Future trends in car design

Conference or Workshop Item

FUTURE TRENDS IN CAR DESIGN

Keith Martin MSc, C.Eng., M.I. Mech.E., MBIM, MSAE.

Senior Engineer, Aston Martin Lagonda (1975) Ltd

Paper first presented to British Association of Young Scientists Seminar at the National Motor Museum, 9th July, 1980. Subsequently presented as Dudley Coram memorial lecture at the Brighton Engineerium, 12th Sept. 1981. Reprinted in AM Quarterly Vol 19, No. 78, pp21-23.

I should like to begin by introducing myself and my work. I am by Profession a Chartered Engineer and work in the Engineering Department at Aston Martin Lagonda in Newport Pagnell, England. I was the Project Manager of the Aston Martin Bulldog, the full story of which is being serialised in the AMOC magazine. The Bulldog is a research and development prototype car which contains many detail features novel to automobile design which may be suitable for future production, but the car itself is not destined for production. Bulldog is discussed in more detail later.

Aston Martin currently employs about 360 people and our production volume is 210 cars per year. These are sold all over the world our largest markets being the UK, USA and Japan. The model range comprises the 2 door Aston Martin V8 and its derivatives the Vantage high performance version, and Volante convertible, and the 4 door luxury Lagonda. Our philosophy is to combine imaginative Engineering with traditional British craftsmanship. We are responsible for the design, build, testing and production of all our cars and most items on them, including the engine. I believe ours is the smallest Company in the world still producing its own engine. Being so small we are able to experiment with many new ideas and processes, and incorporate detailed modifications to our production cars much quicker than large volume manufacturers, but conversely we are unable to spend much time and money on fundamental research.

Our research is of necessity applied research, closely defined and planned using network analysis with an on-line computer terminal. Target dates and allocation of resources are of prime importance. This means that we cannot investigate open ended more esoteric projects such as alternative types of engine. My remarks on future trends on car design will therefore be based on my inside knowledge of the car industry, illustrating where appropriate the effect on Aston Martin. Later I shall illustrate some of the detail features of the Bulldog project indicating where we have broken new ground and where our ideas may have future potential for volume production.

I must also emphasise that when Engineers talk about design they mean a concept which may not be apparent to the layman. Engineering Design is “The use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform pre-specified functions with the maximum economy and efficiency.”

To put that in simple English "Is it strong enough, is it stiff enough, does it fit and can you make it?" However rude that may sound, I believe in Engineering terms it is a suitably succinct philosophy for the Engineering Designer, Design is lot more than the exterior shape or appearance which more correctly on its own should be called "Styling". Having digested that I hope no-one will expect predictions of fantastic new developments, totally new shapes, miracle batteries or engines that run on tap water.

I believe that the car as we know it today is a tremendous achievement of engineering design and development and that it is here to stay. No other form of transport has given such freedom and mobility to the everyman. I also believe that liquid hydrocarbon fuels represent the most convenient and efficient method of fuelling such transport, and illustrate what I mean in the following way:
A modern car battery will provide the same amount of useful work as half a cupful of petrol, even allowing for worse case efficiencies in the car.

In fact if one considers the whole energy picture from the extraction of crude oil to the car on the road including the energy used and lost in refining, generation of electric power, grid transmission losses etc, it soon becomes apparent that the most efficient use of the prime energy source, for a widespread universal transport system, is to manufacture petrol and burn it in engines. This applies even for the most advanced available batteries, and even if the prime energy source is coal instead of crude oil. Less coal is consumed when it is liquefied for use in an engine than when it is burned to generate electricity to provide power for equivalent transportation in an electric vehicle, even with the most advanced nickel/zinc batteries. Research is therefore being directed to obtain new sources of liquid fuels as cheap crude oil stocks become used up.

I believe that cars will continue to be powered by internal combustion engines fuelled by liquid hydrocarbon fuels but of course more emphasis will be given to improving efficiency and fuel consumption. New developments in materials and production processes to save time, weight and space enable designers to improve the utility and efficiency of mass produced cars. I think the new Fiat Panda and Mini-Metro are typical of this approach, and are very elegant pieces of engineering.

