SPOTLIGHT

on wear and abrasion in industry

by D. D. HOWAT*

The first joint colloquium between the South African Institute of Mining and Metallurgy and the South African Branch of the Institution of Metallurgists was held in Kelvin House on 23rd April, 1981. About eighty delegates registered, the majority being associated with the local branch of the Institution of Metallurgists.

Types of Abrasion and Wear

Professor A. Ball, of the University of Cape Town, gave the opening address, which he entitled 'Some Thoughts on Abrasion and Wear'. In his thought-provoking talk, he quoted some figures showing that, in the highly industrialized countries, loss by wear and abrasion might amount to about 4 per cent of the gross national product but, in the Republic of South Africa, it was believed to be about 6 per cent of the gross national product—probably associated with the massive influence of mining in our economy.

Professor Ball described wear as being of three main types.

The first of these is adhesive wear, which is characterized by very high local stresses with high strain rates, leading to work-hardening and high frictional heating. A typical example is a piston operating in a cylinder liner of grey cast iron. Preventive measures centre on the reduction of the local stresses by the production of smooth surfaces between which a lubricating film is continually maintained. Localized heating leading to thermal fatigue may be reduced by the use of materials with high thermal conductivity.

The second type, erosive wear, is characterized by very high local stresses and extremely high local strain rates, leading to plastic deformation of the surface resulting from the impact of solid particles, by particles in a high-velocity liquid, by liquid droplets, or from a collapsing cavity in a liquid (cavitation erosion). Prevention in these circumstances could be partially afforded by maximum effort in design and by an endeavour to employ, where possible, materials that have the ability to absorb impact energy, e.g., rubbers or polymers.

The third type is abrasive wear, in which hard particles cut grooves in the wearing surface, removing 'chips' of the material, this being the type of wear normally encountered in rock-crushing and ore-handling equipment. Because of the very high local stresses and strains characteristic of this type of wear, a material or coating is required with a microstructure capable of withstanding very high surface strains without fracture. In the ultimate, this combination of properties is unattainable in any known material. The medium- to high-chromium white cast irons with carbides of the M_7C_3 type, which are capable of withstanding very high surface strains but are brittle to a greater or lesser degree, are nevertheless being used on an increasing scale for wear-resistant purposes. Stressing the great importance of the microstructure of metals and alloys in wear resistance, Professor Ball referred to the dangers of a bad 'mismatch' between elastic hard particles and a highly plastic matrix. The interface between the two phases is weak, and small interfacial cracks develop that may result in final fracture, particularly under the very high local stresses that are typical of abrasion wear.

Wear-resistant Materials in the Steel Industry

Mr A. Ross, of Dunswart Iron & Steel Works Ltd, read a paper prepared by Mr R. R. Preston, Manager Rails and Sections of British Steel Corporation, on 'The Role of Wear-resistant Materials in the Steel Industry'. This interestingly descriptive paper highlights many of the problems in wear and abrasion in many facets of steel-making and rolling by describing the operations involved in the production of a rolled steel beam. Interesting points emerging from the paper concern, first, the production of railroad rails with high wear resistance of the rail head. The higher yield stress to resist plastic deformation and higher hardness to resist abrasion can be achieved by the production of an extremely fine interlamellar spacing of the fully pearlitic microstructure of the rail. This can be brought about if the cooling of the rail steel through the transformation temperature range is accelerated, giving a higher nucleation rate but lower growth rate of the ferrite and cementite laths in the pearlite. This procedure requires the use of special cooling equipment on the rail banks, and is practised on a considerable scale in the U.S.S.R., Japan, and the eastern States of the U.S.A. The alternative procedure is the addition of alloying elements, particularly chromium, to the steel, such elements increasing the hardenability and lowering the transformation temperature of the rail during normal cooling after rolling. The alloying procedure is adopted in Europe, Australia, and the western States of the U.S.A. With the increasing use of flash-butt welding of rails in track laying and maintenance, alloyed

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steels present problems through the formation of martensite in the heat-affected zones. The unalloyed, but rapidly cooled, rails may present fewer difficulties in welding.

Reference was also made to the development of the SARCLAD type of rolls for steel rolling This joint work by British Steel Corporation and ESAB has resulted in the development of a process for surfacing the roll by submerged-arc welding cladding, a process that can be used for the production of new duplex rolls with a combination of toughness and wear resistance. The performance of over a hundred rolls was monitored during the rolling of 2 million tons of steel products.

