ROLE OF A MATERIALS-SCIENCE BASE IN SUSTAINABLE DEVELOPMENT

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ABSTRACT

Materials are the backbone of technological development in a country. No industry, no machinery and no product can by-pass a thorough knowledge of the materials. The Metallurgy Division, KRL, is routinely involved in characterization of materials, and recommending best-suited alternate materials for different high-tech applications. With its state-of-the-art equipment and highly educated and trained manpower, the Division has a diversified experience in addressing problems encountered, not only in KRL, but also in state and private industries in Pakistan. The paper discusses our potential and experience to handle a wide spectrum of projects in the field of materials and the assistance this Division has rendered to the public and private industry in the country.

MATERIALS BASE

The Metallurgy Division of KRL caters for the materials-problems in our centrifuge and missile projects. The collaboration of the Metallurgy Division with public and private industry in the country is evolving. It is imperative that organizations capable of collaborating with local industry should discuss their potentials and disseminate information about their capabilities. The potential of the Division as a materials base is discussed in terms of the existing facilities and manpower. Its role to sustain industrial development can be judged by the activities of the Division, both within the organization and with the organizations in the vicinity.

EQUIPMENT

The division is equipped with state-of-the-art equipment, which deals with the following:

Metallography and Microscopy

Investigations on materials start form Metallography. The optical microscopy system is attached with a computerized image-analysis system, which quantifies the micro-structural features. If higher magnification is required, we go to electron microscopes. The scanning electron-microscope can accommodate a variety of samples, including fracture surfaces. In transmission and scanning transmission, we may go to magnifications up to one million times. The electron microscopes have an attached spectroscopy-system, to conduct chemical analysis of selected localized features.

Spectroscopy

The general chemical analysis of bulk samples is usually conducted by energy- dispersive spectroscopy, attached with scanning electron-microscope or emission spectroscopy. The concentration of trace elements is determined by using atomic absorption spectroscopy or inductively coupled plasma. The concentration of carbon/sulphur or dissolved gases is determined by using rapid determinators. It may be pointed out that the concentration of 4 atoms of hydrogen in one million atoms of matrix is sometimes not permissible in high-strength steels. The chemical analysis determines the elements present in the material and their concentrations, but does not discuss their arrangement which affects the mechanical properties of the material.

Crystallography and Texture

The arrangement of atoms in the material is determined by x-ray or electron diffraction. The most commonly used instrument is diffractometer, while Debye Sherrer camera is used for precision work. To determine the orientation of atomic planes in a single crystal, for example in wafers used in solar cells, Weisenburg Precision Camera is used. The texture goniometer is used for research purposes.

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To impart required structure to a material of given composition, the material is subjected to the required heat treatment cycle.

Heat Treatment

The laboratories are equipped with a variety of heat-treatment facilities. The process can be conducted in air and, for cleaner materials, in vacuum or in the presence of inert gases. Sometimes, heating in reactive gasses is needed to synthesize the required coatings on the surface of components. The heat-treatment furnaces are programmable and can ensure required temperatures and heating/cooling rates. The appropriate heat-treatment gives the required mechanical properties to the material, which can be confirmed by testing standard samples in the mechanical testing laboratory.

Mechanical Testing Laboratory

The facilities in mechanical testing include traditional macro-hardness testers, while micro-hardness testers determine hardness values of individual phases, surface layers/coatings or localized regions. The impact-testing facility determines toughness of the material at room, as well as cryogenic temperatures. The universal testing-system determines uni-axial properties of the material: these include tensile, compression, shear, three-point bend test, etc. Standard samples, components and intricate joints are routinely tested at room, cryogenic and elevated temperatures. The fracture-mechanics lab is involved in studying the crack-propagation behavior and fatigue properties. For aerospace materials, thermo-mechanical fatigue testing can be conducted. In addition to the above, the manpower is capable of designing and conducting dedicated tests, like the phenomenon of hydrogen embrittlement.

