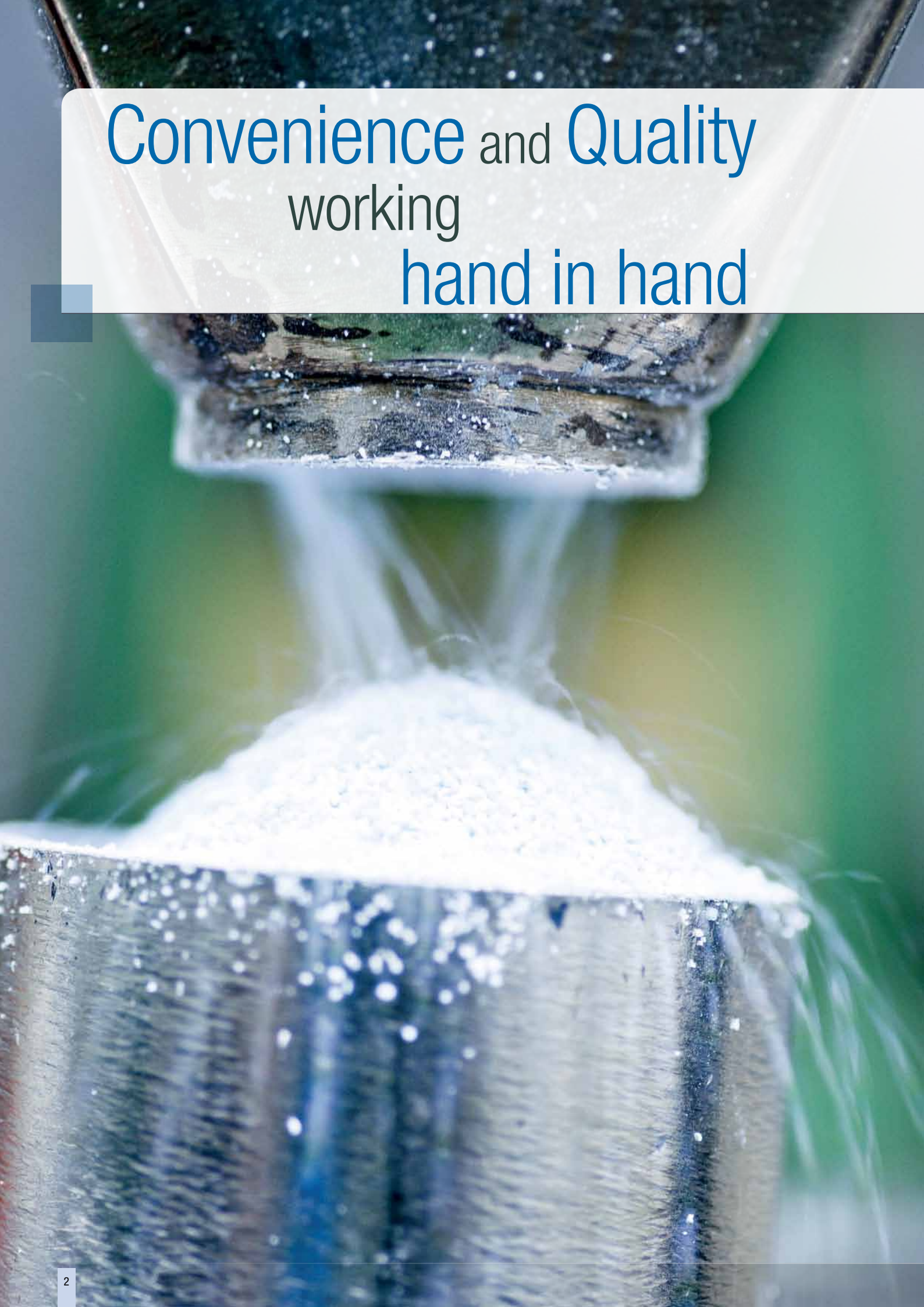
3M™ Dyneon™

PTFE Compounds and TFM™ Modified PTFE Compounds

State of the art quality

Custom-made solutions

Convenience and Quality working hand in hand



Introduction

This brochure offers an overview about the composition, properties, and processing of PTFE Compounds and eases selection from the offered range of products. It is supplemented by a selection of typical application possibilities.

