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To evaluate the technological capability of Far East countries, the author attended the first Pacific Rim International Conference on Advanced Materials and Processing in China, and visited Nippon Steel and several universities. China is an old country with a glorious history in technology. She recently re-established her diplomatic relationship with western countries. Attendance at this conference provided an opportunity to communicate with Chinese scientists and evaluate their capability and progress. The average Chinese scientific capability still lags behind most western countries. However, as a nation China is comparable with most industrialized countries on an absolute scale. The percentage of college educated engineers in China is relatively low, but the total number is very high compared with many other countries. During this trip, it was observed that their scientists are studying almost every important materials science topic at several national key institutes. China should become one of the leading countries in science and technology in the future. Nippon Steel is the largest steelmaking company in Japan. It has one of the most up-to-date research facilities in the world and is conducting leading edge research in materials science. The visit to Nippon Steel established a preliminary contact with their scientists, and mutually-beneficial collaboration in Titanium-based alloy programs is planned. The visits to three universities in China, Hong Kong and Japan provided the author a unique opportunity to compare and evaluate their education systems and research capability. Potential collaborations are also being discussed.

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INTRODUCTION

The objectives of this trip were to attend and present a paper at the First Pacific Rim International Conference on Advanced Materials and Processing (PRICM-1) in Hangzhou, China, present a seminar at Osaka University, and visit Nippon Steel. The U.S. Army Research Office-Far East (ARO-FE) financially sponsored the author's visit to China and Japan from June 21 to July 8, 1992. In this trip to the Far East, Jiao Tong University, Shanghai, China and the University of Hong Kong, Hong Kong were also visited. The recent openness is rapidly moving China into a high-tech society and a free market economy. Drastic changes were also observed in Chinese academia and industry. China has been the location for several international science and technology conferences in recent years. Communications between Chinese scientists and their counterparts in western countries have been mutually beneficial. This report summarizes the author's observations and an evaluation of Chinese technical capability in materials science and engineering.

After 100 years as a British colony Hong Kong is now in a mode of transition back to China; the official transition will start in 1997. An evaluation of materials research in the University of Hong Kong and observations of Hong Kong in this transition period are also given.

Japan is the most industrialized country in the Far East. Nippon Steel is the largest steelmaking company in Japan and its researchers have always actively communicated with American scientists. Osaka University is one of the most prestigious national universities in Japan. These visits to Nippon Steel and Osaka University have helped gain an appreciation of the current status of materials research in Japan. As a United States educated materials scientist with deep oriental roots, the author will report, compare and analyze the status of materials research and manufacturing capabilities in China, Hong Kong and Japan from both technological and cultural points of view.

EVALUATION CRITERIA AND APPROACH

Criteria

The following criteria were used to evaluate the technical capability of some Far East countries and regions: facilities, resources, and system. The rationale for employing these criteria is briefly explained below. Only the best facilities will produce world class scientific results. Thus the author will summarize the facilities observed in this tour of various institutes and laboratories. Human resources are always an important factor in a country's scientific development. The attitude and self-confidence of intelligent scientists usually are the key to any successful scientific research. Natural resources are another critical factor to understand and evaluate a country's technology policy and their future success. Finally, a country's political and economic systems often are the key to it's rise or fall. China, Hong Kong and Japan have their own distinctly different social systems. Their technological capabilities are closely related to their respective systems.

Approach

Instead of mechanically listing the equipment and facilities of each institute and statistically comparing the number of publications or patents, this report will analyze each country's technological capacity from a broad cultural point of view. To truly evaluate the technological capability of a foreign country, people first have to appreciate and understand each country's fundamental cultural background and value system. For example, after World War II, both academia and industry in Japan held a very strong feeling against the military. Most of their research is aimed at commercial instead of military applications. To evaluate the strength of the

Japanese materials industry one should concentrate on their achievements in the automobile industry instead of the defense industry.

To approach Japanese scientists usually is another challenge. For United States military technical personnel, it is a dedicated and sometimes difficult task to build a close relationship with Japanese scientists. The anti-defense feeling is still strong almost 50 years after World War II; they are often hesitant to collaborate with United States military personnei. However, if we understand these Japanese feelings, and encourage academic scientists from prestigious U.S. colleges, like MIT or the University of California at Berkeley, or other people with a strong academic background to communicate with them and build a mutually-trusting relationship, future collaboration will be much easier.

