Innovative clutch facing materials –

Cool facings for hot applications!

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Introduction

More powerful engines, longer ratios and new lifetime specifications have led to the development and introduction of more complex clutch designs. Along with other important components, the facing is the heart of the clutch. Looking back at the history of the clutch facing, it becomes apparent that the technological advancement of the clutch has had very little impact on clutch facing technology. LuK has begun to tap this potential.

History of the clutch facing

The very first cars used the first dry-running clutch. Facings made from beech and oak wood served as friction material. The invention of phenolic resin at the beginning of the 20th century laid the cornerstone for the facing technology customary today. Quickly, the advantages of phenolic resin became apparent and were put into use as a binding agent in brake linings and clutch facings. For the first time, components of any shape could be made of an easily formable material, which – after appropriate hardening – remained hard even under intense heat.

Figure 1 Friction coefficient test up to 470°C from 1940

Clutch facings as we know them today have been manufactured since around 1930. Already in the 1930s, comprehensive material tests were performed on clutch facings on inertia test rigs beyond 400°C. Fully synthetic polymers with excellent final properties that can be processed efficiently are still the basis of the clutch facing today.

As in many other cases, when conventional technologies reach their limits, new approaches need to be found to surpass these limits. The following presentation shows the requirement profile, the limits of the current state of the art, and provides a glimpse into the future of the clutch facing.

Clutch facing requirements

Temperature stability and operational robustness

Current complex clutch designs allow for a clutch to last for the entire service life of a vehicle. For this to actually happen, the facing must handle all high-load situations without significant loss of lifetime.

The facing must survive occasional severe events, while affecting friction properties, structural integrity and remaining lifetime as little as possible. The higher the temperature robustness, the greater is the operational robustness of the facing. At the same time, more powerful engines with only insignificantly changed installation space conditions increase the power density for the facings.

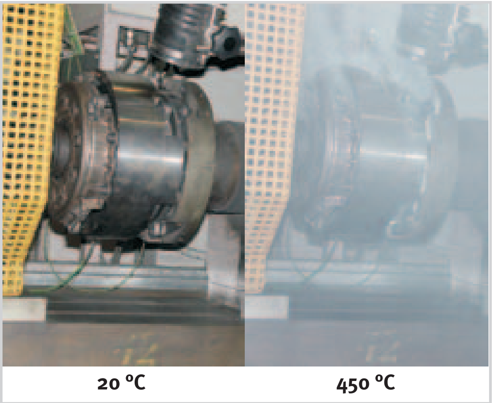

Figure 2 Destruction of the facing material under the influence of heat

The current technology for dry-running clutches is a facing made of an organic base material, a duroplastic/elastomer compound with a chemical structure that changes significantly above 320 °C and completely decomposes above 450 °C. This means that the wear curve of a facing is a function of temperature and increases exponentially with temperature.

Lifetime

The wear behavior of the facing is highly dependent on the temperature level, which varies greatly during vehicle operation, the friction power and the specific unit pressure.

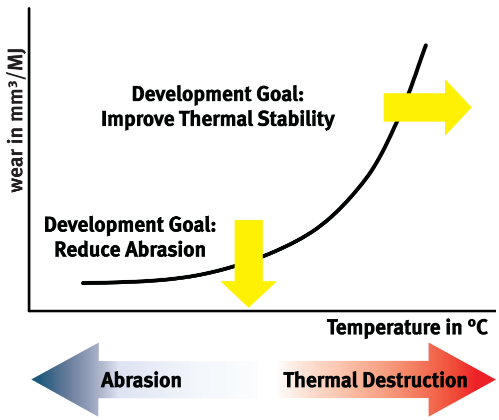

Figure 3 Facing wear as a function of temperature

An overwhelming proportion of the distance driven is covered at temperatures around or below 100 °C, while peak loads can exceed 400 °C. The wear rates then increase exponentially. A good facing has a low wear rate in a broad time-weighted spectrum of the different temperatures (Figure 3).