3M™ Dyneon™ Fluoropolymers help to prolong equipment life-cycles. These materials are capable of withstanding corrosive chemicals, temperature extremes (-200 °C to 260 °C), aging, and physical wear and tear. General resistance to bases, acids, hydrocarbons, alcohols and steam make Dyneon fluoropolymers the materials of choice for contact with chemicals in a wide range of industries – transportation-, chemical-, petrochemical-, oil & gas and many other industries. Dyneon, a 3M company, offers a broad product range of fluoropolymers, assisting experts in material selection for their application requirements. Dyneon combines the resources of a global leader with 40 years of fluoropolymer specialisation and innovation.

What is 3M™ Dyneon™ PTFE and 3M™ Dyneon™ TFM™ Modified PTFE?

The PTFE portfolio is topped of with PTFE or TFM Modified PTFE Compounds. PTFE is the acronym for polytetrafluoroethylene, an organic fluorine compound, and is sold under the Dyneon brand name. Dyneon is a worldwide leader in advanced fluoropolymer technology.

TFM Modified PTFE is maintaining the preferred mechanical and chemical properties of classic PTFE, but offers some additional unique benefits to the user.

Reduced deformation under load (cold flow), a lower permeability and an enhanced weldability of components made of TFM Modified PTFE are just some of the characteristics of this versatile product.

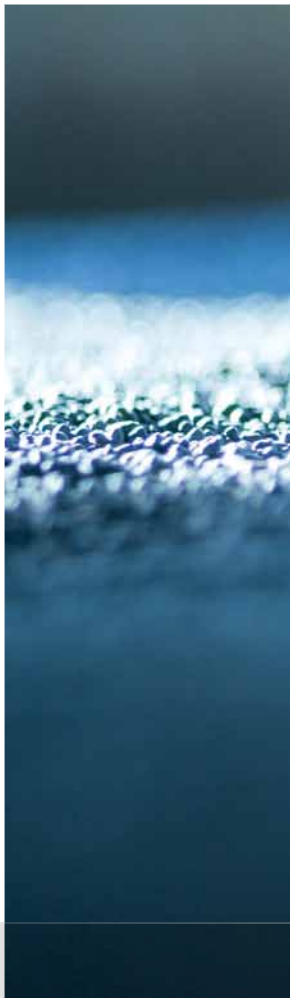
Dyneon PTFE and TFM Modified PTFE are rapidly becoming the materials of choice where characteristics like low friction, high durability, excellent thermal properties, and chemical inertness characteristics are required.

PTFE Compounding has earned an excellent reputation in providing products which offer exceptional physical properties – providing hundreds of solutions for some of the most demanding applications. The unique properties of PTFE have made it an indispensable material for modern industry.

Dyneon PTFE offers the following exceptional properties

- Widest temperature-application range of all currently available plastics. It is capable of continued service between -200 °C and + 260 °C and can withstand temperatures up to 300 °C for limited periods.
- Lowest friction coefficient of all known solids. Static and dynamic friction coefficient are nearly the same (no stick-slip). These properties remain near the crystallite melting temperature of 327 °C.
- Exceptional chemical resistance. It is stable in most aggressive and corrosive media, exceptions being liquid or dissolved alkali metals, fluorine and other extremely potent oxidisers.
- Excellent electrical and dielectric properties, which are independent of temperature and frequency.
- Low flammability LOI (%) > 95.
- No embrittlement or aging.

In comparison with first-generation PTFE products, TFM Modified PTFE allows the use of new designs and processing methods to be used, especially in applications which specify high levels of safety and reliability.