THE PROGRESS IN CHINA

Background

In the late 1970's, China gradually opened its door to the United States and other western countries. More and more Chinese graduate students came to the United States for advanced studies. This population of Chinese graduate students is growing very quickly and has increased from a few pioneers in the early 1980's to earn them the most populous foreign student status in the United States in recent years. The academic and research environment inside China has also gradually changed from a rather conservative and closed infrastructure to a more liberal and open western style. Around 1980, a group of professors and scientists representing the Minerals, Metals and Materials Society (TMS) visited China for the first time in decades. Their tour included Hangzhou, the location for this first Pacific Rim International Conference on Advanced Materials and Processing. As a graduate student at MIT, the author listened to the exciting trip report of Prof. J. Elliott, who was one of the TMS representatives. He is now proud that he has the honor of reporting his own observations and evaluation of the progress in China 10 years later. It was particularly enjoyable to meet again in Hangzhou one of the first Chinese visiting scientists to the United States 10 years after they first met at MIT.

Conference Review

The First Pacific Rim International Conference on Advanced Materials and Processing was primarily organized by the Chinese Society for Metals and jointly sponsored by many international professional societies including TMS, the Japan Institute of Metals and the Korean Institute of Metals and Materials. Dr. G.H. Geiger and three other scientists from the United States were on the international advisory board of PRICM-1. Other members of this advisory board came from China, Japan, Korea, India, Canada, Germany and Australia. Prof. N.J. Grant from MIT and several other international renowned materials scientists were invited to present their research results in plenary sessions. Prof. Grant discussed his recent research in liquid dynamic compaction of metals. This is a new processing science and technology. Other invited speakers also presented in-depth discussions of a variety of topics including composite materials, intermetallic compounds and amorphous alloys. The author presented an article entitled "Microstructure Control and Engineering Characterization of Super-α_2 Titanium Aluminide Alloys" in Symposium E1: Special Materials on June 25, 1992; the abstract is attached in Appendix I. This article will be published in the conference proceedings and it reported the recent study on a super-α_2 titanium aluminide alloy at the U.S. Army Research Laboratory (ARL). It was warmly received by the audience. Other presentations in Symposium E1 included processing of intermetallic thin wires and diffusion mechanisms in intermetallic compounds by scientists from China and Japan. Prof. J. Wu from Jiao Tong University presented his study on the intermetallic phase $Ti_5(Si,Al)_3$ in $Ti_3(Al,Si)$ and $Ti(Al,Si)$ based alloys. Another interesting article entitled "The Influence of Heat-Treatment on the Microstructure and Properties of Ti-25Al-10Nb-3V-1Mo" was also presented by a Chinese scientist. Their studies are very similar to the research conducted at ARL, that is, heat treatment/microstructure/mechanical properties on the super-α_2 titanium aluminide alloy.

After the presentation, several researchers from the audience expressed interest in this research and also discussed their own research results in this field with the author. There is strong evidence indicating that Chinese researchers in both colleges and industry are already at the cutting edge of some advanced materials research. The major materials research topics, for example, high-temperature intermetallic compounds and rapid solidification processing, have been widely studied in China.

Human Resources and Education

It is worthy to note that China is an enormous country with a population of about 1.2 billion people. It is very difficult to bring every researcher and institute up to a world class level at the same time. As a result, foreigners are often misled into believing that China is still "far" behind in certain science and technology fields. The Chinese government has set up a few key national institutes in each field, capitalizing their facilities and intensively trains the researchers affiliated with these key institutes. The facilities in these key institutes are often world class and the scientists affiliated with these institutes are usually very informed and intelligent. For instance, the Institute of Composite Materials at Shanghai Jiao Tong University is one of the key institutes for composite materials. The following information in this paragraph is cited from the institute brochure edited by Dr. R. Chen in 1991. Most of these topics were also cited by Dr. G. Zhang, Director of the Institute of Composite Materials, in private conversation during the author's visit. This institute, founded in 1978, has 60 faculty and staff members. It has three divisions (metal matrix composites, non-metal matrix composites and surface techniques), one analytical & testing laboratory and a composite materials research and development center. The composite materials R&D center concentrates on manufacturing and processing developments for industrial applications. It has manufactured carbon-copper composite electrical brushes, short fiber-reinforced aluminum engine pistons, etc. The scientists affiliated with this institute essentially cover research topics on every important aspect of the composite materials field from design, processing, microstructure, performance, interfacial behavior and fracture mechanisms. In metal matrix composites, carbon-aluminum composite plate has been successfully made from carbon-aluminum composite wires by hot pressing in vacuum. The carbon fiber is first CVD coated with Ti-B and is then infiltrated with molten aluminum. It is reported that the fiber volume fraction is about 50% to 60%. The diameter of the composite wire which contains 3,000 carbon filaments is about 0.5 mm (0.020 in). In addition to carbon-aluminum composites, Dr. G. Zhang also showed the author their carbon-copper composite brush that has been successfully applied to several A.C. and D.C. electric motors and generators. This carbon-copper brush demonstrates excellent electrical contact and performance. Also exhibited was their prototype pistons made of aluminum alloys reinforced with short fibers. Dr. Zhang specifically pointed out that the institute has the capability to produce moderately complicated parts from various composite materials. They have presented and published more than two hundred scientific papers at international conferences and in journals. They also frequently carry out international collaborations and have exchange programs. In the non-metal matrix composite area, the institute has studied several new functional composites, such as acoustic absorbing and damping polymer composites, friction reducing and wear resistant composites and piezoelectric ceramic composites, etc.