Roll-quenched and Tempered Steels

Dr Rocco de Villiers, of Iscor, described some of the features in the testing, quality control, and procedures employed in the manufacture of roll-quenched and tempered steels. He cited some of the possible applications of these steels for use in the mining industry in circumstances requiring abrasion resistance, for example ore-chutes and ore-hoppers. He emphasized the ease of welding of these steels in fabrication jobs, provided that low-hydrogen welding rods are employed.

SX3CR12 Steel

Dr C. R. Thomas, Southern Cross Steel (Pty) Ltd, gave an interesting paper on 'SX3CR12 - a Material for Abrasion–Corrosion Control'. Pointing out that 403, 430, and 304 stainless steels have been fairly extensively tested in various mining operations, he stressed that, although the 304 types perform very well in coal-preparation and coal-handling equipment, they are very expensive. The 12 to 16 per cent chromium steels of the 403 and 430 types are substantially cheaper and have achieved considerable success, but they present serious fabrication problems, particularly hardness and difficulties in welding.

Southern Cross decided to develop a ferritic 12 per cent chromium steel with a low-carbon content in the hope of substantially reducing the fabrication problems. A typical carbon content of 0,025 per cent in 3CR12 can be compared with the maxima of 0,15 per cent and 0,12 per cent in 403 and 430 respectively. In addition, a stabilizing effect is produced in 3CR12 by the addition of about 0,2 per cent titanium. The optimum combination of mechanical properties and resistance to corrosion is produced by the annealing of the rolled product at 700 to 750°C for 1 to $1\frac{1}{2}$ hours to yield a ferritic matrix with a few coarse blocky Ti (CN) precipitates dispersed throughout. In this condition, the steel has a hardness of HV. 170 — only slightly higher than mild steel — and, under pure, dry sliding conditions in chutes, performs no better than mild steel. Dr Thomas showed that, in general, 3CR12 gives poor performance under impact-erosion conditions, as was proved when the steel was used to line a skip in the area where ore impacted on loading.

Under conditions involving abrasion–corrosion factors, Dr Thomas stated that 3CR12 shows great promise. The corrosion resistance of the steel in waters from typical gold mines and coal-washing plants, and in brackish water in platinum, phosphate, and asbestos mines, implies that the corrosion factor in abrasion–corrosion wear has been largely overcome. Substantial data on the performance of this steel have been accumulated from the coal-mining industry, and fairly extensive tests have been conducted on its use in ore-hoppers in the gold-mining industry.

Grinding Balls

At the National Institute for Metallurgy, tests on a 0,6m by 0,6m rotary mill have been directed at a determination of the relative performances of different types of grinding balls when used on gold and copper sulphide ores. The testwork was discussed by Professor D. D. Howat, in presenting his paper 'The Wear of Grinding Balls in the Milling of Different Types of Ores'. The testwork was initiated because of the large market for grinding balls in the gold-mining industry — *circa* 50 000 tons per year — and because of the greatly increased interest overseas in the use of high-chromium white cast-iron grinding balls. With the co-operation of local manufacturers, agents for overseas foundries, and one of the mines, fourteen different types of grinding balls were accumulated for the tests. A composite charge of six different types of balls was used in each test, and the basic data, expressed as grams of metal worn off per square centimetre of surface area, were expressed in the form of percentage index of performance values.

In the grinding of quartzitic material, the differences in performance of the different types of balls were found to be relatively small. The best performance, obtained from 16 per cent chromium white cast-iron balls produced by Fonderies Maggoteaux in Belgium, was greatly offset by their high cost. Medium-carbon cast-steel balls, which are relatively cheap, gave by far and away the most economic results. In grinding the softer copper sulphide types of ores, the Maggoteaux balls gave greater improvements in performance than before. For ores in decreasing order of hardness, i.e., ores from Black Mountain, O'Okiep and Palabora, the Maggoteaux balls were 2,5 times, 3,5 times, and 9 times better than the standard drop-forged carbon-steel balls. At comparable feed rates, the consumption of Maggoteaux balls per ton of ore milled was 0,75 kg, 0,65 kg, and 0,2 kg per ton respectively. At the same feed rates, the consumption of Maggoteaux balls when grinding quartzitic material was 4 to 5 kg per ton. Obviously, in grinding softer ores, and ores that may give rise to pulps with pH values of less than 7, high-chromium white cast-iron balls may show a decided cost benefit.