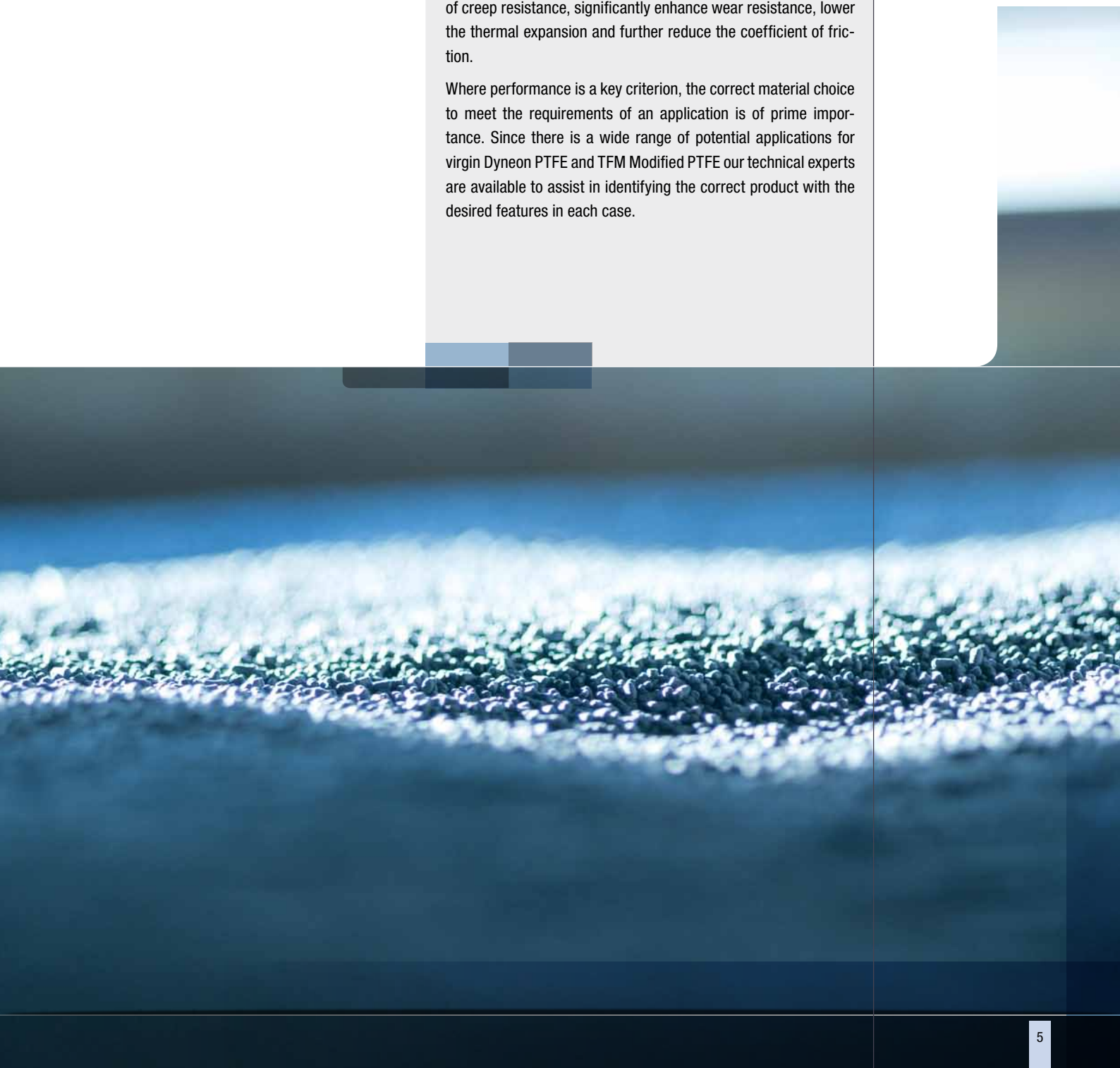


Custom-made solutions

- Excellent weldability
- Substantially lower deformation under load
- Denser polymer structure

By incorporating selected fillers into PTFE or TFM Modified PTFE, many different kinds of compounds can be manufactured to offer the perfect solution for solving customer problems. Fillers are used to reinforce the PTFE/TFM Modified PTFE matrix in terms of creep resistance, significantly enhance wear resistance, lower the thermal expansion and further reduce the coefficient of friction.

