Brake Lining

The products

The products of this application are in general friction materials. These include brake pads and brake linings for automotives and trucks (see Figure 1), heavy duty high temperature brakes (e.g. trains, race cars) and friction parts for industrial equipment. Often, the term brake lining includes all the diverse products mentioned. Brake linings can be classified into 4 classes (Table 1). One of the basic differences for classification is service temperature; organic friction materials typically operate up to 350-400 ^{o}C (continuous temperature) with short term temperatures as high as 700 ^{o}C while ceramic friction materials can withstand temperatures above 1000 ^{o}C.

Figure 1: Brake pads (left) and brake linings (right)

Table 1: Classification of brake lining materials

Classification	Ingredients
Non-metallic (or Organic)	Mineral powders and fibers bonded into a composite by an organic resin
Semi-metallic	As above but mixed at some proportion with flaked metals
Metallic, Ceramic	Predominantly consist of metal fibers, metal oxide ceramics and carbon bound by sintering or carbide formation

Organic linings are the most common. These are a complex mixture of numerous ingredients that generally fall into 4 categories (see Table 2).

Table 2: Typical ingredients in an organic lining

Ingredient type	Ingredients
Friction modifiers/abrasives	Steel fibers, aluminium oxide, zinc oxide, iron oxide, magnesium oxide
Lubricants	Copper flakes, graphite, pet-coke, antimony sulfate
Fillers	Recycled rubber, rockwool, cellulose, PAN fibers, Aramid fibers, barite, calcium carbonate, kaoline, talc, vermiculite
Binders	Nitrile rubber (NBR), phenolic resin (solid)

The phenolic resin used is typically of the novolac (or novolak) type although resol type resins are also used.

Production

Organic friction materials can be produced by either the dry (solid resin) or wet (resin in solvent) process. The dry process is the most popular, mainly due to health issues related to the wet process. The dry process consists of the following steps:

1. Raw materials are weighed and mixed.
2. The mixture is then pre-molded at room temperature into a friction material pre-form.
3. Next, an adhesive coated steel backing plate is put into a mold cavity followed by the pre-form. The mold cavity containing pre-form and backing plate is then pressed under heat and pressure. Molding time is generally 3–10 min depending on the thickness of the pre-form. Molding temperature is generally 130–180 ^{o}C. While molding, several "bump" steps are included in the mold cycle in which the press opens for a few seconds to release gas (mainly water and ammonia).
4. In most applications, friction materials are not completely cured and the gas is not completely released after the molding process is finished. Therefore, post-curing in an open bake oven is required. Generally, the post-curing temperature is 180–220 ^{o}C and the time required is 1–6 h for a dimensionally stable part. After the post-curing process, polishing and scorching is done and finished products are obtained.

One of the basic targets of the molding procedure (under high temperature) mentioned above is to a) melt the phenolic resin binder which flows under pressure and is homogeneously mixed with the other ingredients and b) keep it under high temperature until it is adequately "crosslinked" and solidified (thermosetting). Novolac powder resins do not self-crosslink at high temperatures and therefore they usually come pre-mixed with hexamethyl tetramine (HMTA, hexamine or "hexa") which is a crosslinking agent that functions at high temperatures (emitting ammonia as a by-product). On the other hand, resols spontaneously crosslink even at room temperatures (with or without hardening agents) but their disadvantage is low shelf-life (i.e. 6 months).

The role of MgO

Magnesium oxide is typically added in the formulations at around 2-5 % (note however that special ceramic formulations can contain up to 50%) to adjust the friction coefficient at desirable values in brake pads and brake linings.

Moreover, its intermediate hardness imparts sufficiently low wear on metal while adequately conducting heat from the friction contact surfaces.

MgO can also increase the thermal stability of the phenolic resin (possibly via the hardening effect) and the fade resistance of the friction material and suppress low frequency noise during braking. Fade resistance is a measurable property and is basically the ability of the lining to suffer controlled drops in its friction coefficient at high temperatures.

Finally, due to its high refractoriness, it can help impart high life and maintain frictional grip in demanding high braking temperature friction applications.

Note that the hardening effect of MgO in phenolic resins is mentioned for both novolacs and resols, although it is typically associated with the latter.

MgO Requirements

Friction material formulating is very particular to each customer and is more a craft than science, being the result of pain-staking trial and errors until the product meets standardized requirements. Magnesium oxide may or may not be used, depending on the formulation.

88-95% natural caustic calcined, dead burned or even fused magnesia products are used, depending on the specific application and the particular friction material composition. CCM products are the most often encountered. It is certainly not a high-end magnesia application and Chinese CCMs can in principle be used. However, there exist quality and consistency requirements that are difficult to guarantee with Chinese grades. Chinese (VMC/Possehl) and GM grades are being successfully used in the market.

The two most critical CCM properties are tamped density (in g/L or ml/g) and moisture content and all users have specific requirements. High moisture levels (and in some cases LOI) lead to increased gas emissions during curing whereas powder density affects the specific consumption of MgO in the formulation and the % void volume of the lining. Friction material ingredients are loaded on a % volume basis, since a product with specific dimensions is produced. Moreover, the packing ability of the powders will affect the “compactness” of the lining. Note that requirements on tamped density will restrict the particle size distribution and reactivity of the material. -63, -75 or -100 μm powders are used, whereas the reactivity is in the low to medium range. Ceramic friction materials may have coarser PSD requirements.

Added requirements for DBMs are bulk density which is directly related to crystal size and porosity. Added benefits for DBM or EFM use could be high resilience during extreme (high temperature) braking conditions with minimum drum and disk wear, high thermal conductivity.

Note: A very fine and pure natural CCM (#325) of high activity (80 m^2/g) was also encountered in the market. The user considers it a friction additive, in particular a soft abrasive that helps to reduce wear.

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