High clamp loads for average clutch sizes lead to clutches with higher power density, which lead to a high specific facing unit pressure.

When friction power is high, the friction surface temperature quickly increases to values high enough to damage the base material and the coefficient of friction drops quickly. The slow heat conductivity of the facing causes initially only the surface to be damaged, provided the heat generation is interrupted on time.

Comfort

In principle, facings can only be used if they contribute to damping the power train vibrations through their friction coefficient over slip speed gradient and thus prevent judder. In the past, judder was one of the biggest clutch-related quality problems. Judder is noticed when the first natural frequency of the drive train is excited so much that the longitudinal vibration of the vehicle can be felt. Even so-called unsusceptible vehicles with above average power train damping are prone to judder in some areas of the wide usage spectrum.

Structural integrity

In practice, facings are exposed to a wide spectrum of centrifugal forces and temperatures. For a clutch to be able to function under all circumstances, the facing must have a high structural integrity. High-revving engines and wide ratio transmissions lead to challenging burst speed requirements.

The burst speed requirements and thus the tensile strength of the facing material is an important criterion for the clutch facing require-

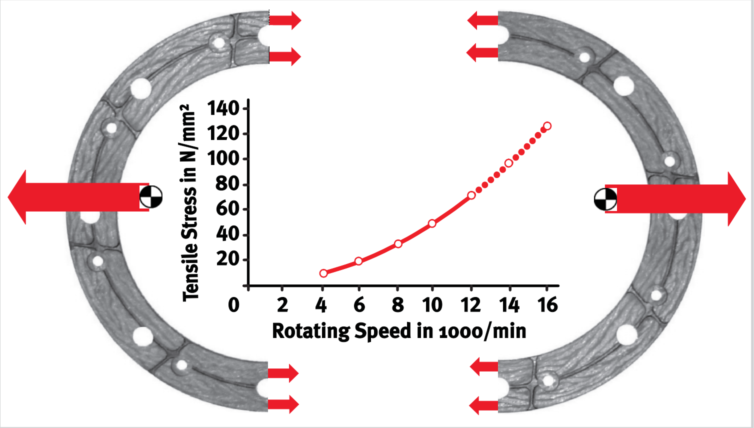

Figure 4 Requirements of the centrifugal force influence on the material compound strength

ments. The burst speed must significantly exceed the maximum engine speed because inadvertent mis-shifts, in connection with capable transmission, lead to very high clutch disc speeds.

Occasional high temperatures can significantly reduce the facing strength permanently. Therefore, state of the art facings must exhibit high material strength even after taking the facing to its thermal limit.

Coefficient of friction

The clamp load and coefficient of friction determine the torque in the clutch. The higher the coefficient of friction, the lower are the forces needed in the clutch, and in the actuation system. The goal in facing development is thus to achieve the highest possible coefficient of friction while all other facing properties remain acceptable. Theoretically, levels between 0.1 (slide friction) and 1.0 (tyres) are possible. When the whole temperature range and all of the facing properties are considered together, a lower boundary limit of 0.2 is achievable. It is, however, important to maintain a constant coefficient of friction.

Installation space and weight

The total wear reserve of the facings consists only of a few millimetres and thus makes up only approximately one-third of the facing thickness. The majority of the facing thickness is needed for mounting the facings.

Good transmission shiftability requires a low inertia from the clutch disc and thus the facings. The goal is to keep the volume and specific weight of the facings as low as possible.

Cost

When considering large production series, there are two drivers that determine the cost of the facing: material expense and processing expense. On a more detailed level, however, there are two additional cost drivers to be taken into account: design effort for the clutch and the warranty costs, which both are influenced significantly by the facing properties.

Conflicting goals for facing development

Organic friction facings represent a satisfactory compromise of the required properties. A compromise, because some tribological and structural facing properties are diametrically opposing. In addition, there are interactions between all facing properties. That means that when one property is optimised, all of the others change with it.