Where performance is a key criterion, the correct material choice to meet the requirements of an application is of prime importance. Since there is a wide range of potential applications for virgin Dyneon PTFE and TFM Modified PTFE our technical experts are available to assist in identifying the correct product with the desired features in each case.



Step by step - the product that you need!

The customised product range

Besides a range of commonly used 3M™ Dyneon™ PTFE Compounds and 3M™ Dyneon™ TFM™ Modified PTFE Compounds with fillers such as glass fibers, glass bubbles, bronze, hard and soft carbon, graphite, carbon fiber, and several possible combinations of those, Dyneon offers custom-made compound solutions fine-tuned to serve any application challenges.

How to use our products

Dyneon PTFE Compounds and TFM Modified PTFE Compounds are offered in the form of free-flowing and non-free-flowing powders. Depending on the customer process, the flow properties can be tailor-made as soft-free flow for isostatic moulding or pre-sintered for ram-extrusion. For paste extrusion processes, such as wire and cable, tubing or linings, Dyneon offers compounds based on fine powder PTFE or fine powder TFM Modified PTFE.

Quality counts

The overall market trends show significantly growing demand for faster, powerful, more flexible, safer, and more durable materials that have to withstand the aggressive media and substances used in the industry. Regardless of the application, be it in the transportation sector, chemical sector or any other which demands quality and reliability, the increasing demands require optimum performance which can be provided by customised compounds.

Influence of PTFE / TFM Modified PTFE Matrix and fillers on general properties of compounds

Parameter	Mechanical Properties	Deformation under load	Friction Coefficient	Wear	Chemical Resistance	Expansion Coefficient	Thermal Conductivity
PTFE → TFM PTFE	→ / ↗	↘	→ / ↗	→	→	→	→
+ Fillers	↘	↘	→ / ↗	↘	↘	↘	↗

Trends: → No change, ↘ / ↗ Deterioration, ↘ / ↗ Improvement

Filler types

Practically any material that can resist the sintering temperature of PTFE can be used as a filler. Characteristics such as particle shape and size and the chemical composition of the filler greatly affect the properties of the compound. All fillers used in Dyneon PTFE Compounds or TFM Modified PTFE Compounds are carefully selected and, in many cases, are specially composed for the customer to give the best balance of properties. Below are the main features of the most commonly used fillers.

Filler	Typical filler content in % by weight	Effects of the filler	Limits of use / special characteristics
Pigments	0.5 - 2 %	· Functional dyeing	· Observe existing approvals for the pigment
Glass fibres	up to 25 %, maximum 40 %	· Good resistance to abrasion of the compound · Strong abrasion of the sliding partner · Well suited for lubricated applications – also frequently used in connection with graphite or molybdenum disulphide · Good chemical resistance in acids · Significant reduction of the cold flow	· Increased permeation, channelling along fibres · Grey discolouration in the centre of thicker profiles · If necessary Dyneon can also offer a grey-core-free, 'white' variant
Soft coal (E-coal)	Standard up to 25 %; if required up to 33 %	· Good cold flow reduction · Good resistance to abrasion · Good thermal conductivity · Electrically conductive from about 15 % · Excellent chemical resistance · Low tool wear when machining · Protects sliding partner, even without dry lubricants	· Not stable towards oxidising media · Makes material brittle
Hard coal (coke)	Up to 35 %	· Excellent resistance to abrasion, 'continuous runner', used for piston rings · Abrasive to sliding partner	· Requires abrasion-resistant materials as sliding partner
Graphite	Up to 5 % or up to +20 %	· Inexpensive dry lubricant · Usually used as secondary filler in concentrations up to 5 % · Low coefficient of friction · Used in concentrations of 20 % for good thermal conductivity · Good chemical resistance · High thermal resistance	· Not stable towards oxidising media · High concentration if good thermal conductivity is demanded
Carbon fibres	Up to 15 %	· Excellent resistance to abrasion · Protects the sliding partner · Resistant to hydrofluoric acid · Good thermal conductivity · Good in water applications, e.g. water pumps · Reduced thermal coefficient of expansion · Very good chemical resistance · Good cold flow reduction	· Not stable towards oxidising media
Molybdenum disulphide, MoS_2	Up to 5 %, in combination with glass fibres up to 10 %	· Usually used as secondary filler = dry lubricant (glass fibres, hard coal, bronze) · Reduces coefficient of friction of compounds · Good chemical resistance	· Not resistant in oxidising acids · Starts to decompose at higher sintering temperatures
Bronze	Up to 60 %	· High resistance to abrasion · Good under high pressure (hydraulics) · Good thermal conductivity · Good resistance to abrasion · Excellent cold flow characteristics → hydraulics applications · Also used in combination with MoS_2 · Pigments act as lubricant	· Low chemical resistance · No approvals possible for foodstuffs, etc. · Discolouration during sintering · Short shelf life of the compounds · Not suitable for electrical applications
Stainless steel, V2A	Up to 60 %	· Very good chemical resistance · Good thermal conductivity · Significant reduction of the cold flow	· Observe abrasiveness
High-performance polymer (PEEK, PI, aromatic polyesters, PPS, $PPSO_2$)	Up to 20 %, possibly higher in combination with other fillers	· Excellent resistance to abrasion · Protects the sliding partner · Reduces cold flow at the same time · Good chemical resistance · Also suitable for aluminium sliding partners · Non-abrasive · Use of an additional pigment is recommended	· Starts to decompose with degassing under sintering conditions · Fillers with polar groups (e.g. PEEK) are critical in water applications · FDA conformity only conditionally available

