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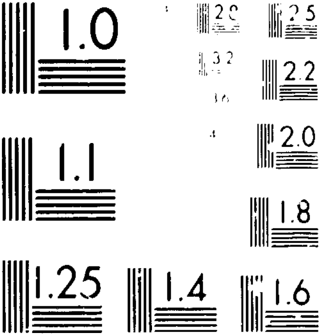

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SOME METALLURGICAL RESEARCH AND DEVELOPMENT ACTIVITIES IN THE PEOPLE'S REPUBLIC OF CHINA *

by

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This report is mostly based on a keynote speech given by Dr. T. Ko, Professor and Vice president of Beijing University of Iron and Steel Technology at the first China - USA Bilateral Metallurgical Conference which was held in November, 1981 in Beijing.

China had practically no metal industry before the founding of the People's Republic in 1949, in spite of the facts that she is abundant in mineral and fuel resources, and had a long tradition of ancient metallurgy.

The known reserves of iron ore in China amount to approximately 44×10^9 tons. It is believed that the known reserves of tungsten, antimony, tin, rare earth elements are the largest at present among all countries; zinc, lead, copper, aluminium, nickel, molybdenum, tantalum, niobium, mercury and titanium are also abundant, some of them rank the second or third in the world. These provide a reliable basis for the development of a self-supporting metallurgical industry in the long run.

There was no lacking of metallurgical technique in ancient China. The casting technique of bronzes of Shang and Zhow Dynasties (16 -5 centuries BC) is well known. Iron artefacts dated back to mid-seventh century BC have been unearthed and cast iron was already in use at the end of sixth century BC and became wide spread in the third to fourth centuries BC after the invention of malleabilizing process in the early fifth century BC. Remains of one of the iron and steel works of Han Dynasty (221 BC - 220 AD) covered an area of 6 hectares (15 acres) with two blast furnaces of 8.5 m^2 hearths and estimated height of about 6 meters have been found, among them are salamanders over 20 tons. Steels made by decarburization in solid state, but puddling of molten iron and forged wrought iron were in use by the end of the pre-Christian era. Eutectic silver copper alloy was known and used in 113 BC for cast arrowheads, dental amalgam of silver and tin was recorded in a Pharmacopoeia of 659 AD; Zinc and a copper nickel zinc alloy (later known as German silver) were exported from China to Europe in the 18th century.

The development stopped completely, however, after the 18th century. Effort was made to build a modern iron and steel work in 1890, the total tonnage of steel produced in the more than half century following, however, was not more than 7 million tons, and the maximum annual production never exceeded 1 million tons including that produced in the Japanese-occupied areas. The steel production in 1949 was only 158,000 tons.

Founding of the People's Republic saw the rapid development of metallurgical industry, iron and steel productions increased to 38 and 37 million tons in 1980 respectively. The metallurgical education and research have expanded accordingly to meet the needs of metallurgists and metallurgical engineers to implement new methods, technology and materials.

Metallurgical researches in China are carried out in various institutions which can be grouped into following catagories:

1. Universities.
2. Metal and metallurgical research laboratories of the Chinese Academy of Sciences, e.g.

   Institute of Metal Research, Shenyang;
   Institute of Chemical Metallurgy, Beijing.
   Institute of Metallurgy, Shanghai.

   These institutes are concerned in principle with fundamental researches or long-term applied researches.

3. Research establishments maintained by various ministries, e. g.

   Central Institute of Iron and Steel Research, Beijing.
   Central Institute of Nonferrous Metals Research, Beijing.
   Central Institute of Mining and Metallurgy, Beijing.
   Institute of Noble-Metals Research, Kunming.
   Institute of Rare-earth Research, Baotou.
   Institute of Aeronautical Materials Research, Beijing.
   Institute of Materials Research, Baotou.
   Institute of Materials Research, Shanghai.

4. Research laboratories maintained by local authorities

5. Research laboratories maintained by various metallurgical works, e.g.

Wuhan Iron and Steel Works.
Anshan Iron and Steel Works.
Daye Steel Works, Huangshi.
Light Metals Research Laboratory, Harbin.

