It can be deduced that wear resistance is proportional to hardness of the material, and in the case of metals during the initial period of wear, significant work-hardening of the surface material may occur. In hard abrasion, the hardness of the abrasive is very much greater than that of the metal surface, whereas in soft abrasion the hardness of the two is comparable. When the hardness ratio is 1·2, abrasion will just occur.

J. K. Lancaster (Royal Aircraft Establishment, Farnborough) said that when the abraded surface is a polymer the relative roles of plastic and elastic deformation become significant. For any one polymer the wear process changes, as the counterface asperities become less sharp, from the cutting process to fatigue or tearing or both. The mechanical properties also affect the wear process, cutting becoming important for rigid polymers and fatigue/tearing for the more elastic polymers. In cutting wear, the product of the elongation to break and the breaking stress is related inversely to the wear rate.

The mechanism of abrasion for brittle–crystalline–non-metallic solids was outlined by C. A. Brookes (University of Exeter). For a hard stylus on a flat surface the degree of penetration and the extent of brittle fracture can be predicted by considering the distribution of resolved shear stress in the bulk of the crystal. Abrasion can then be considered in terms of three areas of fractures produced during sliding. First, there are cracks produced by tensile stresses; second, dislocation reactions may result in crack formation on planes; and third, cracks parallel to the sliding surface may be encouraged by the presence of piled-up edge dislocations.

Liquid impact erosion is increasing in importance for its connexion with the damage caused by rain to high speed aircraft, such as Concorde, and to missiles, and, of course, it is also important with regard to the erosion of blades in steam turbines. Sand erosion is also important; it seriously impairs the operating performance of helicopters and hovercraft in sandy terrains. Sand erosion is caused by the impact of particles up to 1,000 microns across resulting in the removal of surface material. G. P. Tilly (National Gas Turbine Establishment) described how this type of wear can also result in serious damage to industrial equipment such as chemical plant, rocket nozzles and gas turbines. Erosion is dependent on impact conditions (velocity, angle, temperature and exposure time), the properties of surface material and the nature of the impacting particle. A typical value for the erosion of steel at ambient temperature by quartz at 90° and velocity 800 feet per second is about 5 mg/g (weight of material removed/unit weight of abrasive).

Abrasive wear arises in diverse situations in engineering. Discussions included the role of casting alloys in resisting the abrasion of clinker in cement milling, the wear of cutting edges in agricultural soil and the wear of rubber tyres on cars. In a more personal note, K. H. R. Wright (National Engineering Laboratory) showed why almost all dentifrices contain abrasives to assist in cleaning the teeth, and to provide them with a high polish to resist staining. Using a radioactive tracer to detect wear and a machine to simulate brushing, it has been possible to study the rate of wear of both enamel and dentine with a high degree of sensitivity. The technique has been developed to show the interaction between brushing fibre, geometry and dentifrice concentration.

THREE-BODY PROBLEM

Theoreticians Wanted

from a Correspondent

THE three-body problem, which describes the sort of interaction between three particles that cannot be treated readily (if at all) as a sum of separate two-body interactions, was the subject of an international conference at Birmingham on July 8–10. The particular interests of the conference were in the three-body problem in nuclear and particle physics and, as Professor Sir Rudolf Peierls remarked in his summing up of the conference, the revival of interest in the three-body problem is very largely the result of the enormous improvement in experimental results.

The great improvement in experimental techniques over the past decade was brought out by J. D. Seagrave (Los Alamos), W. Haeberli (University of Wisconsin) and I. Slaus (Institut Ruder Boskovic). They presented an impressive amount of precise data, which still lack a proper theoretical framework. The scattering of neutrons and protons by deuterium nuclei was discussed in detail by Haeberli and Seagrave, while Slaus dealt with the study of final state interactions including the phenomenon of neutron–proton Bremsstrahlung.

It became clear that three-body final states in, for example, proton–deuteron scattering can yield accurate information on the two-body proton–proton scattering interaction in the presence of the light binding of the target nucleon. Such information is invaluable to the solution of the two-body problem. In addition, because of the practical problem of neutron targets, the neutron–neutron interaction is most easily studied through a three-body final state.

Examples of relevant reactions are $T(\mathrm{d},{}^3\mathrm{He})\ 2n$ and $\mathrm{d}(\pi,\gamma)\ 2n$. These problems, which were discussed at the conference, can as yet only be solved in stringent conditions, such as the supposed non-existence of specifically three-body forces in the three-body interaction. The need for more theoretical work was emphasized by the vast strides which have been made on the experimental side during the past decade.

Professor L. D. Faddeev (Mathematical Institute, Leningrad), whose article in 1961 may be thought to have inspired this conference, dealt with the inclusion of Coulomb effects in the three-body problem. He also indicated with great clarity how his original method of coupled equations, derived from a description of the three-body problem in terms of two-body forces, might be extended to the study of the four-body problem.

The real gain in studying the three-body problem, as Dr. Pierre Noyes (Stanford University) pointed out, is that it is sensitive to features which do not show up in straightforward two-body experiments. Although great advances have recently been made in understanding the two-body nucleon–nucleon interaction, until there is some agreement on the question of whether to think of the three-body interaction in terms of off-shell behaviour of the two-body scattering amplitude or in terms of the actual interaction potential, the interaction cannot be considered to be understood. If the potential approach is valid, it must also be asked whether the potential is static, local, energy dependent or separable.