2. PM Structural components

2.1 CRITICAL SIGNIFICANCE OF THE AUTOMOTIVE INDUSTRY

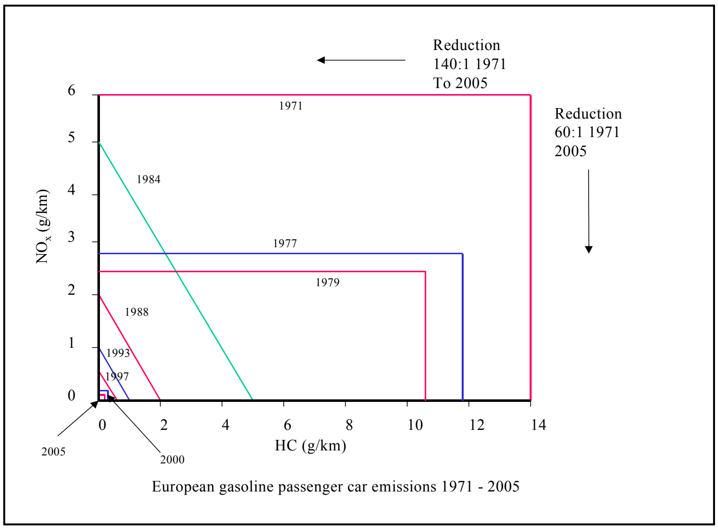
As 75-80 % of all PM components are used by the automotive industry, the future of that industry is obviously of paramount importance to any growth in the PM industry in the UK. It was therefore imperative in the investigation to determine the future direction of the automotive industry in order to suggest a future strategy for the PM in this country.

2.2 DOMINANT TRENDS IN THE AUTOMOTIVE INDUSTRY

It became evident very quickly in this exercise that, apart from vehicle cost factors, the future of the automotive industry anywhere will be driven by emission regulations. Legislation already exists in the USA and Europe which is aimed at a drastic reduction in vehicle emissions by 2005. Legislation is known as LEV/ULEV (low emission vehicle/ultra low emission vehicle) in the USA, and EU III/EU IV in Europe. Today passenger cars are responsible for about 15% of the emissions of CO_2 in the UK. This means that in 6000 miles, a car will have generated about its own weight in CO_2 It is difficult to reduce emission of CO_2 other than by reduction in engine size, and there has been very little change in CO_2 generation over the past 10 years. Fuel consumption has also changed little (even though engines are now much more efficient), due to the need to drive ancillary equipment such as power steering and air conditioning, and to carry added weight to meet crash safety regulations.

The control of NO_x and hydrocarbon emissions is somewhat easier to deal with than the emission of CO_2. Progressively, the emissions allowed have been, and are still being reduced, as shown in Figure 1. In 2005 the emission of NO_x will be 1/60th, and the HC emissions will be 1/140th, of that allowed in 1971.

Fig. 1 European gasoline passenger car emissions 1971-2005



From June 1999, the UK vehicle excise tax was reduced for engines under 1100 cc. It has also been announced that, in future, the vehicle excise tax will be based primarily on CO_2 emission, and that in 2002 cars provided for employees will be taxed on their CO_2 emissions. There is also a suggestion that from 2005 there will be a requirement for onboard monitoring of emissions.

It seems highly probable, stringent though the emission standards are, that the automotive industry will meet the emission requirement by introducing a variety of technologies, including engine design, exhaust gas management, and catalyst design.

It is therefore almost certain that the internal combustion engine will remain the dominant power source to the end of the period covered by this study (roughly the first decade of the new century), and beyond.

2.3 SPECIFIC RESPONSES TO THE CHALLENGES

There are many developments in hand in the automotive industry aimed at reducing both emissions and fuel consumption.
These include **variable valve timing** devices, some of which are already fitted to current models, and which will give improved control of residual gases and reduce NO_x and HC emissions.

Exhaust gas recirculation will be used to reduce peak combustion temperatures and hence the formation of .NO_x Reducing the mass of the catalyst system, and placing it as close to the engine as possible, will also ensure more rapid heating of the catalyst to activate the catalysis of the exhaust gases. Better engine control management systems will also ensure that the emission levels will be attained. The development of sulphur-free petrol will also allow more efficient NO_x catalysts to function properly.

Gasoline direct injection (GDI) has received substantial funding over recent years and has resulted in an increase in fuel efficiency of some 5%.