This institute recently received $1.2 million to update their research facility. A recently purchased new scanning electron microscope (SEM) with microhardness capacity will significantly improve their research capability in studying the interfacial behavior of composite materials. The institute is not only equipped with advanced research facilities, but also well trained scientists. A recently returned (from Europe) Chinese scientist is in charge of this SEM; he has several years of experience in this field with this facility in Europe before he returned to China. They also purchased a brand new transmission electron microscope and an MTS mechanical testing machine with computer-aided data acquisition capability. The institute has several other SEM's and TEM's and an "old" composite material processing facility. Dr. Zhang indicated that he is considering the purchase of another more advanced composite processing facility from the United States in the near future. It is the author's observation that in this key institute, their facilities are comparable with those of many universities and research institutes in the U.S.

The training of young scientists is the most important step in retaining American leadership in science and technology. The current American education system is very different from that in China. The author will objectively compare these two systems with minimal commentary, so the reader can reach his/her own conclusions. Chinese school children usually work hard on weekdays and usually get more homework for the weekends. However, the huge population base and relatively small capacity of universities have severely limited the chance for many Chinese high school graduates to enter colleges. Chinese training always starts with the selection of prospective trainees, i.e., college students in this case. There is very stiff competition in the college entrance examination in China. As a result, most college students are usually either hard workers or very intelligent. A much smaller percentage of Chinese high school students can attend universities compared to American students, but the total number of college educated students in China is comparable with most industrialized countries. It is noteworthy that traditionally many outstanding Chinese students, particularly boys, prefer engineering and science colleges to other schools. China is extremely rich in science and technological human resources.

How are science and engineering students trained in colleges? Most American science and engineering colleges are better equipped. However, the professor-to-student ratio is much higher in China. America is in a unique position in science and engineering education. In most American materials science and engineering graduate schools, about 20% to 50% or even more are international students and half of them come from Far East countries. It is partially because more international students are interested in science and engineering than American students - only about 10% to 15% of American high school students are interested in engineering. It would be a bargain if America institutions can employ these international students after their graduation because American tax payers did not educate them from kindergarten to college. Considerable educational expenses are saved when these world class scientists work in America, provided that they enhance American scientific research capability and not compete with American scientists for (limited) job opportunities. America is a great country because it can accept people with different cultural backgrounds. These international students provide one of America's greatest human resources in science and technology.

Technology Potential

The infrastructure of Chinese society allows them to organize a great number of people in a relatively short period of time to accomplish a special task. Average Chinese living standards might be 20 to 30 years behind those of the U.S., but their technological capability, as a nation, is not too far behind any industrialized country. The great human and natural resources will make China very competitive and a great industrialized power in the next century, if there are no more internal political or social turmoil. In summary, China is a country that has great technology potential and most probably will become one of the world leaders in science and technology in the future.