Most major manufacturers are also looking at radical new designs of engine such as the Stirling engine, high speed diesels, Rotary engines, Stratified charging, Lean burn and so on. Whilst all these engines have there own specific advantages none has yet shown to be better than the conventional piston engine in terms of specific power output, flexibility and versatility. Other manufacturers, including Aston Martin, continue to develop and refine the conventional piston engine. To illustrate our difficulties, however, a recent technical report from the Society of Motor Manufacturers recommended the adoption of the following features to improve fuel economy: aluminium cylinder heads, controlled turbulence and combustion, breakerless ignition systems, comprehensive tuning, efficient breathing, reduced internal friction, radial tyres, close wheel and suspension adjustment, improved cooling, and light alloy road wheels. This report was of little help to us as all these features have been standard on our cars for years.

Without doubt the biggest single input to the future design function is the need to comply with worldwide safety and environmental legislation. At present about half our total engineering budget is spent on meeting and keeping up with it all. This percentage is fairly typical of most companies and consideration has to be given constantly to the costs involved in producing a design that meets the legislated requirement, proposed requirements and the costs of actually demonstrating compliance to the appropriate authorities. As an example the USA manufacturers are busily downsizing their cars to meet the legislated future fuel consumption requirements. Their costs for re-tooling and re-investing for this add up to more than three times the entire cost of the Apollo moon landing programme.

The USA Government has mandated fuel consumption standards to be achieved year by year rising to a corporate average fuel economy for each manufacturer of 27.5 miles per US gallon by 1985. There is also a separate scale of taxes called the Gas Guzzler tax imposed on manufacturers who do not meet other targets. The net result of this is that in our case by 1985 we shall have to pay fines of nearly $5,000 on each car sold in the USA. Obviously the threat of this encourages us to research ways of reducing fuel consumption. In addition to the fuel consumption requirements there are all the exhaust emission requirements which have to be met with guaranteed durability for 50,000 miles. The specified limits of hydrocarbons, carbon monoxide and nitrogen oxides were recently becoming so low that in some areas in California car exhaust cases would be cleaner than the ambient air so that the car is acting like a mobile air purifier.

On the safety side the USA has proposed the fitting of passive restraints starting in September 1982. These are devices or systems designed to restrain occupants during an impact but which do not require any action by the occupant beforehand, i.e. they are passive and not active. The most common options are the so called "air bags" and automatic seat belts, or a mixture of the two. We have experimented with both systems and carried out dynamic testing on a Lagonda chassis. The air bag is designed to suddenly inflate in milliseconds after a frontal impact to absorb the occupant's kinetic energy by controlled deflation as he hits it a split second later. They are a good idea in principle but vast sums of money have to be spent to ensure that they will work reliably when required and not beforehand, and of course they are no good in a complex series of impacts, side impacts or rollover conditions. Passive belts are at least reliable but again impose great problems in mounting sufficiently strong anchorages in the correct positions which allow easy access and exit, and there is strong customer aversion to them. I feel it is a tragedy to have to spend such vast sums of money on passive restraints when it has been proven beyond all doubt that a correctly designed and adjusted seat belt is the most cost effective and efficient safety device ever invented for the car. I feel that more should be done to educate people of this fact rather than mandate manufacturers to provide cover for their folly.

It is not only the USA market that imposes legislative constraints on the car designer. The UK introduced the National Type Approval system for all passenger cars manufactured on or after 1st October 1977. This initially covered 19 different items on the car, 17 of which are international and 2 BSI standards. Since that time other standards have been added and some of the original ones tightened up. The standards include noise tests, emission tests structural strength tests for seats and seat belt anchorages, brake tests, visibility requirements and of course the big one - the crash test.

It takes anything up to a year to complete all the testing and paperwork to get approval for the UK and in the case of the Lagonda all our testing had to be carried out on our only available car. This car, our press demonstrator, was displayed on the Motor Show stand, used for 50,000 km durability driving and most of the Type Approval testing. It was also demonstrated in immaculate condition to the Duke of Edinburgh but a couple of weeks later ended its days by impacting a 100 ton concrete block at 30 mph.

Since there was neither the time, nor available Lagondas for development tests the official crash test was in fact the first and only test we did. In order to be reasonably certain of passing, therefore, various analytical techniques were employed to determine exactly where the energy would be absorbed, and to ensure that the components and structural members behaved in the way expected. The car industry is turning now to sophisticated computer aided design and finite element techniques to design efficient body and chassis structures. These techniques are not new to aircraft designers but unlike aircraft design car design has also to consider detailed analysis of modes of structural failure and collapse in an impact. During the design of the Lagonda an analysis was carried out by the Structural Design Group of Cranfield Institute of Technology with particular reference to demonstrating conformity with the USA requirements for roof crush resistance and side door strength.

