MECHANICAL WEAR

SUMMER CONFERENCE AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

A SPECIAL summer conference on mechanical wear was held at the Massachusetts Institute of Technology, Cambridge, Mass., on June 14–16, under the joint sponsorship of the American Society of Mechanical Engineers, the General Motors Corporation and the Chrysler Corporation, together with the Institute itself. The object of the conference was to take stock of the present knowledge and theories on this very important subject so that the most profitable directions of future research might be more clearly indicated. The absence of any general meeting on the subject in either the United States or Europe during recent years made this especially desirable.

The papers presented and accompanying discussion covered laboratory and service experience on wear in internal-combustion engines, steam turbines, brake materials, journal bearings, gears, electric brushes (in the absence of electric currents), surface plates and cutting tools. In addition, results of laboratory tests on laboratory machines simulating some of these service operations and also on specially designed wear-test machines were reported. Specifically excluded from consideration at the conference were the subjects of cavitation erosion by liquids and the wear of current-carrying electric contacts.

It was the general consensus that the wear phenomenon is exceedingly complex and depends on numerous factors. Some of these factors were discussed in considerable detail by one or more of the speakers. They included hardness, fatigue strength, gas adsorption, chemical reaction and viscosity. These discussions were too long to report here in detail, but the following notes indicate matters which were especially interesting to those present.

F. P. Bowden and D. Tabor (University of Cambridge) summarized the various ways in which rubbing surfaces can operate, depending on the quantity and type of lubricant present (in other words, full-fluid, boundary or dry), and they cited various evidence for presence or absence of metal-to-metal contact in each of the three regions. The evidence showed, on one hand, intermittent contact even under conditions of sliding hydrodynamic lubrication, but on the other hand the transmission through thick oil-films of compressive stresses exceeding the yield point of the metal without direct solid contact. In a separate connexion they showed that fatty acids, which are supposed to attack metal surfaces chemically to form metal soaps which are very effective boundary lubricants, will not attack these same metal surfaces if the latter have not previously been exposed to air and moisture. R. Savage (General Electric Research Laboratory) described his recent findings on the mechanism of the lubrication and wear of graphite. He found that the presence of oxygen or water vapour was necessary for graphite to lubricate in its familiar manner. In the absence of these gases it wears extremely badly, producing a fine dust having strong surface-active properties.

E. S. Starkman and A. G. Cattaneo (Shell Development Company) showed that the corrosive wear of piston rings increased with the amount of sulphur in the fuel, owing to formation of sulphur trioxide; it increased with the amount of tetra-ethyl lead in the fuel owing to the simultaneous presence of the halogen scavenger, and it increased sharply below the dew-point of the water vapour in the combustion gas mixture owing to the formation of carbonic acid. R. Holm (Stackpole Carbon Company) proposed a relation, for the purpose of correlating wear measurements, which involves the hardness of the rubbing surfaces. He also discussed the relation of this contact hardness, as measured by an indenter, to the yield point of the metal. In addition, he showed that the measured contact-hardness depended on the size of the indenter.

H. Blok (Royal Dutch Shell, Delft) showed that the failure of gear teeth under exaggerated impact loading depended much more on the viscosity of the lubricant than on its oiliness or extreme-pressure characteristics. This was attributed to the ability of viscous liquids to withstand suddenly applied compressive loads. J. O. Almen (General Motors Research Laboratories) discussed the wear of gear teeth and especially that type known as scoring or welding wear. He showed a correlation between failure due to this type of wear and the product of the factors of compressive stress, sliding velocity, and the length of time the teeth are in contact. E. Buckingham (Massachusetts Institute of Technology) and G. J. Talbourdet (United Shoe Machinery Corporation) reported data on the failure of gear materials from another type of wear, namely, pitting fatigue.

J. H. Dedrick (University of Cincinnati) and John Wulff (Massachusetts Institute of Technology) described friction and wear measurements on certain ternary-bronze powder-metallurgy brake-materials containing lead, graphite and silica. They found that only a small region on the corresponding ternary diagram gave alloys having suitable characteristics as regards wear-rate and quiet operation. This area is limited to compositions containing both lead and graphite, but silica is not necessary. R. G. Larsen (Shell Development Company) tabulated and discussed all the possible adsorption and chemical reactions that could take place between the rubbing metal surface and its gas or lubricant environment. These were found to be quite numerous and sometimes complex. C. M. Allen (Battelle Memorial Institute) reported qualitative information on the minimum oil-film thickness in a fluid-lubricated journal-bearing just prior to failure. He measured the electric break-down potential of the oil film and showed that this often gave warning of impending failure.