Direct injection diesel engines will increase as a percentage of all power units, due to their greater fuel efficiency and, again, low sulphur fuels will enable NO_x catalysts to reduce emissions to an acceptable level.

There is also a trend to use more **environmentally friendly fuels** such as LPG (liquid propane gas) and CNG (compressed natural gas), and there are a number of bi-fuel vehicles available in the UK and elsewhere. One of the basic problems is, of course, the provision of an infrastructure of filling depots to support such developments.

Weight reduction is of paramount importance in improving fuel economy and considerable effort is being directed towards the introduction of lightweight structures based on improved steels for lightweight panelling, plastic composite materials, and aluminium. The principal problem is that of cost. There is also public conception that a heavy, solidly built car will give better crash protection than a smaller, lighter car.

Automatic transmissions are not as popular in Europe as in the USA. In the UK about 11% of cars are fitted with it and this is not likely to increase substantially over the next few years. This compares with approximately 88% use in the USA. While the system in general decreases fuel efficiency, **modern automatic transmission designs** can actually improve fuel efficiency slightly. In addition, **continuously variable transmissions** (CVT) are replacing conventional automatic gearboxes for smaller engines. These are essentially belt driven devices in which the power delivered is restricted by the ability of the belt to transmit the required load. The advantage of the CVT is that the engine can be run continuously at its optimum efficiency and the power to the drive wheels is regulated by the CVT device.

As an alternative to the automatic and CVT devices, the Torotrak **infinitely variable transmission** is being developed. The device does not require belts and can be scaled up or down for any required application. The speed variation is accomplished by effectively altering gear ratios in a continuous manner using disc rollers running between an input disc and an output disc. It is claimed that by using this device, in conjunction with an engine management system that drives the IVT optimally, fuel economy of at least 17% can be achieved.

2.4 OTHER AUTOMOTIVE DESIGN TRENDS

There is a move from hydraulic actuation to electric actuation for several automotive devices. The fact that hydraulic power assisted steering can increase fuel consumption by up to 5% provides an incentive to replace such systems with **electric power assisted steering** (EPAS). This ensures that power is only used when necessary, in contrast to the hydraulic pump which is engine mounted and runs whenever the engine runs, regardless of where power assistance is required. The leading global manufacturer has predicted that all new passenger cars will be fitted with EPAS by 2006.

Following the same argument, **electrically actuated systems** are likely: electrically actuated braking means replacement of large sensor rings for ABS systems, and electric water pumps and electric throttle devices are others. Their introduction will depend on absolute cost and on safety considerations.

To cope with the increasing use of electrical devices, the current 12V system will be replaced by a **42V system**, in part to reduce the size of the copper wiring looms, and also to provide more electrical power for device actuation.

Aluminium cylinder heads will also have an increasing number of laser remelted in-situ valve seats to replace current separate valve seats inserts. This will improve heat transfer and allow a **redesign of the cylinder head** inlet and exhaust passages for better fuel efficiency.

2.5 ALTERNATIVE DRIVE CONCEPTS

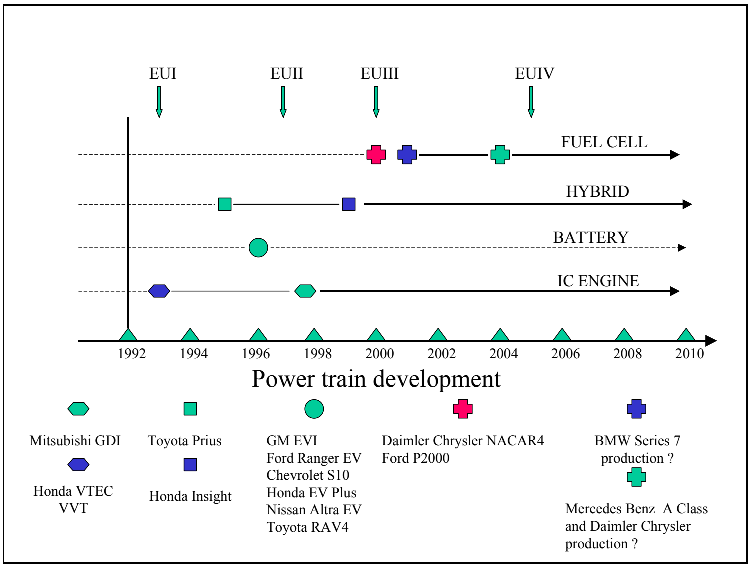
Despite the low emission targets set in the USA and in Europe up to 2005, there will be pressure to reduce emissions still further. In the USA, specific Californian legislation is in force to provide locally reduced emissions. In the UK there is already legislation in place that will allow local authorities to restrict emissions. This pressure has led to the introduction of ultra low emission vehicles, and zero emission vehicles.