Product properties

Wear & friction behaviour

The tribological properties of PTFE Compounds are influenced by:

- Chosen filler type and morphology
- Percentage of filler
- Load
- Velocity of movement
- Material and surface roughness of the counterpart

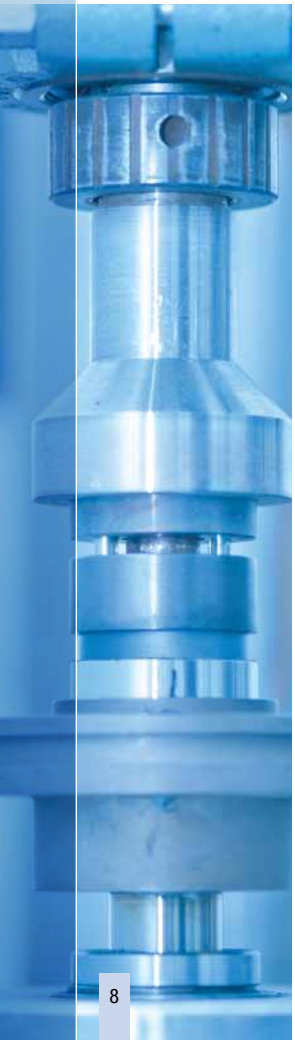
Regardless what your counterpart surface will be, the right filler will create the matching surface. From soft to hard and from clean and smooth to rough and abrasive.

Deformation under load

The addition of a small amount of certain fillers reduces deformation under load. Carbon is one of the most effective in this respect.

When considering thermal stability, the maximum temperature for continuous use of 3M™ Dyneon™ PTFE Compounds is 260 °C. Mechanical load bearing capacity declines with increasing temperature. The 2 parameters tested in deformation under load are:

1. Deformation (after 100 h under load)
   ↳ user-selectable temperature
2. Permanent deformation (Test according to 1. and measurement after 24 h relaxation time without load at room temperature)