The number of technical personnel engaged in the 66 research establishments maintained by the metallurgical industries alone now totals 39,000 in addition to the 110,000 scientists and engineers employed in the metallurgical industry.

As for the research fields, starting from scratch, the earlier efforts in the few research establishments founded in early fifties, such as the Institute of Metal Research, Shenyang, and Institute of Metallurgy, Shanghai, both of Academia Sinica, and the metallurgical universities, were directed towards the production of metals and alloys urgently needed for the large scale construction of modern industries, such as high speed and other tool steels, bearing steels; towards problems concerned with quality of products, such as hydrogen flakes in steel, hardenability of steel, which became a problem due to lack of trace elements normally introduced from scraps; and towards the development of new steels and alloys in which alloying elements already known to be abundant in China, such as Mo, B were used to replace those yet being regarded as scarce or stretegically important, such as nickel and chromium, for example, the development of Co-free FeCrAl heating elements, FeCrMnN stainless steel, FeMnAl cryogenic and heat resisting steels, Mo or MnMo or SiMn steel for high tensile duties, and development of high quality refractories, as the alumina magnesia bricks to replace chrome-magnesia bricks for open hearth furnaces. What is more important in this stage of development was the training and growing up of a new generation of metal scientists and metallurgical engineers with the help of the few senior metallurgists and by self-education learning from experience. Some of them were also trained in the graduate schools and research laboratories abroad. Lack of domestic as well as international contacts in the part, however has caused them parochial, and we look forwards to various kinds of conferences as an effective remedy in this respect.

Beginning from late fifties and early sixties, the metallurgical investigations had been directed towards the development of China's natural resources and their utilization. For instance, the technologies developed include the technique of smelting high titania-vanadium iron ore in blast furnace and also by direct reduction, the recovery of rare earth metals from the blast furnace slag by ferro-silicon reduction, the recovery of niobium in the form of pure metal and ferro-niobium from hot metal and from open hearth slag, the development of processes, pyrometallurgical and hydrometallurgical, of extracting nickel, cobalt and noble metals from complex deposit.

The application of these resources and saving of others comprised a major part of the efforts made by physical metallurgists. The development of Mn and Mn-V HSLA steels, Ni-Cr free HSLA steel used for missiles, pearlitic boiler tube and hydrogen-resisting steels for chemical reaction vessels, Ni free heat-resisting steels and stainless steel, B, Nb, V, Ti bearing and R. E. bearing steels, etc. In connection with Cu-bearing iron deposit, extensive study has been made on copper-bearing steels, including the effects of copper on welding and other technological properties, on tin plating and galvanizing, on recrystallization and texture formation, on atmospheric marine and oil corrosion, the development of nodular iron using ferro-silicon-rare earth alloys from blast furnace slag. Considerable work has gone into the development of low nickel low cobalt magnetic and other alloys such as low cobalt Kovar, Fe-Al-C magnetic alloys, and Sm-Co alloys.

The self-relied development of defence measures in the sixties, drew heavily the scientific man-power in materials development. Nevertheless, such requirements, thanks to the foundation laid in the fifties, both in the training of scientists and engineers and in the large-scale planned orgainzation of research works, for which China had had no experience before then, have furthered the development of new technology and new materials.

Technological and plant equipment designs have been developed for large blast furnaces, up to 2580 m^3 working capacity, including bellless top and dome-combustion hot stoves, 150 ton LD furnaces 50 ton electric arc furnaces, ESR furnaces up to 120 ton ingots, 1.7 m continuous strip mill, etc. Ladle metallurgy and injection metallurgy are being studied actively. Solid state electrolyte for oxygen sensing has been developed actively, used not only in steel works, but also in copper and nickel industries.

Techniques concerned with continuous casting, especially of curved billets, planetary mill, 20 and 36 roll mills for foil rolling down to 1.5-0.8 micron have been developed in the early sixties and late seventies respectively. Skew rolling mills for hot and cold rolling of shapes, such as balls and rollers for bearings, twist drills bicycle hubs, etc , have been developed and widely used with many advantages.