The complete proceedings of the conference will be published shortly by the American Society for Metals, Cleveland, Ohio. J. T. BURWELL, JUN.

ORIGIN OF THE SOLAR SYSTEM

PROF. HAROLD JEFFREYS has published a paper in which he examines a number of theories proposed to explain the origin of the solar system[1]. In the early part of the paper he points out that the resonance theory of the origin of the moon can no longer be maintained; and, in fact, it was shown many years ago to be quite untenable for various reasons, though it is still referred to in popular works as a possible explanation of the existence of our satellite. Dealing with the origin of the planetary system, he refers to his earlier view of a collision between the visiting star and the sun, which appeared to make some successful quantitative predictions,

but which Russell showed to be dynamically unsound. Lyttleton's theory that at the time of the encounter with the visiting star the sun was a double star, and that the encounter was with the companion, seemed to offer a way out of the difficulty. On this theory there was the possibility that the visiting star and the companion would escape from the neighbourhood of the sun, and yet leave a considerable fraction of the ejected matter revolving around the sun. Nevertheless, as Jeffreys shows, in all catastrophic theories there is a fundamental difficulty. In Jeans's tidal theory it was assumed that the elongated filament would be gravitationally unstable and would break up into a number of pieces—a view which is difficult to maintain if the matter ejected from the sun (or its companion) had an initial high temperature. Jeffreys investigated a number of cases nearly twenty years ago and showed the difficulties in the view that the gravitation of the mass could maintain equilibrium, though there was the possibility that adiabatic cooling during expansion would lead to the formation of liquid drops at an early stage, and thus the pressure might be relieved before the velocities became uncontrollable. More recently, Spitzer dealt with the same problem and concluded that during the expansion of cylindrical and ribbon-like filaments these would disappear completely.

Another difficulty arises in connexion with the compositions of the planets; it is interesting to note that the greater densities of the inner planets find a natural explanation if they were originally gaseous, because the greater masses of the outer zones would retain lighter materials, which would be lost by the smaller ones. If bodies of different masses were set free suddenly in a vacuum, we should expect that there would be these differences in composition; if gradual evolution took place, the materials would be mixed and the compositions nearly uniform. Hence the present condition of the inner and outer planets favours a catastrophic theory which, as has just been pointed out, is itself open to very serious objections. At this stage Jeffreys discusses some recent results on possible modes of disruption of rotating bodies, and deals with the question of a disrupted planet giving rise to two or more independent planets, thus accounting for the differences of composition among the inner planets. Originally there might have been one or two bodies which acquired too rapid a rotation for stability as they condensed, but before the development of instability the central cores would have had time to form. Lyttleton suggested that all the planets could be brought into this scheme, and secondary disturbances, like a splash, might be associated with the separation. Some pieces might continue with each of the main bodies, giving rise to satellites, while others might become independent of both bodies, forming the terrestrial planets and the moon. In 1941 Lyttleton showed that a planetary system might be formed by fission without any external disturbance. Starting with a triple star with two very close companions, he showed that if these coalesced the angular momentum would be sufficient to produce fission and make them separate indefinitely. The two parts might both escape from the third body (the sun) while leaving part of the splash to be captured by it. The accretion of interstellar matter would cause the coalescence of the two companions, and, as Jeffreys admits, there is no obvious quantitative objection to this theory except that just referred to, namely, the high initial temperatures of the planets.

