SUV AERODYNAMICS

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1. Introduction

Sport Utility Vehicle, SUV, is a generic term which covers all those vehicles which have, or pretend to have off-road driving capabilities. They range in size from the small Japanese fun recreational vehicles, weighing less than a ton to the so-called Full size SUVs which are mainly only found in the USA which can weigh over four tons. They are invariably 2-box by design, except for the pick-up trucks which form a major part of the American SUV market, and mechanically can have two or four wheel drive. Their performance in terms of speed can vary from being just able to maintain the motorway speed limit because of low power and appalling aerodynamics to over 250 km/h with a turbocharged engine producing 450 hp.

There has been a phenomenal growth in the market for SUVs in recent years. The first vehicle which would today be recognisably an SUV is generally considered to have been the original Range Rover from Land Rover, which was launched in 1970, and at the time was a unique concept. From the mid 70’s the growth in this sector was an almost exclusively North American trend, and today 25% of all passenger cars sold in the States are SUVs and the best selling vehicle is the Ford F150. The cult of the SUV, however, has spread and it has become an almost universal phenomenon.

A significant portion of this paper is written from the perspective of Land Rover vehicles, which may not be typical of many current SUVs in that the brand values demand that extreme off-road performance is essential and the design language retains a bluff body appearance. The paper is also presented from a European viewpoint. Thus no consideration is given to the aerodynamics of pick-ups because they are not yet significant in Europe.

The primary role of the car aerodynamicist is to ensure that the aerodynamic drag remains competitive, without compromising high speed stability. Although many roles can be included under the heading of Aerodynamics, including cooling airflow, heat management and aero-acoustics they are not included in this paper. Only the external airflow and its effect on the aerodynamic characteristics of the vehicle are considered.

The axis system employed throughout this paper is sketched in Figure 1. It is a right handed axis system, where the x-axis is forwards and the z-axis is down, so that the drag coefficient, $C_D = -C_X$ and the lift coefficient, $C_L = - C_Z$. The moments are positive clockwise around the respective axes. Thus yawing moment, C_{MZ}, is the moment about the z-axis.

Note: the author was until recently manager for the Aerodynamics department at Land Rover. He was responsible for Land Rover aerodynamics from 1990 under initially Rover, then BMW, and finally Ford.

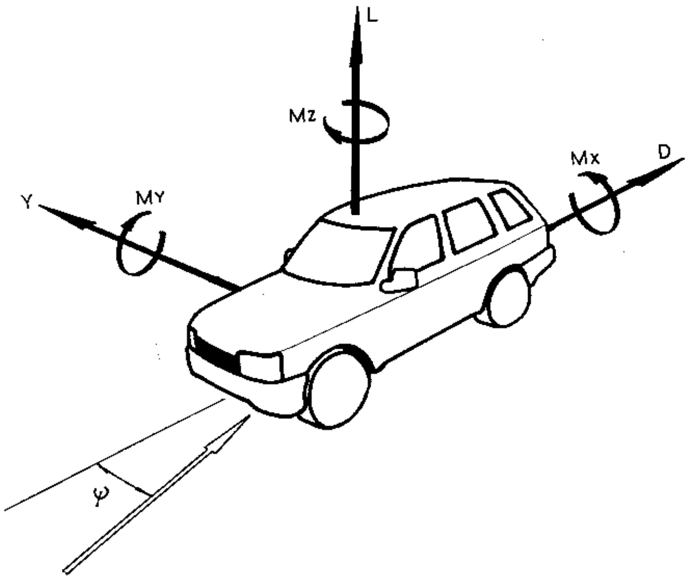

Figure 1. Axis System.

2. Drag

2.1 Effect of drag on performance and fuel economy

Aerodynamic drag has an influence on vehicle performance and fuel economy. In particular drag has a significant impact on maximum speed. In the past a reasonable performance on road was considered acceptable, in part because the suspension characteristics required for good off-road behaviour, such as high levels of articulation, compromised the vehicle dynamics and high speed handling on the open road, especially motorways. As these vehicles have evolved, however, the balance between off-road and on-road behaviour has changed and good on-road performance is seen as essential even if the off-road capabilities are compromised. Only a few companies such as Land Rover consider that excellent off-road performance is essential to maintain brand values for its whole product range.

Drag is a function of both shape, as represented by the drag coefficient, and size, given by the frontal area. In comparison with passenger cars, SUVs have large frontal areas and high drag coefficients. The variation of resistance to steady motion with speed for a typical medium size car and an SUV is plotted in Figure 1. For comparison the SUV is assumed to have a frontal area of 3.0 m^2 and a drag coefficient of 0.40, while the comparable car data is taken to be 2.0 m^2 and 0.30, respectively. Tyre resistance is assumed to be a function of vehicle mass and to increase linearly with speed. The typical SUV requires approximately twice the power to maintain a given steady speed as the medium sized passenger car. It can also be seen that, for a vehicle travelling at a steady speed on a flat road, the aerodynamic drag for an SUV actually becomes the dominant resistance to motion at a lower speed than is the case for a car.

The basic dimensions for a particular type of vehicle seem to grow inexorably. This applies to all vehicle types. Twenty years ago a frontal area of 2.0m^2 was considered large for a saloon car but now almost all cars exceed that figure and the larger saloons now exceed 2.3m^2. SUVs