but also because different approximation schemes are used with the same starting point. Recent careful applications of the methods of non-linear analysis have shown that a class of non-linear equations which, it had been hoped, would describe bootstrapped particles is unlikely to do so. The class of equations is those which incorporate the properties of analyticity, crossing symmetry and unitarity in as large a manner as has yet proved possible. Analyticity is expressed by means of dispersion relations, either for the Low equation[2] or by means of the Mandelstam representation[3]. For models based on the Low equation, unitarity is approximated by two particle intermediate states only; for the Mandelstam representation these two particle intermediate states are again handled exactly, and the contribution from the remaining intermediate states is assumed to be given. Crossing symmetry is exact in both approaches, though distorted in the Low equation by the cut-off necessary to give finite results.

The resulting non-linear equations are analysed by means of fixed point theorems of non-linear functional analysis. For both models, solutions are found which have arbitrary numbers of free parameters, these being the positions and widths of narrow resonances arising from CDD poles put explicitly into the equations. Furthermore, these solutions exist for a large range of crossing matrices (which describe the internal symmetries of the particles in question).

The implications of these results are that, at least for the class of functions considered, the bootstrap idea cannot work; there are too many solutions to merit a choice of a particular one of them. There is still a faint hope that the bootstrap can be resuscitated by replacing the class of functions in which solutions are being sought by functions which have an oscillatory high energy behaviour. Such a behaviour is more realistic, for it arises from a Regge-type of behaviour. The present difficulty of such a behaviour is that the methods of non-linear analysis are difficult to extend with such a class of functions; what is worse is that if the Regge trajectories used in describing the high energy behaviour of the scattering amplitudes are increasing indefinitely, the Mandelstam representation or Low equation approaches break down, and completely different equations have to be considered. Suggested equations which involve essentially the bootstrapping not of particles but of whole Regge trajectories are considerably more complicated. But they may allow bootstraps to become feasible again.

[1] Gasiorowicz, S., *Elementary Particle Physics* (Wiley, New York, 1966).
[2] Warnock, R. L., *Phys. Rev.*, **170**, 1323 (1968); Warnock, R. L., in *Lectures in Theoretical Physics*, **11** (University of Colorado Press, in the press).
[3] Atkinson, D., *Nuclear Phys.*, **87**, 375 (1968).

TRANSPORT

Handling Vehicles in Emergencies

from a Correspondent

IMPROVEMENTS in vehicle performance, more and better highways and the rapid increase in the number of road vehicles make it essential that safety considerations are treated as top priority. This in turn demands a more exact understanding of the dynamic performance of road vehicles under emergency conditions. And this was the basis for the theme of a symposium at Loughborough, attended by about 150 people on January 8. It was arranged by the Automobile Division of the Institution of Mechanical Engineers, in association with the Department of Transport Technology of Loughborough University of Technology.

Emergency conditions are largely concerned with the response of vehicles under combined sideways and braking forces, and these principally involve tyre/ground characteristics, vehicle dynamic representation, the driver's behaviour, and their interaction. All the papers presented were concerned with one or more of these aspects, although the emphasis was on vehicle response, for which the simplest mathematical models have been developed consistent with the data available, the limits of the required accuracy and available computer facilities.

Dr H. B. Pacejka discussed a linear model describing the skidding of a vehicle due to locked wheels. This was an extension of work carried out in the 1950s by Professor Koiter of Delft University, and from which the theme of this symposium flowered. Dr Pacejka concluded that the highly unstable condition of a vehicle with locked rear wheels could be improved by reducing the vehicle's inertia and the relative cornering stiffness of the front tyres and increasing the wheel base. Members of the Road Research Laboratory described a steady state graphically oriented analysis of a four wheeled vehicle model moving on a constant radius path and subjected to braking during cornering. It presented useful limits of maximum cornering acceleration at various braking decelerations to maintain the vehicle's stability.

R. R. McHenry of the Cornell Aeronautical Laboratory described a digital computer time-history analysis (including all major non-linearities) of an eleven degree of freedom four wheeled vehicle, using vehicle fixed coordinate axes similar to those used when dealing with aircraft. The predicted motions of combined cornering and ride over irregular terrain correlated well with performance in actual tests—paving the way for more complex analyses. These comparisons were spectacularly demonstrated by film of the actual test motions and the corresponding computer predictions—the latter was possible because the digital computer analysis presented the results as graphical vehicle positions at successive time intervals.

Professor F. D. Hales of Loughborough University of Technology and Mr M. P. Jurkat of the Stevens Institute of Technology were concerned with the way people adjust their driving behaviour when vehicle stability is degraded. They tested nine subjects using a driving simulator which reproduced the conditions in understeer and oversteer vehicles. It is also important that a satisfactory laboratory technique for simulating some real driving situations has now been developed.

Three contributors from the Pirelli Company, Milan, described how a "loose inverse" procedure allows for the behaviour of drivers in a seven degree of freedom mathematical model analysis concerned with matching tyres to vehicles to reduce hazards in emergencies. Essentially, the car followed the reference path with a series of drivers having different anticipation, reaction time and sensitivity threshold. Results showed that tyres with greater cornering stiffness were better in emergency conditions but could increase driver stress in normal manoeuvres because of rapid handling response.