Although the existence of small bodies presents a difficulty in all theories, owing to their feeble gravitational pull on their material, and Lyttleton's fission theory of the planets offers some hope of explanation as the fission was supposed to have taken place after liquefaction, there is another possible explanation. A liquid or solid, however small, will grow if immersed in a gas, provided that the density of the gas exceeds the saturation vapour density at the actual temperature. A. L. Parson has dealt with this problem[2], and it seems that even with the present small density of interstellar matter, iron, calcium oxide, magnesium oxide and silicon dioxide are capable of condensing; but water, methane and ammonia would be unlikely to condense near Jupiter and Saturn at the probable densities—about 10^{-15} gm. per c.c. Jeffreys admits that Parson's results answer one of his chief objections to the planetesimal theory that the small bodies would collide and volatilize one another before they could produce any notable effect on the planets. If they did, the vapour would condense again and form new dust, the accretion of the planets proceeding. Hoyle has examined the question of accretion by the planets[3] and finds that it would take place at an increasing rate as the planet became larger; and if a condensation reached the mass of the earth, it would grow rapidly to attain a mass of the order of that of one of the major planets.

Other theories on the formation of the planets and satellites are considered; but Jeffreys is not satisfied with any of the existing theories. Thus he says: "But many notable advances have been made in the last twenty years, and the problem is to decide which of them are relevant to the origin of the solar system".

[1] *Mon. Not. Roy. Astro. Soc.*, **108**, 1 (1948).
[2] *Mon. Not. Roy. Astro. Soc.*, **105**, 244 (1945).
[3] *Mon. Not. Roy. Astro. Soc.*, **106**, 406 (1946).

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FORTHCOMING EVENTS

*(Meetings marked with an asterisk * are open to the public)*

Monday, February 14

INSTITUTION OF THE RUBBER INDUSTRY, MIDLAND SECTION (joint meeting with the BIRMINGHAM SECTION of the ROYAL INSTITUTE OF CHEMISTRY, at the James Watt Memorial Institute, Great Charles Street, Birmingham), at 7 p.m.—Dr. H. W. Melville, F.R.S.: "The Degradation of High Polymer Substances".

INSTITUTION OF THE RUBBER INDUSTRY, PRESTON SECTION (joint meeting with the ROYAL INSTITUTE OF CHEMISTRY, the SOCIETY OF CHEMICAL INDUSTRY, and the BRITISH ASSOCIATION OF CHEMISTS at the Victoria and Station Hotel, Preston), at 7 p.m.—Dr. W. J. S. Naunton: "Natural and Synthetic Polymers" (with special reference to Rubber and Synthetic Fibres).

Tuesday, February 15

SOCIETY OF PUBLIC ANALYSTS AND OTHER ANALYTICAL CHEMISTS, BIOLOGICAL METHODS GROUP (joint meeting with the AGRICULTURAL GROUP of the SOCIETY OF CHEMICAL INDUSTRY, in the Chemistry Department, Royal College of Science, Imperial Institute Road, London, S.W.7), at 2.30 p.m.—Discussion on "The Evaluation of Selective Weedkillers" (to be introduced by Dr. M. A. H. Tincker).

ROYAL INSTITUTION (at 21 Albemarle Street, London, W.1), at 5.15 p.m.—Sir Edward Salisbury, F.R.S.: "Types of Distribution in the British Flora". (Further Lectures on February 22, March 1 and March 8.)

UNIVERSITY OF LONDON (in the Physiology Theatre, University College, Gower Street, London, W.C.1), at 5.15 p.m.—Dr. A. Schweitzer: "Reflexogenic Areas of the Vascular System".* (Further Lectures on February 22, March 1, March 8 and March 15.)

SOCIETY OF CHEMICAL INDUSTRY, CHEMICAL ENGINEERING GROUP (at the Geological Society, Burlington House, Piccadilly, London, W.1), at 5.30 p.m.—Prof. T. R. C. Fox: "Technical Education".

INSTITUTION OF THE RUBBER INDUSTRY (at Caxton Hall, Caxton Street, London, S.W.1), at 7 p.m.—Dr. C. Bondy: "The Colloidal Aspect of Rubber Latices"; Dr. W. H. Bodger: "The Applications of Various Types of Rubber Latex".

SOCIETY FOR VISITING SCIENTISTS (at 5 Old Burlington Street, London, W.1), at 7.30 p.m.—Discussion on "The International Organisation of Science". (Speakers: Prof. M. J. Sirks, Prof. F. J. M. Stratton, F.R.S., Dr. Joseph Needham, F.R.S., and others.)