The macroscopic properties of a facing are the result of the interaction of its material contents. A clutch facing recipe contains up to 25 different raw materials. The many raw materials create a complex multi-component system with even more interactions.

The large number of raw materials and the amount of possible interactions leads to extensive testing and requires to work systematically.

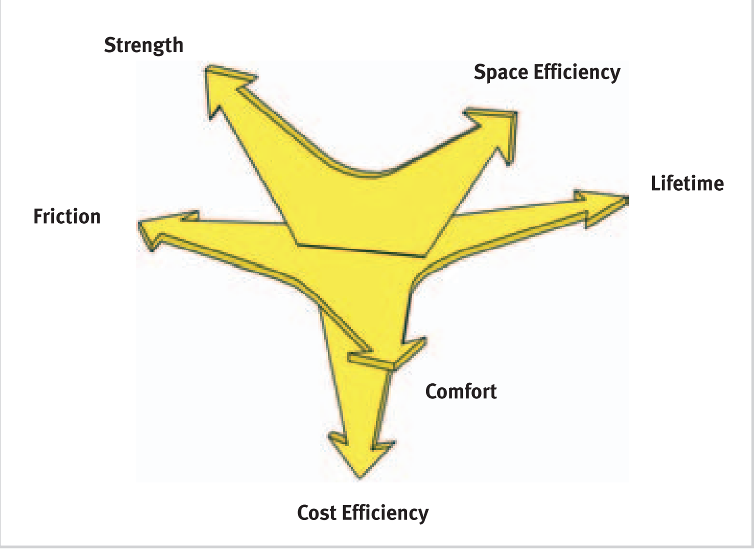

Figure 5 Conflicting goals in facing development

Actual facing solutions

Base technology-woven facings

Apart from meeting certain basic requirements, cost is of primary concern for normal applications. State of the art Fare facings made from a woven composite of resin-impregnated yarn.

The development goal is to find a balanced compromise of all facing requirements.