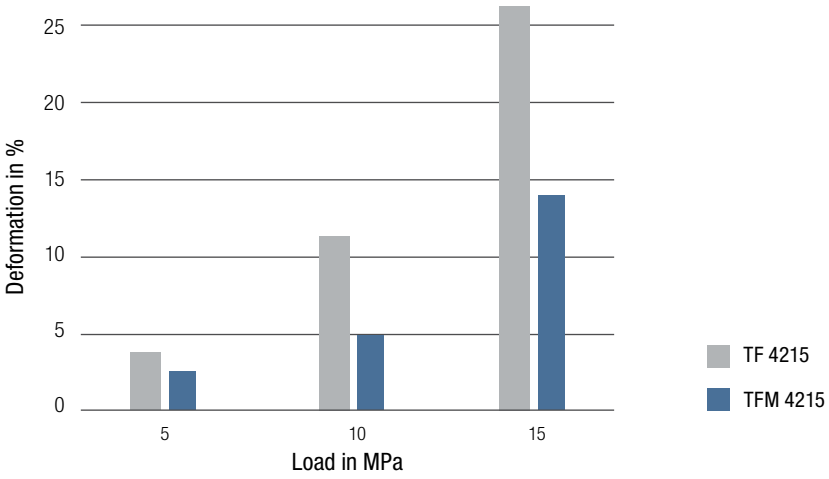


Fig. 1: Deformation after 100 h @ 100 °C

Wear

In the following graphs the wear behavior of several PTFE Compounds is illustrated. All PTFE Compounds are tested at 0.5 m/s and 0.7 MPa.

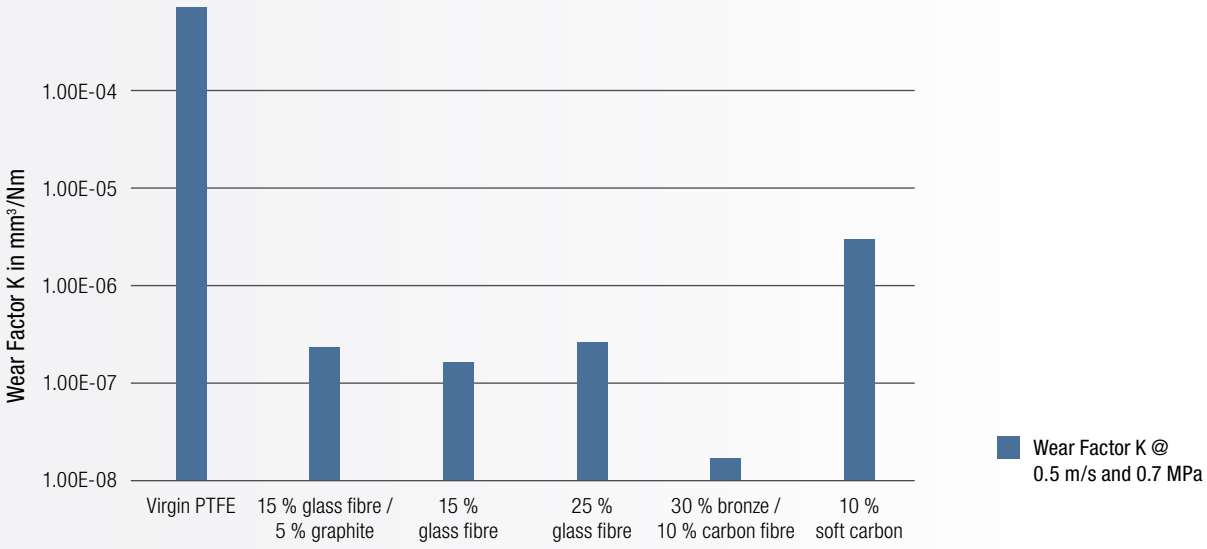
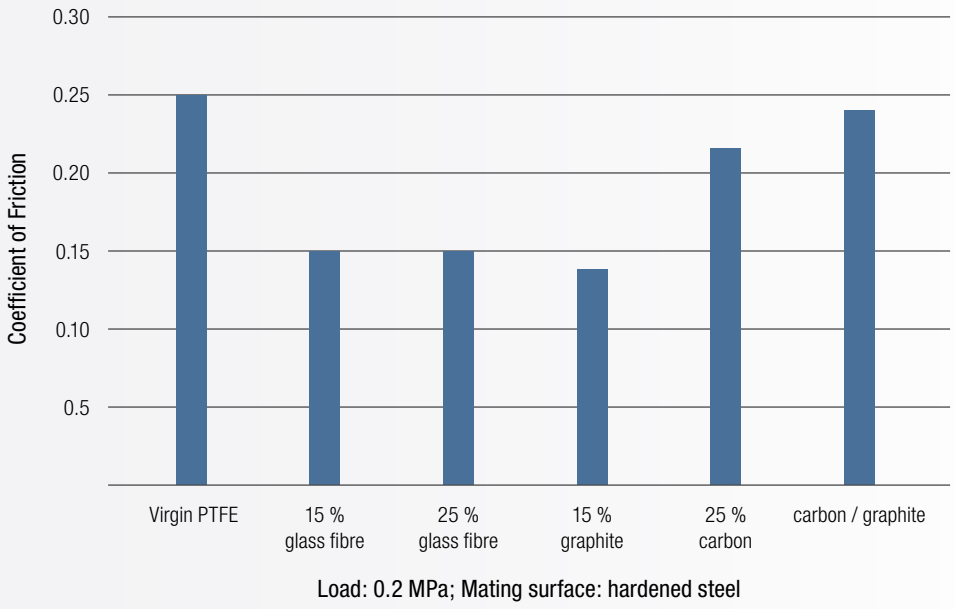