An immediate answer to local emission control has been the development of hybrid vehicles. These have two power units, one an internal combustion engine and the other an electric motor. There is also a battery system to store electrical energy. An example is the new Honda Insight in which a small 1 litre internal combustion engine is run in conjunction with the electric motor. At speeds below 5 mph the engine shuts off to conserve fuel and reduce emission. Restarting the engine is simple and quick. Achieving about 60 mpg in city driving conditions and about 70 mpg outside, it qualifies as an ULEV in California.

It should be possible with a hybrid system, when in a restricted areas, to use the battery supply only and run with the electric motor, thus yielding zero emission. There are currently two hybrid cars available in the UK. They are expensive, due to their dual power source, but there will undoubtedly be more in the near future.

Zero emission battery powered vehicles are also available but remain limited in speed and range (typically less than 100 miles between charges). The cost of production is high, and in the USA such cars are leased with a heavy subsidy from the manufacturer. The development of all-battery vehicles depends critically on the development of high storage capacity, cheap, batteries. Although NiMH (nickel-metal hydride) batteries are being developed they are inherently expensive. An alternative zero emission strategy is the use of fuel cells to provide electricity to power an electric motor drive system. The fuel cell would be fuelled ideally by hydrogen and oxygen, producing only water as a waste product. Plastic membrane fuel cells are being developed which have reduced the size of the fuel cell unit to under-floor dimensions. They are still very expensive and require stored hydrogen for them to function. Even so, the three largest automotive companies in the USA have stated that they will have

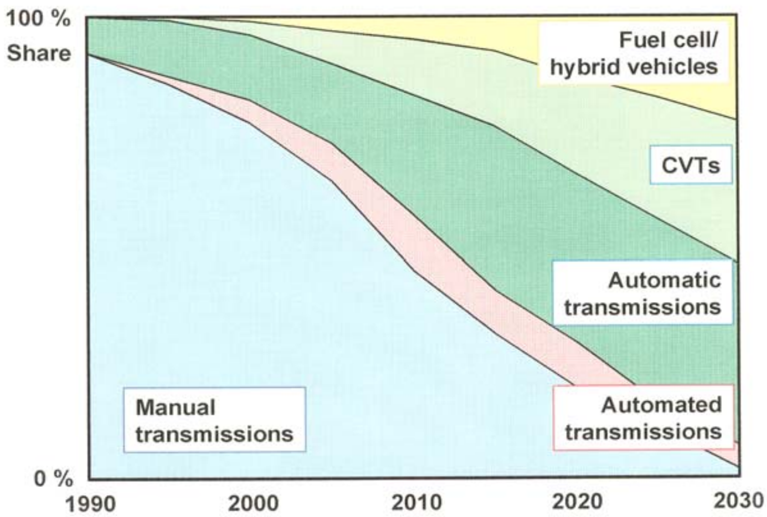
Fig. 2 Power system development and introduction of EC legislation



production-ready fuel cell powered vehicles by 2004. Alternative fuels, such as methanol are being developed which require a reformer on board to convert the methanol to hydrogen.

A DTI technical Mission to North America reported that in general the UK technological capability in hybrid and electric vehicle powertrain systems was equal to that of the USA. [5] Although major automotive companies are involved in the development of both electric and fuel cell vehicles it is unlikely that these will be a significant challenge to the internal combustion engine in the immediate future. Figure 2 shows a time line for the introduction of the different technologies set against the timing of European legislation. Introduction however does not mean public acceptance and volume production in all cases. Figure 3 is a view of the shift in transmission systems over a forty-year period.

Fig. 3 Passenger car transmission, a Western European scenario
(Courtesy ZF, Friedrichshafen, Germany: originally presented by Paul of ZF Saarbrücken GmbH at the CVT'99-Congress at Eindhoven University of Technology in the paper 'CVTs driving the future of transmission technology')



2.6 SIGNIFICANCE FOR THE PM INDUSTRY

The developments described will affect the demand for structural components, hard magnetic components, and soft magnetic components in very different ways. (The outlook for structural components is reviewed here. Magnetic materials are dealt with in Section 3.)