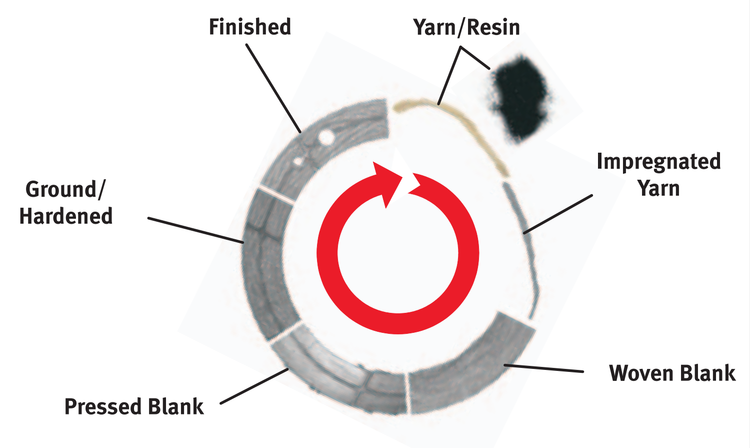

Figure 6 Production cycle of a wound-type facing

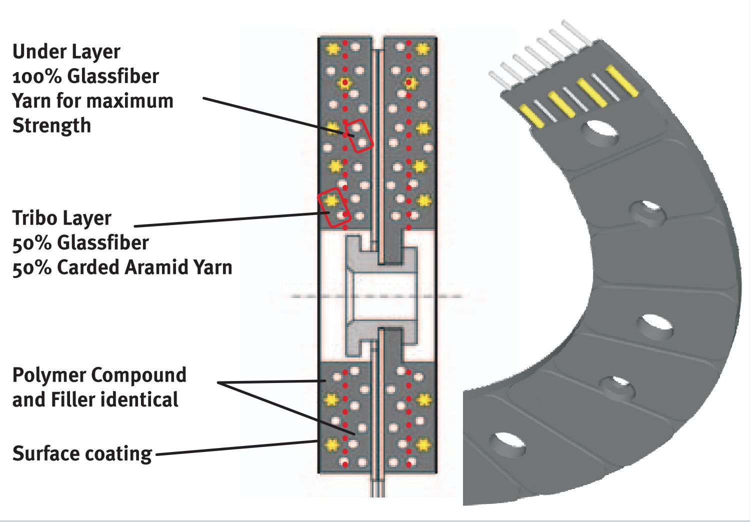

Figure 7 Structure of the LuK C3002 facing as a wound-type facing in two layers

Woven facing with functional division

The result of the facing development is a balanced compromise of all of the facing's technical properties. In order to achieve a larger degree of freedom in the development of clutch facings, a facing with two functional areas can be conceived.

The base layer of the facing serves as the basis for structural integrity and strength and is optimised in this regard. The friction layer of the facing can be tribologically optimised for long lifetime and coefficient of friction performance. A thin surface coating ensures a high initial coefficient of friction and alleviates the need for break-in.

Strength and wear behaviour are influenced overwhelmingly by the types of fibres used. Both layers differ with regard to the types of yarn and carrying fibre structures, whereas the same bonding agent with the same fillers is used. Material flow of the agent between the layers improves the bond between the layers.

The material C3002 achieves with this multi-layer technology a high degree of strength, even after continuous high thermal load, while also having very good tribological properties.

Dry powder mix facing with functional division

The idea of dividing the clutch facing into different functional areas was first launched with LuK's dry powder mix facing RCF-1. This facing has been produced by LuK for many years and is a proven technology in millions of vehicles.

The dry mix organically bonded clutch facing has the same chemical structure as the woven clutch facing. There are two principle differences. The reinforcing fibres are random-oriented in the facing instead of being incorporated straight in the form of yarns. In addition, the duroplast-elastomer compound consists of a powder mix instead of a liquid solution. A steel plate in the facing ensures structural integrity and strength.

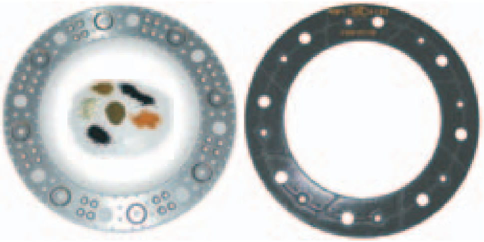

Figure 8 Structure of the LuK RCF-1 facing with steel retainers

Slim Disc concept

The high power density, particularly for the east-west power train applications, requires clutches with compact dimensions and high thermal capacity. In many cases, the thickness of the pressure plate represents a compromise between the necessary thermal capacity and available space. Thinner clutch discs and thus facings contribute to a sturdier clutch due to thicker pressure plates.

The development of LuK's "Slim Disc" design takes these requirements into consideration. "Slim Disc" combines the steel plate reinforced mass-pressed facing technology developed by LuK with a new type of mounting concept. The facings hold their parallel shape through the entire temperature spectrum. This is achieved by tabs between the sides of the facing pad retainers.

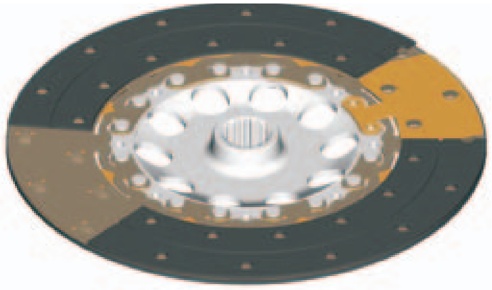

Figure 9 Slim disc design with inside radially mounted facing rivets

With the same wear allowance, approximately 2 mm of installation space can be gained. As a result, thicker pressure plates and flywheels, thus increased thermal capacity, are possible, which contributes significantly to a more robust clutch.

High temperature concept Slim Disc HPF

With the development of the new HPF (High Performance Facing) material system based on a special temperature-resistant Duroplast and the previously described disc design, LuK has succeeded in creating a clutch disc that functions reliably at high temperatures while still fulfilling all other facing requirements.