THE TRANSITION OF HONG KONG

Hong Kong combines a traditional Chinese background with modern western culture and has developed a unique mixed society. It is a city culturally, socially and economically in transition. A politically rotten imperial China lost Hong Kong, and after 100 years it faces a much stronger and very different China waiting to take her back. Despite it's overly crowded population and prosperous economics, Hong Kong has only three major universities. One of them has just recently been founded. Hong Kong has well developed light industries, e.g., consumer electronic products and textile industries. However, its high-tech development is relatively limited. There is no automobile, aerospace and other heavy industry. The University of Hong Kong is the most respected institute of higher education in Hong Kong. The author visited the materials group in the Mechanical Engineering Department. This is one of the few materials research groups in Hong Kong. In an interesting contrast to many U.S. universities that are currently being cut back (sometimes up to 50%, particularly in engineering colleges), the Mechanical Engineering Department at the University of Hong Kong currently has 26 full-time faculty members and is expanding during this transition period.

The author met two materials science faculty members and toured their laboratories. Dr. W.L. Cheng, a young British educated materials faculty, is a polymer scientist. Dr. B.J. Duggan is an expert in textural structure. Their program grants both master's and doctoral degrees in materials science. Many of their materials science faculty are recruited from overseas, but the majority of students are either from the Hong Kong area or mainland China. The official teaching language is English. They are equipped with moderate research and teaching facilities. Much of the equipment was made by European countries. One multiple-specimen creep facility, made by Ceast in Italy, has a test capability up to 300°C (572°F). It can apply axial load to test specimens and a computerized data acquisition device has been added by Dr. Cheng and his research associates. We discussed our respective experiences in creep testing, particularly in axial loading which is often difficult and critical. Dr. Cheng is currently utilizing this facility for the study of polymers at their upper use temperatures in his laboratory. Several graduate students are studying the microstructure and the formability of several hot and cold rolled ferrous alloys under Dr. Duggan's supervision. There are also relatively extensive studies of environmental effects and corrosion science at the University of Hong Kong.

There are only limited human and natural resources in Hong Kong for materials science research. However, Hong Kong has the potential to become the largest importing and exporting port for metallurgical products produced in China and other Far Eastern countries, where a much brighter future is forecast for materials and other heavy industries.

THE MATERIALS RESEARCH STATUS AND CAPABILITY OF JAPAN

Technology Base in Japan

Japan is the most industrialized country in the Far East, and the U.S. Department of Defense (DoD) has stationed technology personnel in Japan since the 1950's. They help to establish collaboration between scientists of the United States and Japan. They also constantly evaluate the technological capacity of Far Eastern countries. The author briefly met with Dr. Iqbal Ahmad of the Army Research Office-Far East (ARO-FE) at PRICM-1 in Hangzhou, China. Dr. Ahmad is stationed in Tokyo, Japan but was unavailable while the author was in Japan.

The author visited ARO-FE in Tokyo on July 2, 1992, where Ms. Nao Suzuki from Dr. Ahmad's office kindly helped arrange a visit to Nippon Steel. Ms. Suzuki also arranged the author's meeting with Dr. Sachio Yamamoto who is the Director of the Office of Naval Research Asian Office, located in the same building as ARO-FE. He is a Japanese-American and grew up near San Francisco, CA. Dr. Yamamoto is a veteran American expert in Japanese affairs for DoD, he was stationed in Japan before and is in his second term as Director of the Office of Naval Research Asian Office. He first told the author that while he looks like Japanese and speaks Japanese he is a native American. He candidly expressed his concerns that many Americans do not understand Japanese culture and customs. For example, in contrast to the American "phone call" approach, personal contact is essential to build up collaboration with the Japanese. A cold phone call from a stranger requesting a visit, usually does not work to most Japanese companies. He is convinced that the typical way Americans conduct business is just too different to work with the Japanese. Dr. Yamamoto strongly feels that to truly understand Japanese ways, Americans should come to Japan, live there and learn to actually deal with them day after day. The very strong resentment against the military among many Japanese industrialists and scientists (particular physicists) has made it difficult for American DoD civilian and military personnel to make good contact with their Japanese counterparts. Dr. Yamamoto believes that a respectable professor from a prestigious American university can significantly ease Japanese scientists' concern about the military linkage between themselves and international scientists even though they are sponsored by DoD.

Understanding and Expectations

Before his visit to Japan, the author talked with several Americans who have closely collaborated with the Japanese in recently years. Unfortunately, their experiences were not encouraging. More understanding between American and Japanese scientists and engineers will help to established a better collaborative environment. The satisfaction or disappointment usually results from the extent of mutual understanding and expectations. The expectations will be more realistic if both sides understand their counterpart's culture and customs better. After World War II, the United States became the free world leader and the American government helped millions of foreigners to understand American culture by sending American aides and advisers to foreign countries and by establishing U.S. cultural centers around the world. However, most Americans do not have much opportunity to learn the cultures of other countries. This might give scientists of other countries an edge in dealing with their American counterparts.

