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TRENDS IN EUROPEAN VEHICLE DESIGN

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1. INTRODUCTION

* To assess the trends in car design it might be a more defatigating task than one could foresee at the beginning.
There is, as usual, the difficulty to collect "comparable" data. Apart from this, the real difficulty rest on what is at the root of the success of passenger car in its whole history: its flexibility in responding to the mobility needs.
As a matter of fact, the assessment should be based on the analysis of trends of some "figures of merit", which, incidentally, should be the same one would like to see written in an ideal "cahier des charges". In other words, the objectives to be met by the car designer not-wistanding the several compromises and trade-offs among different design choices that he is compelled to make.

* The specifications to be included in such "cahier des charges" should be related, among others with:
  - transportation ability (performances)
  - safety, reliability, and ecological acceptability
  - comfort
  - costs.

For the sake of the present analysis we will limit to the first and the last items.

The first big difficulty is related to the choice of a mission on which to base the definition, first, and then the measurement of the "figures of merit" of the design. To define a standard mission it is a difficult task because, due to the flexibility of use, the car has always been designed to meet maximum performances requirements and, therefore, severely tested on very hard missions.

* The problem of defining a "standard" mission have taken momentum with the increasing importance of emission control and fuel economy.

  The variety of "fuel economy road cycles" developed by car manufacturers (Fig. 1), the difficulties to arrive at a "standard" road cycle for regulatory purposes (Fig. 2) shows that we are faced with a complex problem. The fact that different geographical area and driving habits make difficult to arrive at a worldwide "standard", it is responsible for quite a confusion when trying to compare car's fuel economy and, more importantly, it makes more difficult the design compromises and trade-offs for car to be sold worldwide (see Fig. 3 for a comparison between ECE and Japanese proposed urban road cycles). To the difficulties in defining the "vehicle mission" one has to add the difficulties in measuring fuel economy. Fig. 4 give a qualitative comparison of different test methods. Standardized procedures testing, using chassis dynamometer, have a lower repeatability than track tests. (Fig. 5).

* The temptation to simplify what is an intrinsically complex situation, might be large both for the regulatory agency and for the car designer.

The problem is that such "standardization" of the mission might be of no meaning to the car driver, according to his specific use of the car. So, for an average european commuter, fuel economy in cold start condition might be much more important than that of standard hot cycle (see Fig. 6). Moreover, a used car not properly tuned might give fuel economy losses larger than the differences found when testing a new car in a "standard" road cycle (see Fig. 7).

* The remarks above are made as a note of caution not to expect dramatic changes in car design trends: to the intrinsic complexity of the car technology one as to add the difficulties to optimize the design for the multiplicity of missions of car use.

2. DESIGN FIGURE OF MERITS

* Vehicle performance should be valued according to:
  - payload
  - time to accomplish a given mission.

  Figure of merits should be based on the benefit/cost ratio.

  In the introduction we have already pointed out how difficult it is to define a mission on which to evaluate fuel economy. The same difficulties applies when defining the performance characteristics, both due to the variety of missions and to the difficulties to define the payload (because of car flexibility in term of passenger and baggage transportation ability).

* To get rid of this uncertainties, in the car's cahier des charges are usually specified, as performance targets:
  - vehicle internal volume (including baggage)
  - vehicle acceleration (measured, f.i., as the time needed to cover a certain distance from idle)
  - vehicle maximum velocity.

* A first set of figures of merits or "design efficiency factors" can be obtained by comparing the "payload" with the total vehicle weight.
  In Fig. 8 are compared the 1978 model year cars sold in the USA, taking the ratio of:
  - interior volume/exterior volume
  as a design efficiency factor.
  In Fig. 9 the interior volume is compared to the vehicle curb weight, while in Fig. 10 a more direct benefit/cost index is given in term of the ratio :
  - interior volume/fuel consumption per unit distance.
  The large spread of the indexes shown in Figs. 8, 9 and 10, throw doubts on their significance. A closer look shows a positive trend when comparing the average of the index from the year 1976-1977 to 1978, and the better efficiency, in term of payload to total weight, of smaller cars and of the European vs. the American models.
  It is therefore plausible that the
  - payload/total weight
  ratio will be included among the specific design targets to be met, and will be properly valued by the market. It could therefore be retained as a figure of merit in assessing design trends.

* The case is more complex when dealing with the "time to accomplish the mission" figure of merits. Because higher

acceleration and greater maximum speed characteristics will assure lower time of travel, one could use acceleration and max speed as indicators for the reverse of time of travel.
It has to be noted, though, that in practice the top value of acceleration and speed might seldom be used. The setting of design values for acceleration and speed is therefore a matter of benefit/cost evalutation.

* Acceleration and maximum speed are interrelated through: the aerodynamic drag and rolling resistance (internal volume and total weight), the power plant-to-vehicle matching, and the engine characteristics.
To meet values, indipendently fixed, for the acceleration and the maximum speed, require a complex optimization design effort with the ability to operate on all the above mentioned vehicle subsystem (body, transmission, engine). To meet stringent requirement on fuel economy while not compromising much on vehicle performance, will require a "revolutionary" technological change approach, where all the design variable will be modified relying on innovative opportunities in new materials, and in improved power plants.
When analysing the last decade design trends one should expect a more "evolutionary" design changes such that for instance of reducing the acceleration characteristics by changing the engine-vehicle matching to improve fuel economy. In Fig. 11, it is remembered, as an example, what could be accomplished by changing the axle ratio, for a given car.

* Notwistanding these remarks, we can offer no better choice than to use the two ratios:
  - max speed x interior valume/max power
  - acceleration x interior volume/max power,

as indicators of figure of merits related to the time to accomplish a given mission.
The max power needed to propel a vehicle play the role of a rough indicator of the total efficiency of the automobile subsystem chains from the work used at the wheel up to the engine (see Fig. 12).

* The development of better figure of merits will have an impact also on regulations.

* Fiscal measure have had different impacts on several countries on car design.
New fiscal rules are now proposed which try to take into consideration the vehicle efficiency in term of fuel consumption.
An interesting formula has been proposed in France which relate the "fiscal power" to the ratio of engine displacement to the arithmetic mean of the vehicle speed at 1000 rpm in the different gears (see Fig. 13).

3. ANALYSIS OF HISTORICAL TRENDS IN EUROPEAN CAR DESIGN

* With the guide of the above discussions on the choice of compromise "figure of merits" we can now turn to an analysis of existing vehicle data to try to trace the innovation path that lead to improvements of such "figure of merits".

* Innovation is a learning-type process with long time lag especially in a complex system such as that of designing-manufacturing-marketing passenger cars.