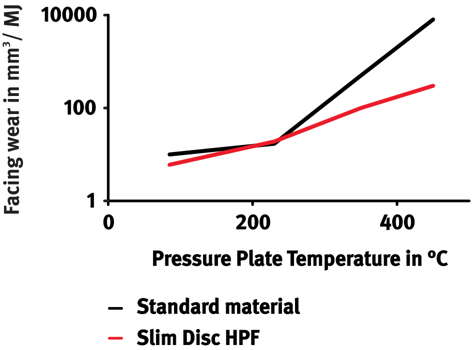

Figure 10 Advantage of the new high-temperature HPF material

The brittleness and the process technology favours producing the facing material in the form of facing pads. As with the Slim Disc design, dimensional stability at high temperatures is achieved using a tab connection and the pads are mounted radially on the inside of the clutch disc.

In addition to a clutch that is thermally optimised by a pressure plate with higher thermal capacity, the HPF concept allows for much higher temperature levels on the friction surfaces and in the ambient. The clutch facing material is no longer the thermally limiting factor.

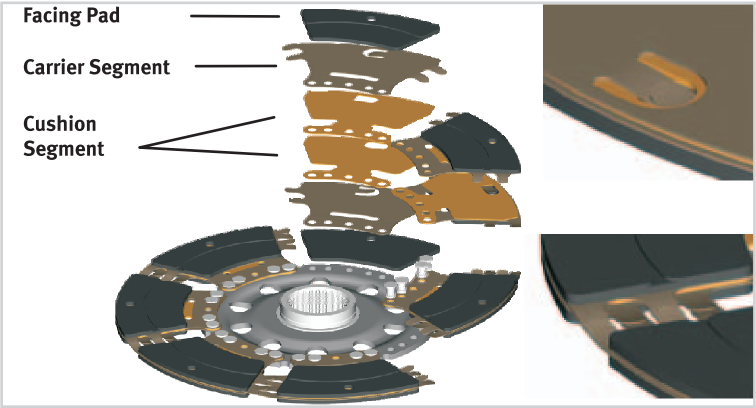

Figure 11 Structure of the Slim Face HPF high-temperature concept

Other facing materials

Cerametallic materials

Cerametallic materials are used in tractors and heavy construction machinery and if outstanding temperature resistance and high friction coefficients are desired. Serious weaknesses in launch behaviour and opposing material wear limit its applications.

Carbon fibre compounds

Carbon fibre compounds exhibit a very interesting property. The friction coefficient increases over temperature, particularly above 300 °C. The cost situation and the wear behaviour against conventional materials are, however, problematic. Therefore, carbon fibre compounds are only used in aeronautic and racing applications.

Ceramic materials

Ceramic materials based on silicates, carbides or oxides are still in the experimental stage. Ceramic materials are so far used primarily as replacements for cast iron as friction surface, while the wearing friction element still remains an organic material compound. Interesting new applications using inorganic friction elements still show too much abrasive wear.

Summary

LuK can offer a broad range of facing technologies, from the widely used base technology to very economical new solutions to high-end solutions for very demanding applications. LuK can provide a tailor made facing technology for every vehicle application.

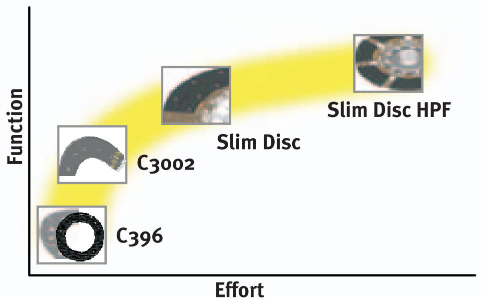

Figure 12 Product range of LuK clutch facings

Outlook

The development of clutches and facings has become more closely interconnected and the interdisciplinary cooperation of chemical and mechanical engineers has created new solutions with concrete potential for mass-production.

More concrete ideas are in early development stages and are bound to lead to further technically and economically interesting clutch facing alternatives.