Nippon Steel

(1) Background

The following review and comments are based on the author's personal observations, conversations with Nippon Steel scientists and the information listed in a 144-page booklet "Basic Facts About Nippon Steel."[1]. Nippon Steel started in 1857 and was incorporated into the present organization in 1970. It had total annual sales of about $16 billion in 1991, compared with about $18.7 billion for USX Corp. It is a very diversified company. The major business include steelmaking, titanium, chemicals, new materials, engineering and construction, and electronics and information/communications, etc. The steelmaking business has persistently declined from about 84% in 1987 to 75% in 1990 and is projected to be about 64% of total sales in 1993. It is the author's belief that the invention and usage of new engineering materials and the shift of steelmaking to newly industrialized countries, like Taiwan, Republic Of China (ROC) and South Korea have forced Nippon Steel to face a similar challenge as U.S. Steel did two decades ago. From 1980 to 1990, Taiwan, ROC and South Korea's crude steel production almost tripled, while both the United States and Japanese crude steel production was decreasing. About 20% of Nippon Steel's total sales are exported; more than half of export sales are shipped to Asia and about 20% to North America. The United States and Japan signed a Voluntary Restraint Agreement in February, 1990. This agreement is based on the steel trade policy implemented by Presidents Reagan and Bush. The United States urges major steel exporting countries to limit their total steel exports to the United States to 18% (excluding semifinished products) and 20.2% (including semifinished products) of apparent consumption in the United States. This policy will give American steel

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[1]. Basic Facts About Nippon Steel, 1991, Nippon Steel Corp. Booklet, Tokyo, Japan, 1991, 144pp.

industry a transition period in which to adjust its product market position to better compete against foreign producers in this rapidly changing world.

Nippon Steel's total employees decreased from about 79,638 in 1970 to 71,669 in 1980 and 54,0462 in 1991. However, it is noted that the white collar employment only decreased from 22,229 in 1970 to 20,223 in 1991 (a 9% decrease), compared with a 41% blue collar employee decrease from 57,409 to 33,839. This is an indication that Nippon Steel is retaining research, engineering and service personnel. The average age of employees is more than 40 years old, most top executives and directors in Nippon Steel are about 5 years older than their American counterparts. The average period of continuous service is more than 20 years. Whether these factors have made Nippon Steel more conservative has yet to be studied.

Intelligent and hard working human resources are the supporting strength of Japanese industries. However, in contrast to the United States and China, the lack of natural resources is the weakest factor of Japanese materials industries. The import dependence of the Japanese steel industry on iron ore and coking coal in 1990 was 99.8% and 99.1%, respectively. Japan needs to reach out for her raw materials supplies. The United States dependence on foreign sources of iron ore is much lower, usually less than 30%.

Nippon Steel has a principal office in New York, and two branch offices in Los Angeles and Houston, respectively. Two joint ventures between Nippon Steel and Inland Steel Industries, Indiana, U.S.A. have been established for the production of cold-rolled and coated sheet steel.

(2) Visit Notes

The author would like to briefly report the research and engineering activities at Nippon Steel. The Technical Development Bureau at Nippon Steel supervises all the research and engineering programs. It operates four laboratories and a research and engineering center. It is composed of about 1,155 researchers, 360 plant engineers, 1,000 technicians and 260 service staff. The major research and development of titanium-based alloys is conducted in the stainless steel and titanium group in the Steel Research Laboratories. Three other laboratories are Process Technology Research, Advanced Materials and Technology Research, and Electronics Research Laboratories. The 700,000m^2 Research and Engineering Center, newly constructed in Futtsu, Chiba Prefecture, is Nippon Steel's central base for integrated research. It currently concentrates on the company's steelmaking research and plant engineering and technology. In the future, the chemicals and new materials research will also be incorporated in the Center. Nippon Steel filed a total of 3,299 patent applications in 1990 (in Japan and abroad). The research and development expenditure of Nippon Steel in 1991 was about 71.1 billion yen (about $570 million), about 3% of it total sales, but relatively considerably more than that of U.S. steel companies.

