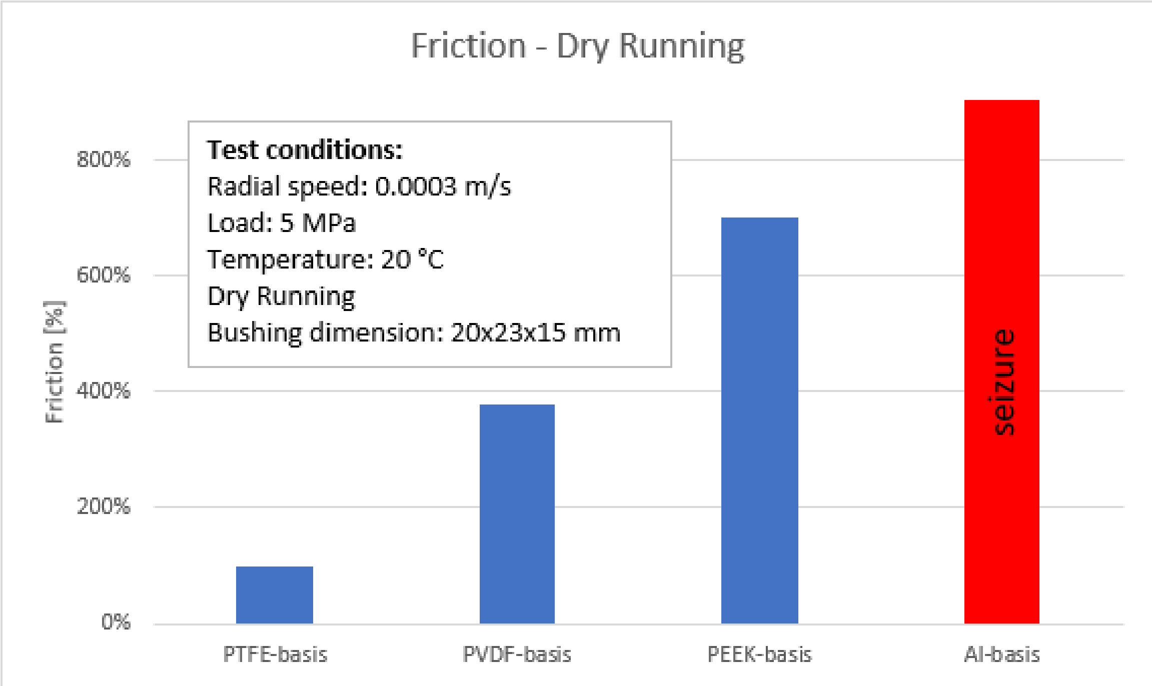

Figure 3: Comparison of friction for different base material under dry running conditions.

6.5 Additional Remark

It cannot be expected that a detailed consideration and assessment of the cost-benefit ratio for all, especially small-scale applications can be prepared by the supplier side. Nevertheless, these applications can have corresponding relevance and importance. We therefore see the danger that such applications might not be mentioned specifically and thus be automatically banned.

Even if this consideration can therefore not be carried out for every application, it can be assumed that the special properties described above (low COF, a large range of service temperature, excellent damping and very good chemical stability) are decisive for use in the corresponding applications.

7 Economic Impact on KS Gleitlager

A ban of fluoropolymers would have a significant economic impact on KS Gleitlager. For our plant in Rot, this would mean a loss in turnover of more than 50% which would be associated with layoffs in a similar range.

8 Comments on Proposal Documents

Annex E, Table E.113 (p. 349/350):

Due to bad formatting of the table, corresponding comments related to “lubrication free bearing” in column 3 (“Substitution potential”) and column 4 (“Estimate of time needed for substitution”) are not correctly aligned and might therefore lead to wrong conclusions. Considering the details on p. 353/354 the comment “alternatives are missing one or two of the key requirements: either low friction, low stiffness or high temperature resistance” belongs to “lubrication free bearings” as well as “>10 years” as estimate of time needed for substitution.

In the present proposal, plain bearings are, as far as we can see, only explicitly considered in the transportation sector regarding alternatives. However, as we have previously shown, they also play an important role in other applications that are assigned to other sectors. Also in these sectors we do not see suitable alternatives in many applications.

9 Concluding Remarks

In the information we have presented, we showed that sliding elements (e.g., plain bearings) are key parts in many applications. We therefore request a general exemption of fluoropolymers for sliding element applications (in particular plain bearings) from regulation. Due to the special properties of fluoropolymers, we do not see any possibility to adequately replace them, even with long transition periods. A ban of fluoropolymers for these applications would make it very likely that the goals of the EU Green Deal, among others, will not be achievable. Especially considering, that these fluoropolymers are considered as polymers of low concern (PLC) according to the OECD definition, we perceive a restriction to be disproportionate. In our opinion, a mere classification based on the persistence of fluoropolymers is also not justified. It is precisely this stability of fluoropolymers that makes them indispensable in many applications, also besides plain bearings or sliding elements.

Besides that, we recognise that regulation of critical low-molecular-weight PFASs is necessary, also to avoid regrettable substitutions and to reduce the risk to humans and nature in the long term.

10 Submission of Additional Information

We are planning to submit further information that can support the opinion making during the consultation period. Please contact us in case you need more data, e.g., for a specific sector or use-case.

11 Disclaimer

The information has been compiled to the best of our knowledge and the current technical state of the art.

12 References

[1]: PlasticEurope (2021): Guide for the Safe Handling of Fluoropolymer Resins. (https://fluoropolymers.plasticseurope.org/application/files/5116/3671/1909/Fluoropolymers_Safe_Hand_EN_2021.pdf, accessed 09.05.2023, 15:19)

[2]: Henry, B.J., Carlin, J.P., Hammerschmidt, J.A., Buck, R.C., Buxton, L.W., Fiedler, H., Seed, J. and Hernandez, O. (2018), A critical review of the application of polymer of low concern and regulatory criteria to fluoropolymers. *Integr. Environ. Assess. Manag.*, **14**, 316-334. https://doi.org/10.1002/ieam.4035.

[3]: Korzeniowski, S.H., Buck, R.C., Newkold, R.M., Kassmi, A.E., Laganis, E., Matsuoka, Y., Dinelli, B., Beauchet, S., Adamsky, F., Weilandt, K., Soni, V.K., Kapoor, D., Gunasekar, P., Malvasi, M., Brinati, G. and Musio, S. (2023), A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers. *Integr. Environ. Assess. Manag.*, **19**, 326-354. https://doi.org/10.1002/ieam.4646.

[4]: Domininghaus, P., Elsner, P., Eyerer, P., Hirth, T. (eds.) (2008) DOMININGHAUS – Kunststoffe, Springer Verlag Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-72401-8.

[5]: Holmberg, K., Erdemir, A. (2019), The impact of tribology on energy use and CO2 emission globally and in combustion engine and electric cars. *Tribol. Int.*, **135**, 389-396. https://doi.org/10.1016/j.triboint.2019.03.024.

[6]: Holmberg, K., Erdemir, A. (2017), Influence of tribology on global energy consumption, costs and emissions. *Friction*, **5**, 263-284. https://doi.org/10.1007/s40544-017-0183-5.