Some of the foreseeable changes in the automotive industry will actually provide opportunities for the PM industry. Variable valve timing devices will increase in application and the possibility of alternative automatic transmissions, such as Torotrak, could generate additional business.

The move to electrical actuation will eliminate some currently produced components, but these losses could be offset by the replacements needed for the electrically actuated systems.

As there are of the order of 120 different types of PM component, ranging from washers to camshafts, and with many variations within each type, the PM industry will continue to grow globally as components are introduced using current PM technology. The UK structural components industry could continue to expand, therefore, by natural growth, using current technology to manufacture all possible automotive components. The size of this expansion will depend on the ability of the UK companies to invest, and this must be limited by their ability to generate funds for investment, based against current returns on that investment, and, in the case of multinational companies, on their view of the relative attractions of possible manufacturing locations. From that viewpoint it seems improbable that the UK PM industry could grow significantly by internal investment by way of providing additional facilities for producing the current range of automotive PM components.

Significant growth in the UK can only be achieved through innovation and the provision of niche products to automotive clients. This will require targeted R&D in areas identified by the automotive industry as crucial to PM growth. The ability to produce components replacing several separate ones with varying properties (wear, toughness, corrosion resistance) will be important for success, as will be the provision of stronger, tribologically better components. A recent study by Höganäs[6] has shown that if PM components had the strength of forged material, the PM content in an automobile would rise from the predicted 7 kg maximum to 27 kg, a clear incentive to develop production processes for such components.

So the overall objectives of reducing costs, increasing speed of throughput, improving consistency of product, and ensuring a component with enhanced performance are the obvious imperatives for all UK PM companies.

2.7 PM STRUCTURAL COMPONENTS IN GENERAL

2.7.1 Research and development capability

Of the UK PM structural component companies, only one, US-owned, has significant R&D facilities in the UK. The major company of UK origin has relocated its R&D facilities to Germany and the USA. As a consequence, if R&D is to be carried out in the UK there is a need to identify sites where such activity can be carried out, either in an existing RTO or on an existing academic facility, such as the Near Net Shape Manufacturing Laboratory in Birmingham, or the Wolfson Centre for Bulk Powder Handling, Greenwich.

2.7.2 PM components their properties and costs

Phase 1 of this study established, and Phase 2 has confirmed, that the provision of high strength, cost effective structural components is critical to growth. This implies that increased density is important, and that PM processing demands improvement, especially in terms of powder handling and die filling. The implications are that the following are technologically important:

- density
- chemical composition
- powder characteristics for materials improvement and powder transport
- lubrication for process improvement, cost reduction and improved consistency.

2.7.3 The importance of higher density

A move to higher density components is probably one of the best ways of introducing innovation into PM structural components production. This could happen through materials advances or pressing technology development (including lubrication). Higher density would enable not only stronger but also more complex components to be produced, using green machining to improve complexity and reduce the need for secondary machining operations.

The first step would be to produce single-pressed and sintered connecting rods to replace sinter forged connecting rods. These would be followed by other, more demanding automotive applications. Alternative markets that would then be available, including pressure die-castings, lost wax castings, cold forgings, and machined components.

Improved density would provide components with higher added value; consequently the tooling costs would be recoverable over a smaller number of components. This would lead to the prospect of serving industries, other than the automotive, in which overall call-off of components is lower.

It must not be forgotten that there is always room for innovation in PM which is at present undefined. Such innovation will inevitably occur, and will be successfully exploited, provided that the overriding constraints of the market are appreciated.

2.8 SUMMARY OF THE UK POSITION

In summary the following are evident:

- The internal combustion engine will remain in production for a considerable time, at least beyond the scope of this survey, and hence structural components will still be required.
- Although the world market for structural components will continue to grow, it is unlikely that there will be further expansion of current facilities in the UK.
- As electrically actuated systems replace mechanical and hydraulic systems on passenger cars there will be a change in component types required, but not necessarily any overall change in volume.
- Higher strength components are required for market expansion.
- Industrial R&D in severely limited in scope in the UK, with the major PM company preferring to carry out its R&D overseas.
- It is necessary to identify where R&D could be carried out in the UK.
- Cost and consistency of product are vitally important.
- There is a lack of appreciation by designers of the merits of the PM process.

2.9 THE MAIN OPPORTUNITIES

The major opportunities for UK PM structural components companies are:

- Provide niche products with innovative technology, (especially high strength components).
- Collaborate for process improvement and to reduce processing costs.