Gold-mining Equipment

Mr B. E. Protheroe, of the Chamber of Mines Research Laboratory, presented a paper 'The Selection of Abrasion Corrosion-resistant Materials for Gold -mining Equipment'. This discussed the results of laboratory tests on the abrasion and abrasion–corrosion of carbon, low-alloy, and stainless steels carried out as a joint project between the Department of Metallurgy and Materials Science of the University of Cape Town, and the Mining Technology Laboratory of the Chamber of Mines. Mr Protheroe stressed that, owing to the tendency to increasing mechanization and automation in the gold-mining industry, greater importance must be attached to the selection of the optimum materials for any given operation involving abrasion–corrosion conditions. He described how, after preliminary testing and evaluation of the different types of steels in the laboratory, the more-promising materials were prepared in relatively small rectangular sections and incorporated into a section of a shaker conveyor carrying gold-bearing quartzitic rock. Under wet-abrasion conditions in the shaking conveyor, both the laboratory and underground tests showed the stainless steels to be much superior to proprietary abrasion-resistant alloys, the ferritic stainless-steel grades proving superior on the basis of cost related to percentage of volume lost.

Contaminants in Bearings

Mr P. R. Diener, of Timken South Africa (Pty) Ltd, presented a paper, 'Lubricant Contaminants and Their Effects on Bearing Performance', which had been presented previously at a meeting of the Society of Automotive Engineers in Peoria, U.S.A. Although the theme was rather removed from that of the other papers, this contained some interesting information about how contaminants—some of them very deleterious in their effects—found their way into bearings, particularly of the tapered roller type. Solid particles finding their way into the bearing produce 'bruising' as a result of plastic deformation of the contact surfaces. This may easily be followed by spalling of the surface and rapid failure of the bearing.

Water entering the lubricant is by far the most common form of contamination found in bearings. Seals or breathers on the bearing may allow water to enter, but water may also be formed by condensation when there is a large gradient in the temperature in the bearing housing between operating periods and stationary periods. A chemical reaction between the water and the lubricant may liberate sulphur from the lubricant by hydrolysis, and this sulphur subsequently attacks the bearing surfaces.

Water-etching of the surface is the second form of chemical attack, and consists essentially of corrosion of the bearing surfaces. This may advance to produce random areas of pitting, followed by quite severe spalling. It has been shown that a reduction of up to 40 per cent in the fatigue life of bearing steels may be caused by small concentrations of water in a lubricant. Fine sub-micrometre cracks generated in an early stage, into which water vapour condenses, act as fine capillaries, aggravating corrosion and leading to hydrogen enbrittlement.

The paper also presented some very interesting case histories of different causes of failures in bearings.

High-temperature Furnaces

In the closing paper of the colloquium, Mr Peter Johnson, of J. A. Leys Engineering, discussed 'The Choice of Materials for Use in High-temperature Furnaces—the Effects of Hostile Environment'. Emphasizing that his talk was confined to furnaces operating below 1250°C, Mr Johnson pointed out that, until very recently, the furnace industry in this country had relied very heavily on overseas expertise and design. This position has changed remarkably, and, when furnaces that are to operate in this temperature region are designed and built in this country, the furnace designers arrange for very extensive sub-contracting of the various components and ancillaries of the furnaces. One of the difficult problems is the judicious selection of locally available materials of construction, particularly of the exotic heat-resistant types. Mr Johnson stated that the final choice of materials lies with the furnace engineers and is frequently a compromise. The purchaser must be made aware of the nature of such compromises and their implications for the future performance and life of the furnace.

Obituary: W. S. Findlay

William Schreiner Findlay (1908 to 1980) had a distinguished career in the mining industry, to which a mere account of his appointments does not do full justice. However, they give some idea of his ability as an engineer and a manager.

He joined Randfontein Estates Gold Mining Company Limited as a Learner Sampler in October 1934, and by 1942 was Manager of the North Vertical Shaft. In June 1944, he was apointed Manager of Consolidated Murchison Ltd and, in February 1946, was transferred to Johannesburg Consolidated Investment Company Ltd. He was appointed Manager of Freddies North and Freddies South Lease Areas in July 1947, and returned to J.C.I. as an Assistant Consulting Engineer in October 1949. He became Consulting Engineer in January 1951, Manager in Johannesburg in October 1957, and Director and Deputy General Manager in September 1959. Owing to ill health, he retired from the Company in December 1962.

Mr Findlay was a long-standing member of the South African Institute of Mining and Metallurgy, and served as its President in 1960–1961.

The Institute extends its sympathy to his son and daughter, and their families.