Nippon Steel established a new titanium division in 1984. It collaborated with TIMET and became TIMET's exclusive sales agent in Japan in 1986. The author was invited to visit and present a seminar to Nippon Steel's stainless steel and titanium research group at the Research and Engineering Center in Futtsu . They arranged for his seminar but because the author was unable to confirm his visit with enough advanced notice, they canceled it. However, the author's visit was warmly welcomed. Mr. Mitsuo Ishii greeted him at Kimitsu station and hosted him at Nippon Steel during his visit. Mr. Ishii is a senior research metallurgist and was educated in the United States. The author toured a number of laboratories and workshops in several buildings. During his visit to their Research and Engineering Center, Mr. Ishii pointed out a beautiful new titanium roofed building located in the Center and told him that Nippon Steel has pioneered the application of titanium alloys in construction. Titanium alloys have been widely used in the aircraft industry in the United States. Their beauty, superior corrosion resistance and specific strength could provide market opportunities in the construction industry in the future.

The Nippon Steel Futtsu facility concentrates on material characterization with numerous SEM, TEM and other analytical facilities. One in situ corrosion study utilizing optically polarized light shows a very interesting application of new technology. Another interesting study is the in situ microscopic study of phase transformations. They showed the author a video tape which recorded the dynamic phase transformation of a titanium alloy on cooling from about 900°C (1,652°F) with a continuous record of temperature as a function of time. They were also proud of their huge mechanical testing facility. The author's visit to Nippon Steel was particularly beneficial because Dr. Hideki Fujii, a senior researcher, and the author are discussing a potential collaboration on titanium-based alloys in the future. Dr. Fujii and his colleagues have been working on a high-performance Ti-6Al-4V+TiC composite produced by blended elemental powder metallurgy. The process of blending elemental powder to develop premium quality titanium alloys has also been studied by U.S. companies. His other research interests include phase transformations, aging response and elevated temperature deformation characteristics of titanium alloys. The author and Dr. Fujii exchanged their research publications in fields of mutual interest. At ARL we are also extensively studying the effects of heat treatment, phase evolutions and high temperature deformation characteristics of titanium-based alloys and intermetallic compounds. The recent research activities of Nippon Steel researchers are usually published in the Nippon Steel Technical Report. It is a quarterly technical report published in English, which started in April 1972. Institutes, universities and companies in Japan and many other countries often publish their technical reports and product information in English. U.S. companies rarely publish their reports in any other language except English. We are proud that our national language is the international language. However, we will gain a greater competitive edge by communicating (in their languages) more often with potential foreign competitors. In 1988, the per capita national income in Japan was $18,227 versus $16,128 for the United States. This is a new world and we need to pay more attention to our competitors. The author briefly met with Mr. Yasuo Tsukahara who is the chief researcher.

Osaka University

Osaka University was established in 1931, and is one of the most prestigious universities in Japan. Dr. Hideki Yukawa of Osaka University is the first Japanese physicist who earned the Nobel Prize (in 1949). Also, Osaka University is very proud of their 3 million volt TEM. They claim this is the largest TEM in the world. Osaka University currently has 12 faculties and 1 college. The Faculty of Engineering was established in 1933 when Osaka Technological College was incorporated into the university. The establishment of Osaka Technological College dates back to 1896. The Faculty of Engineering has 20 departments including Materials Science and Processing, Materials Science and Engineering, Welding and Production Engineering, etc. The author was invited to visit the Department of Materials Science and Processing by Prof. Itsuo Ohnaka. He presented the author with a 52-page 1991-92 Osaka University bulletin, and much data and information in this report are cited from this bulletin. There are about 1.1 million books in Japanese or Chinese and 1.3 million books in other foreign languages in the university library. The Osaka University library combines Chinese and Japanese books in one category thus distinguishing Chinese from other foreign languages. It might be because Osaka University inherited a large amount of Chinese works when the library of Kaitokudo was absorbed. Kaitokudo was a Japanese institute established in 1724 under the direction of a Confucian scholar, Sekian Miyake. After all, the Japanese language originated from Chinese. These two countries have culturally influenced each other for hundreds of years. On July 6, 1992 the author presented a seminar entitled "Engineering Applicability of Al-Li Alloys" at Osaka University. The abstract of this presentation is attached as Appendix II.

There are many foreign students in Osaka University, most of them from Asian countries. Chinese students are, like in U.S. colleges, the most populous foreign student group. In the 1990-91 academic year, there were 250 Chinese scholars and researchers in Osaka University. The second most populous group comprises U.S. scientists with a total of 213 people. The collaboration between Osaka University and U.S. institutes is also very close. Osaka University has had a number of academic exchange agreements with U.S. institutes in the last 10 years.