Fig. 2: Wear Factor K Dyneon PTFE compounds

Coefficient of friction

The coefficient of friction (f) is the feature which will be least affected by fillers. The lowest values of f are attained with compounds containing graphite or MoS_2 alone or in a combination with glass fiber whereby the percentage of such filler used also affects the f. For all other fillers, f is about the same.



Load: 0.2 MPa; Mating surface: hardened steel

Fig. 3: Coefficient of Friction of Dyneon PTFE Compounds at 0.5 m/s

Thermal expansion

The linear coefficient of thermal expansion (a) can be higher across the moulding direction than in cross direction. This is due to the orientation of filler particles during the moulding process and a tendency to resume their original positions at higher temperatures. Furthermore, finer grades of fillers, eg carbon, restrain thermal expansion more than particles of coarser materials such as graphite or glass. The linear coefficient of thermal expansion is not constant within the temperature range 30 - 300 °C. The value for the range 30 - 300 °C is double that for 30 - 100 °C .

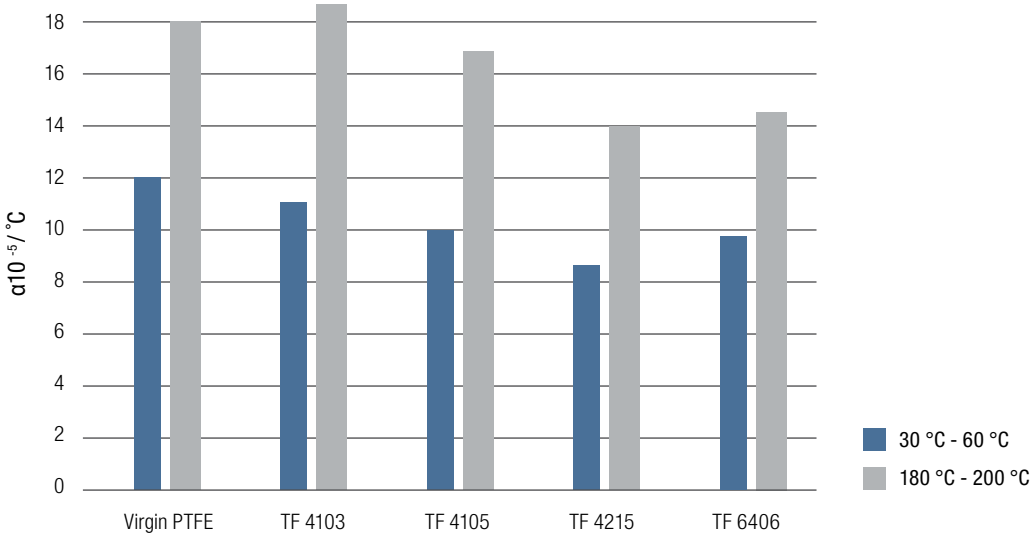


Fig. 4: Linear coefficient of thermal expansion

Thermal conductivity

Unfilled PTFE has a low thermal conductivity, adding fillers can increase this property significantly. This is particularly important in bearing applications, were the maximum load a bearing can carry is determined by the rate at which heat developed through friction can be dissipated. Graphite is most effective for raising thermal conductivity. The thermal conductivity of a number of 3M™ Dyneon™ PTFE Compounds is shown in Fig. 5.