To sum up my general views so far on the future of car design I should say that cars will continue to be freely available and will be powered by internal combustion engines fuelled by liquid hydrocarbon fuels. Much detailed design work will be done to reduce weight by the use of new materials and processes and by the use of computer aided design and stressing techniques. I do not foresee any dramatic new inventions or developments that will render the car as we know it obsolete, but I do foresee many interesting technical ideas and developments which when taken together will improve the car as much as would a single revolutionary new idea. I should like to go on now to discuss some of the individual ideas with particular reference to our research and development car, the Bulldog.

The first of these is turbo charging. Turbo chargers are not new they have been fitted to trucks and some racing cars for years. It is only recently that they have been used on road cars, partly because they require more controls and detailed installation matching to cope with the variety of load and speed conditions experienced by a private car. For those who are not familiar with turbo charging I shall briefly explain the principle of operation.

The turbocharger is just a centrifugal air compressor driven by a turbine which uses the energy of expanding exhaust gases. The compressor will boost the intake air pressure by something like 7 to 14 lbs/sq. in. Quite often a by-pass valve or wastegate is fitted to the exhaust which by-passes the turbine when the maximum level of intake boost is reached.

I believe turbochargers will become more standard in future as they are the most effective method of increasing the performance of an engine, or alternatively enabling smaller more economical engines to be used for a given power output. They also have the advantages of being socially acceptable by their use of waste energy and tendencies to smooth the power and noise characteristics of an engine. The Bulldog is fitted with twin turbochargers and wastegates and we have learnt and developed ideas related to their installation which could be applicable on our future production cars.

Wind tunnel testing. A bit of historical research will soon show there not much we could teach some of the pre-war engineers and stylists about drag coefficients. They were able to achieve with special vehicles drag coefficients below 0.3, and production cars 0.45. This compares very well with today's, the average saloon car drag coefficient now is no better than it was in 1938. Where advances have been made, however, are in lift and stability at speed and in transient cross winds. Drag is also receiving attention again now that fuel has become expensive. For example a vehicle with a typical cross sectional frontal area of 20 sq. ft may need 42 horsepower to overcome air resistance at 70 mph but a well designed aerodynamic shape might only need 10.

Aerodynamics is also important in the design of cooling and ventilating systems - for example a radiator size can be drastically reduced by paying attention to intake and exit air ducts, fan cowlings tec.

Adhesives. Tremendous progress has been made in adhesives in the past few years and I anticipate much more widespread use of all sorts of adhesives on the assembly line. They are much quicker and cheaper than traditional fixing methods. The leather trim in the Bulldog was bonded in position using a non flammable epoxy resin which was suitable for spray application. This is much more economical in time and material and is being considered for production use. The windows of the Bulldog were specially made for the car and imposed tremendous demands on the manufacturer to produce large curved areas free of distortion. Then came the problem of fitting them to the car. Traditional methods of fixing using rubber seals and finisher strips were ruled out owing to our desire to maintain a smooth and uncluttered exterior, particularly along the side of the car. It was decided to bond the glass into position using a new moisture curing polyurethane compound.

This is simple to use and offers phenomenal strength with a strain recovery rate of 500%. It was a little tricky aligning the glass by hand but of course on a production line this would not be a problem as special jigs and fixtures would be made. We were so impressed with this adhesive we began to think of it as an alternative for bonding all sorts of items on the car such as the rear spoiler and side trim strips.

Tyres. Tyres have changed tremendously over the years in terms of compounds, construction and shape. The tyre to road surface inter-action is very complex but it is well known that grip is dependent on contact patch area, and the growth in contact patch is obvious when comparing tyre sizes through the ages. The rear tyres on Bulldog are Pirelli P7 and are the largest width road tyres available being 345/35 VR15, I foresee a continuing change to wider profile tyres as along with extra grip they allow the use of larger diameter wheels for the same overall rolling radius. This in turn allows more room for larger brake callipers and discs to be fitted inside the wheel.