Prof. Itsuo Ohnaka, a full professor in the Department of Materials Science and Processing, hosted the author and also introduced him to several other faculty and research associates from both the Departments of Materials Science and Processing and Materials Science and Engineering. He has worked on aluminum and titanium alloys. He also studies rapid solidification processing which the author has studied for years. They exchanged views of the advantages and shortcomings of various rapid solidification processes, and extensively discussed the directions of future development of aluminum alloys, particularly Al-Fe-based alloys. Prof. Ohnaka pointed out that his focus is usually different from that of U.S. researchers because the research in Japan is aiming at commercial instead of military applications. Prof. Norio Furushiro's research is primarily focused on phase transformations in aluminum alloys. He gave the author three of his technical articles published in English. They briefly discussed possibilities for visiting with each other and potential collaboration in the future. The author's research is more concentrated on the mechanical behavior of aluminum alloys while Prof. Furshiro's interest is more kinetics oriented. A collaboration could be established to complement each other's study. Prof. Shigeoki Saji has conducted extensive research in lightweight alloys, in particular Al-Li alloys. He gave the author six of his publications, three of them are in English, the other three in Japanese. Four of these articles discuss the mechanical properties of Al-Li alloys at cryogenic temperatures. Two articles deal with 8090 aluminum alloy which is also currently being extensively studied at ARL, but the focus at ARL is concentrated on room temperature and elevated temperature properties. The other two articles involve studies of the properties of Al-2Li-xMg (x=0,1 or 2) and Al-2.32Li-1.20Cu-0.67Mg-0.12Zr (wt%) alloys, both of them are of interest to ARL scientists. The fifth article reports the results of his study on the effect of microstructure on high-cycle fatigue behavior of an Al-1.82Li (wt%) binary alloy. Both binary and ternary Al-Li alloys have been extensively studied at ARL. The final article is particularly interesting. It discusses the composite or duplex precipitates in Al-Li-Ti alloys. We have a very similar program at ARL studying the composite precipitates of several Al-Li-Ti alloys. It is the author's belief that a close collaboration could be established between ARL and Osaka University in the study of aluminum alloys, provided it is supported by both institutes.

CONCLUSIONS

This trip has given the author an opportunity to present a technical paper at an international conference in China and a seminar at Osaka University. The chance to communicate with scientists and engineers from other countries and to visit three universities and Nippon Steel was most beneficial. The author found that scientists in China are currently conducting research in almost every important topic in materials science. The extensive human resources and immense natural resources will make China a leader in modern technology in the near future. The researchers and facilities in their key national institutes are catching up with western counterparts rapidly. The progress in China in the last 10 years is very impressive.

Hong Kong is now in transition from a colonial culture to a rather different system. The author visited the University of Hong Kong and the materials science program. They have moderately equipped research facilities. Their research activities are focused on mechanical behavior of polymers, microstructure and formability of ferrous alloys and environmental degradation.

It is interesting to note that researchers at both Nippon Steel and Osaka University primarily aim their applications at the automobile industry instead of aerospace. Nippon Steel is the largest steelmaking company in Japan, but has experienced steady decline in steel production in recent years. However, diversification into other alloy systems, e.g. titanium alloys and other fields, e.g. construction, chemicals and electronics, etc. has been able to keep Nippon Steel at the cutting edge of research in modern technology. The author visited the new Research and Engineering Center in Futtsu and was impressed by their research facility and engineering capability. However, the Japanese steel industry depends heavily on foreign raw materials. During the author's visit he discussed potential collaboration with Nippon Steel scientists and the discussion has continued after his return to ARL. The status of future collaboration is subject to the approval and support of both institutes.

The visit to Osaka University was fruitful. Several faculty members at Osaka University are conducting researches similar to that conducted at ARL. They and the author discussed research interests and ideas and exchanged publications with each other. Future collaborations between ARL and Osaka University and the two other universities the author visited are being considered. In conclusion, this trip was personally very successful and should be beneficial to the author's research at ARL.