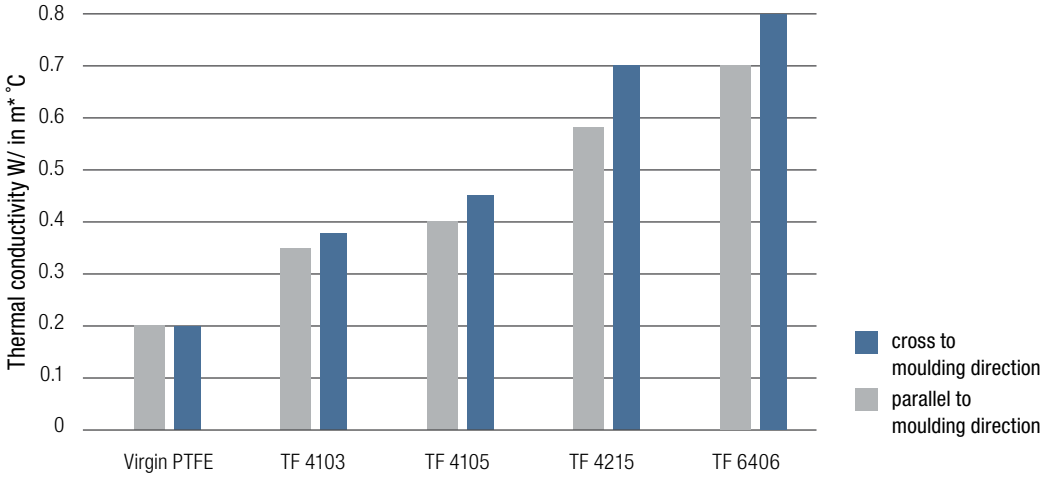


Fig. 5: Thermal conductivity

Bulk density

3M™ Dyneon™ PTFE Compounds and 3M™ Dyneon™ TFM™ Modified PTFE Compounds provide excellent bulk density in order to perfectly fill the moulds, create higher moulds, and improve the overall yield. As a result the sinter and pressing process is economically improved and can lead to overall cost benefits in the process.

Flow

The choice of standard compounds to be used with continuous production machinery should be restricted to powders from the 4xxx and 6xxx series which have very good flow properties.

Flow worsens with increasing temperature, so that processing temperatures above 30 °C should be avoided.

Specific gravity

The following parameters can influence density:

- Moulding pressure
- Sintering process
- Sinter cycle

Tensile strength and elongation

These parameters are, like the specific gravity, related to the chosen processing method. The tensile strength and elongation for the non-free-flowing grades is about 20 % higher than the free-flowing counterparts.

Technical Information and Test Data

Technical information and guidance provided by Dyneon personnel is based upon data and testing which is believed to be reliable. Such advice is intended for use by persons with appropriate technical understanding, knowledge and skills relating to PTFE Compounds. No license under any Dyneon or third party intellectual rights is granted or implied by virtue of this information.

General recommendations on health and safety in processing, on work hygiene and on measures to be taken in the event of accident are detailed in our material safety data sheets.

You will find further notes on the safe handling of fluoropolymers in the brochure "Guide for the safe handling of Fluoropolymers Resins" by PlasticsEurope, Box 3, B-1160 Brussels, Tel. +32 (2) 676 17 32.

The present edition replaces all previous versions. Please make sure and inquire if in doubt whether you have the latest edition.

Important Notice

All information set forth herein is based on our present state of knowledge and is intended to provide general notes regarding products and their uses. It should not therefore be construed as a guarantee of specific properties of the products described or their suitability for a particular application. Because conditions of product use are outside Dyneon's control and vary widely, user must evaluate and determine whether a Dyneon product will be suitable for user's intended application before using it. The quality of our products is warranted under our General Terms and Conditions of Sale as now are or hereafter may be in force.

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