Is there a need to ‘brake’ with tradition…?
…exploring the valuable role of phenolic resins in the friction industry

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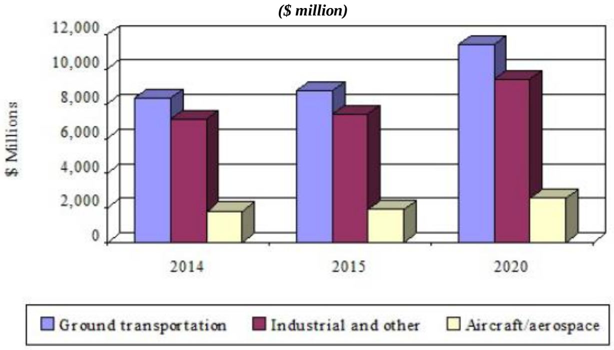
A society ‘on the move’

Although the need to stop vehicles has been present in society since the invention of the wheel, the growth of mass transportation and, in particular, the privately-owned motor car has transformed the demand for appropriate technologies during the second half of the nineteenth century and throughout the twentieth century.

The transfer of mechanical energy into heat energy has been the preferred method of halting vehicles throughout that period and the ‘friction industry’, as it has become known, has developed with the more general growth in demand for transportation. In 2015, the global market for friction products and materials was estimated to be $18.0 billion with the split between ground transportation, aircraft/aerospace and industrial/other being as follows:

Global Market Outlook for Friction Products and Materials by Application, 2014-2015 and projected for 2020



Source BCC Research

As the graph indicates, the use of friction materials has not only been limited to vehicles but has extended into a number of industrial and other applications where moving parts are present.

Additionally, while the slowing of vehicles and other moving components has been a major application, friction materials have been increasingly used as clutch materials in drive systems to convey power efficiently from one place to another. This has applied to all forms of machinery, whether stationary or mobile.

The graph also illustrates that the market has shown slow but steady growth in recent years and is set to do so in the period through to 2020. This is common for a market in which sales of friction products are split between new equipment (OEM) and the replacement market (after-market). In essence, for ground transportation, the amount of friction materials sold will depend more on the miles/kilometres driven than it will on the number of vehicles sold. Therefore, the key drivers to the sector are overall economic activity and the growth of the vehicle-owning public. We will return to this aspect later.

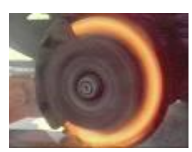
Phenolics - the right product at the right time

In order to produce appropriate friction materials, there is a need to have a material that creates friction and a component that holds the friction-generating materials in place. Typically, the friction-generating materials are fibres of some kind, with the fibre of choice varying with the latest technological or environmental developments. However, the binder of choice, has remained consistent from the first half of the twentieth century onwards. We therefore need to ask what it is about phenolic resins that has made their selection so automatic for so long.

The key requirement for any binder used in friction materials is that of heat resistance. This is seemingly obvious, bearing in mind that the purpose of a friction material is to translate kinetic energy into thermal energy. However, it is no less difficult to achieve as a result. The performance of phenolic resins in this regard arises from two complementary properties. These are:

- Generic heat resistance up to 250^{0}C and beyond
- Carbon formation at the surface to protect against degradation at even higher temperatures

Accordingly, phenolic materials can withstand operating



conditions which would seem totally unrealistic for most other organic materials. As can be seen from these pictures, it is not uncommon for brake discs to reach temperatures at which they glow. Even at these extreme temperatures, friction materials are expected to perform efficiently and not deteriorate. Any such loss of performance (often described as ‘fade’) would make the product unfit for purpose and result in the use of alternatives…if they could be found!

The emergence of phenolic resins in the early part of the twentieth century was one of those fortunate coincidences that are often needed to power major societal change, such as the economic growth and development that were such an integral part of the twentieth century. Without phenolics, it is hard to predict what society would have achieved over the same period.

However, no such progress would have been possible had phenolic resins not found early acceptance. One of the keys to this acceptance was that phenolics were relatively inexpensive to produce. This is often the case where the polymer itself exhibits all of the required performance characteristics without the need for subsequent modification. To this day, the economic benefits offered by phenolic resins are a primary driver to the continued use of the material. Typically phenolic resin costs are less than 10% of the overall friction product cost-structure. Other, more 'exotic' materials with similar properties have since emerged, but have made few inroads into the market because of cost.

The frenzy over fibre

For over thirty years, the choice of fibre was as simple as the choice of binder. Asbestos, the naturally occurring fibre, had become an industry standard – being widely available, inexpensive and capable of excellent performance in all of the adverse conditions described in the previous paragraphs. In fact, no-one realised quite how unique asbestos was until emerging health and safety concerns in the 1960s challenged its continued use.

In order to respond to these well-founded concerns, the industry evaluated numerous alternatives. These fell into a number of sub-categories:

Mineral based fibres

- ceramic fibres
- glass fibres
- rock fibres

Non-asbestos organic fibres (NAOs)

- aramid fibres
- partially oxidized polyacrylonitrile (POA)

Metallic fibres

- copper fibres
- steel fibres

Despite much research, it proved very difficult to match the performance of asbestos and modifications to resins to promote adhesion were a necessary part of the solutions that made the replacement of asbestos possible. Even then, asbestos still remains the fibre of choice for a minority of applications where the health risks associated with the fibre are deemed to be properly managed.

The emergence of new technologies

As aircraft emerged as a key form of transportation through the twentieth century, they brought with them the requirement for high performance, lightweight braking units. In response to this and other demanding applications, a number of newer technologies have emerged. These include:

- Metal matrix composites
- Carbon-carbon composites

The latter of these is probably the most widespread, with uses ranging from Formula 1 racing cars to Airbus 380s. Although initial costs are substantially greater, proponents of carbon-carbon systems argue that life-cycle costs can be lower because of weight-savings and related fuel economy. However, the case for an aircraft is very different than that for a motor vehicle.

In addition to these high performance technologies, there is considerable work being carried out on systems to capture the kinetic energy of moving vehicles to generate electrical energy for electrically powered and hybrid vehicles. However, these systems tend to be additional to conventional brakes rather than replacements for them.

Is there a need to re-invent the wheel?

(or find new ways of stopping it!)

Whilst carbon-carbon technologies may become more affordable if economies of scale start to emerge, the technology seems some way away from the mass market currently served by traditional phenolic-based braking systems – the costs of which are likely to remain relatively stable over coming years. One scenario that might change this could arise if fuel prices increased sufficiently to make the weight-saving benefits cost-effective. However, even this would be more likely to influence disc choice than that of friction material.

Prospects for the future

Although the role of phenolic resins in this application has already matured, the growth of motor vehicle ownership in developing countries is expected to drive global demand for the coming decade. This is reflected in the predictions for growth of 5.3% CAGR to 2020 shown in the earlier graph.

The technological developments within the industry are likely to be limited to refinements of existing product ranges, with most of the evaluation and purchasing decisions continuing to take place within the automobile manufacturers themselves. This business model will continue to keep the phenolic resins industry on its toes for the foreseeable future.