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APPENDIX I. CONFERENCE ABSTRACT

First Pacific Rim International Conference on Advanced Materials and Processing

(Hangzhou, China, June 23-27, 1992)

Microstructure Control and Engineering Characterization of Super-α_2 Titanium Aluminide Alloys

ABSTRACT

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A super-α_2 titanium aluminide alloy was produced by rapid omnidirectional compaction of prealloyed Ti-25Al-10Nb-3V-1Mo (at%) [Ti-14.1Al-19.5Nb-3.2V-2Mo (wt%)] powder. Various solution and aging heat treatments were investigated to yield the best combination of tensile and stress rupture properties. The β-transus temperature was found to be about 1,090°C (1,990°F). The alloy was heat-treated with four different schedules to develop various structure combinations of α_2 and β, and followed by a series of microstructural analyses and mechanical property determinations. The highest ultimate tensile and yield strengths attained at room temperatures were 1,174.9 and 977.7 MPa (170.4 and 141.8 ksi), respectively, for a specimen heat treated at 1,140°C (2,084°F) for 1 hr and aged at 816°C (1,500°F) for 4 hr + air cooling. However, the elongation was less than 2%. Under the same heat treatment condition, the ultimate tensile and yield strengths at 427°C (800°F) were 1,139.1 and 711.6 MPa (165.2 and 103.2 ksi), respectively, with an elongation of 6.7%. The alloy also showed good stress rupture resistance. Profound effects of the morphologies of the constituent phases on the alloy mechanical properties were observed, under otherwise similar conditions, ductility increased with the aspect ratio of the α_2 phase but the tensile strength was inversely related to the aspect ratio. In general a plate-like α_2-phase provided a good combination of ductility and strength. Both optical and scanning microscopy was employed to investigate the fracture mechanism. During the tensile and stress rupture tests, multiple transverse cracks nucleated both along the specimen surface and internally. No preferential crack nucleation sites could be found. The coalescence of cracks within the same plane (transverse to the applied stress) was the fracture-controlling factor. Colony-type intergranular fracture with ductile microvoids was predominant in the stress-ruptured surface. However both colony-type intergranular and sheared transgranular fractures occurred in the tensile specimens depending on the material microstructure. For stress rupture and tensile specimens containing well defined prior β grains, colony-type fracture occurred. The average colony size was usually five to seven times larger than the prior β grain size, and resulted from the linkage of cracks in several β grains.

The comparison between ROC'ed and HIP'ed alloys reveals that the ROC'ed material has superior mechanical properties at both room and elevated temperatures. At room temperature the yield strength for the ROC'ed material is about 50% higher and the reduction of area more than double that of the HIP'ed counterpart. A similar result is observed at elevated temperatures, with the most striking benefit of the ROC process being the improvement of ductility. At 427°C (800°F), the elongation of the ROC'ed material ranges from 6.7 to 22.8% versus 0.1 to 5.9% for

the HIP'ed material. The ROC'ed material also exhibits better stress rupture properties. The inferior mechanical properties of the HIP'ed material can be partially attributed to a coarser microstructure, resulting from longer exposures to higher temperatures during the consolidation process.

APPENDIX II. SEMINAR ABSTRACT

Engineering Applicability of Al-Li Alloys

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ABSTRACT

This comprehensive study on the engineering applicability of advanced Al-Li alloys has involved the effects of processing, microstructure and minor alloying elements on the mechanical/physical properties of these alloys. The lower density, higher tensile strength and stiffer modulus resulting from the addition of Li to Al alloys make Al-Li alloys attractive material candidates for the future lightweight vehicles and aircraft.

The addition of one weight percent of Li to conventional Al-Cu (2000 series) alloys can decrease the density by about 3%, so with the resultant increases in Young's modulus and the tensile strength this can lead to even better specific modulus and strength values. However, the lower ductility and fracture toughness values currently restrict the engineering applicability of this class of alloys. Both rapid solidification and ingot metallurgy processes are being employed to reduce these limitations for advanced Al-Li alloys. The rapid solidification process maximizes the amount of Li in solid solution while helping refine and homogenize the microstructure. Ingot metallurgy processes which can reduce oxide content provide materials with better ductility. The effects of Li content and solidification processing on the microstructure and properties of Al-Li alloys are presented. To improve the inferior fracture toughness of Al-Li alloys resulting from localized slip deformation easily cutting through the ordered precipitates δ' (Al_3Li), the addition of transition elements Ti and Zr, etc. can produce "composite" precipitates which retard the extent of localized slip.

Also included is a brief review of recent studies on Al-Li alloys with their potential engineering applicability. This information is collectively summarized, systematically compared and individually analyzed to establish guidelines for future Al-Li developments.

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