Transmissions. Transmission efficiencies are improving all the time and I foresee the widespread use of automatic transmission systems which allow the engine to run at its peak efficiency for longer periods. Fortunately for those of us who still enjoy driving the manual transmission is far from dead and the Bulldog uses a ZF 5 speed transaxle unit mounted at the rear of the engine. This unit incorporates a gearbox with 5 forward speeds, one reverse, the final drive unit, limited slip differential, and a single plate clutch, The clutch itself is interesting. In conjunction with Lockheed Racing Division we adapted a plate which is made with 4 separate cerametallic drive faces or pads instead of an annular contact surface. This has given satisfactory service and is being considered for future production use.

Fuel system. I illustrated earlier how much energy was contained in a small quantity of petrol and in fact much less than a pint is needed to cause fatal burns to a person. We placed great emphasis on safety with the Bulldog and the fuel is contained in four different tanks positioned amidships so that the variation in fuel load would not affect handling. Each tank is filled with Explosafe foil, a honeycomb of aluminium. It works by dispersing heat quickly and acting as a flame trap. As a bonus it also provides an excellent anti-surge medium eliminating the use of baffles to prevent sloshing. In addition the engine and fuel tanks are separated from the passenger compartment by a 10 mm thick Vernaware insulating material. This is a woven ceramic, far better than asbestos in terms of insulation, weight and safety and makes a first class heat barrier. It is in fact used inside blast furnaces and the Bulldog is the first car to be fitted with it. With the Explosafe foil and the

Vernaware insulation it is possible to fire an incendiary bullet or anti-tank missile right through the Bulldog fuel tanks without any risk of explosion.

Electronics. The developments of electronics have opened up a new era of development of the car. It is now possible to have engine control closed loop systems which make optimum use of fuel and prevent unwanted emissions. It is possible to have oxygen sensors in the exhaust system to monitor intake charge air/fuel ratio, knock sensors to enable optimum ignition settings and maximum compression ratios which give scope for greater boost pressures with turbochargers etc. Control units and processors for such things as tyre pressure sensors and anti-lock brakes have been reduced to manageable sizes. Anti-lock brakes as a concept are not new and their contribution to stability and safety has been well proven but their possible management by electronics opens up new possibilities for their widespread use on mass produced cars.

Another important area is of course instrumentation. The Lagonda fully digital LED instrumentation and touch switches introduced over four years ago are well known by now and it is a fact that many cheaper American and Japanese cars are also fitting digital instruments. Whilst reading digital instruments may appear confusing at first sight, it soon becomes second nature to most people and the use of an essential systems only programme enables one to drive with the other displays switched off. They will automatically switch themselves on, however, and flash if needed (e.g. low oil pressure or high water temperature etc) which is probably much more reliable in bringing a problem to the driver's attention promptly than a needle on a gauge which may go unnoticed for some time.

The Bulldog system uses the same basic circuits and sender units as the Lagonda but we developed a neat Liquid Crystal Display (LCD) instrument unit which shows great potential for mass production. Each of the six LCD units has an adjustable backlight incorporated within it. A covering lithofilm negative shows the legend headings for the instruments. Behind this negative are positioned 4 orange strips which are 1mm thick and luminiferous, connected by fibre optic tapes to a single light source. These strips glow orange and enable the legends to be lit evenly without the need for a dozen or so bulbs and the space and power they need, and the system also does away with the mass of wires and connectors seen behind a conventional dashboard. I feel sure that in terms of space saving, weight saving and power consumption electronic instrumentation and control systems have a guaranteed future.

To conclude my views I shall sum up as follows: There is no doubt in my mind that cars will continue to be the primary mode of passenger transportation. No combination of rail, bus or air transit systems could come close to substituting for even a minority portion of the private cars now in use. Cars will change, however, particularly in the USA, to offer more efficiency and utility with improved fuel consumption and safety.

I believe we shall see a continued use of the internal combustion engine, fuelled by liquid hydrocarbon fuels, with more comprehensive and precise engine management systems to maintain optimum performance and efficiency and reduce exhaust emissions. Fuels will be synthesized or obtained from other sources as the availability and price of crude oil render it less important as a cheap primary source.

Finally I should like to give a plug to that much neglected character, the engineer, He (sadly all too seldom she) is the one that has to figure out how to get 50 miles per gallon, how to crash into a solid wall at 30 mph, how to make the exhaust gases smell sweet, and when through with all that, end up with a car that does not cost the customer £50,000 a copy (except Lagondas of course!).