Considerable efforts have been made in researches in connection with effective utilization of energy since early sixties. Breaking through of the hot blast temperature was the first major success achieved in the late fifties. Injection of pulverized coal in the last for iron making has acheived considerable technical and commercial successes. Efforts are being made to develop materials used in connection with gasification and liquefaction of coal, in MHD generators, and for solar energy utilization.

New heat treating methods studied and some of them applied in commercial production including ion-nitriding, low temperature carbon-nitriding, ion-implantation, laser surface hardening, surface protection by coating and alloying by chemical deposition have been investigated.

It can be seen that considerable efforts have been made in developing independently up-to-date techniques and technology and in procuring materials complying with China's own resources, especially for purposes related to defence requirements. As a result, basic research was neglected although there were much efforts to restore the balance. For instance, a special meeting was held in 1964 to promote studies on dislocation theory, which had been taught in universities since 1954, and also in electron theory of metals and alloys, and there were active groups working in these fields in the years following, Efforts in this respect have been intensified in recent years especially by electron microscopy. Work on Lattice imaging is now in progress and atom imaging is under active preparation.

Studies in phase transformation and diffusion have long been neglected after early sixties, but greater effort is being made in this field, especially in martensitic and bainitic transformations as related to the toughening of high strength materials, dual phase steels, granular bainite, memory alloys, effect of boron on hardenability, grain boundary segregation and precipitation in alloy steels and superalloys.

There have been considerable amounts of work on fracture mechanics and fracturing during fatigue and stress corrosion. Steels with better resistance against embrittlement in hydrogen atomsphere and against stress corrosion in hydrogen sulphide have been developed.

Hydrogen embrittlement had been a favourite subject in our country since early fifties when it was related to hairline cracks in steels, while this interest remains and is even extended to hydrogen embrittlement in single crystals of silicon. Studies on oxidation and corrosion have been carried out by various research establishments. Effects of rare earth metals on the oxidation resistance of heating elements and other heating resisting materials have been studied.

Fatigue studies are another field of interest to Chinese metallurgists, there are many groups studying crack nucleation and propagation of metals under alternating loading related to their microstructures. Investigations of threshold stress and overloading phenomena as well as interaction of fatigue and creep are now undertaken.

Internal friction study, initiated in China by Dr. T.S.Ke, has been renovated since 1976 with even greater vivacity. Important progress has been made in the systematic investigation of the anomalous internal friction exhibiting amplitude peaks, which is believed to be related to the interaction of dislocations and solute atoms. Closely related to this is the hydrogen peak in alpha iron.

Internal friction method has also been applied to the study of martensitic transformation, to the dislocation mechanisms of fatigue, to the grain boundary segregation of alloying elements and to the interaction between rare-earth and interstitial elements.

Studies employing nontraditional techniques are increasing with new instruments, either introduced from abroad or made domestically, such as Mössbauer spectrometry, position-electron annihilation, neutron activation, etc.

Looking back through the overview above, we see that,

1. It has now been formed an army of scientists and engineers, mostly trained domestically, who are capable of tackling various problems although their efficiency and productivity remain to be improved. There are many unnecessary repetitions of work of similar nature in various institutions. This was prompted by the lack of experienced workers on one hand and the duplication in assignment which had to be made to assure the solution of the problems according to a limited time schedule on the other hand. But in any case, materials required for modern industries and for defence purposes could be supplied from our own resources.

2. It is expected that an improved organization and coordination of research and development work must be carried out in order to result in a faster progress and higher efficiency. This seems possible in view of the fact that the present status was achieved in a period of about twenty years considering there was a complete stoppage between 1966 and 1976 of so-called culture revolution and subsequent after effect which has caused a reduced rate of progress.

3. Basic researches have long been neglected in universities and even in the Chinese Academy of Sciences. In order to make better utilization of our natural resources, to minimize the raw material and energy consumptions, to improve the quality, to reduce production costs and to improve the environment pollution, more applied research works directly concerned with metallurgical products should be arranged. This is just the requirement from the State Commission of Science and Technology during recent years.

4. Notwithstanding the entity of China historically and politically, metallurgy in China, as it is elsewhere, forms part of world knowledge and belongs to the whole mankind. We look upon a close international cooperation, especially among the developing countries. May I pray and prophesy that the conference will be most successful.