Coatings

The designer and user of materials today impose stringent conditions, which sometimes cannot be met by one material. A component, for example, is made from steel to impart required toughness and strength and is then coated to provide the required wear, corrosion or fatigue resistance. The steel component used in ammonia atmosphere in a local fertilizer-industry has a life of 2000 hours. After it was coated with TiN in our laboratory, the life is enhanced to more than 3 times this. The coating is only a fraction of a millimetre thin. Other cutting tools exhibit an increase in life from 3 to 10 times.

Corrosion

The group working in corrosion is conducting research, not only in aqueous corrosion, but also in gaseous phase, which is a requirement for the centrifuge- project where corrosive UF_6 gas is used. With Pakistan Navy, we have worked on a project to scan the waters of our shores in order to analyse the hazard of corrosion in our vessels.

Magnets

The magnets group is not only involved in studying magnetic materials but is also responsible for their production. Most of the equipment they are using is designed and developed within the Division itself.

Ceramics

This is a newly evolved group, which has developed quite a few critical components in a short time. The group is capable of manufacturing precision- components of high-density alumina.

MANPOWER

An obvious question would be the calibre and expertise of the manpower in the division. More than 30% of the technical personnel in Metallurgy Division are scientists and engineers. The Division has a number of Ph.D.s working in different fields of Metallurgy, Materials Science and Applied Physics.

In the wake of the financial crunch, it is getting increasingly difficult to acquire new state-of-the-art equipment for R & D in Pakistan. It may be pointed out here that, to keep equipment in running condition is more difficult, while the most difficult task is to use the equipment and generate useful results. Let us now discuss what are the activities of the manpower in our Metallurgy Division.

ACTIVITIES

In general, the activities of the Division are divided into three categories, and these are:

- Production related activities, which include heat treatment, synthesis of coatings on components and vacuum melting and casting.
- The Division provides services of chemical analysis, mechanical testing, failure-analysis of components, etc., to other divisions and also to other organizations in the vicinity.
- The ongoing R & D activities encompass projects of KRL's interest, collaborative work with researchers in other organizations, and basic research.

Topics in Research and Development

The topics of ongoing research include studies on Managing Steel from different aspects; these include:

- Effect of γ-phase on Gas Nitriding
- Formation of solid-state dendrites during heat-treatment in oxidizing atmosphere
- Growth and Texture of oxide film
- Stress Corrosion Cracking
- Effect of Over-load on life-extension
- Surface-hardening, using selective ageing
- Strain-hardening, using thermal cycling

The interest on other materials includes:

- Prolonged ageing of Al-Mg-Si alloys
- Development of Cr-Co-Mo , special steels and Cu-base alloys
- Boriding on Inconal
- Corrosion of special steels in HNO_3
- Synthesis of Tool steel on Mild Steel, using electron-beams and lasers
- Transformations in TiNi
- Recycling of Ni-Cr-Fe-Mo Dental material

The R & D projects include development of components, like IR sensors and turbine blades for missile projects.

Different equipments recently developed, or presently being developed includes:

- Atomization chamber to produce clean metallic powders.
- Vacuum Arc Double Electrode Remelting Furnace, to clean steels from dissolved gases and segregation.
- Magnetic Annealing Furnace, to process magnets.
- Thermo-magnetic Dilatometer
- B-H curve-tracer, operative at elevated/ cryogenic temperatures
- Wear-test machine
- Bend-test machine

Collaboration with other Organizations

The Metallurgy Division is collaborating with various organizations in the country and even outside Pakistan. These include educational institutes, R & D organizations and industries in public and private sector. Keeping in view the interest of participants in this Seminar, we will discuss development of a critical component from weapon-grade material in Pakistan, through collaborative work of KRL, PSM, HMC and HIT. The project is “Indigenous development of the first Pakistani 105 mm tank gun-barrel”.

Development of the 1st Pakistani 105 mm Tank Gun Barrel

The 105 mm barrels are deployed on T-59 tanks in Pakistan Army. The idea to locally produce 105 mm gun-barrel goes back to the times when Heavy Mechanical Complex (HMC), Taxila, acquired (quite sometime ago) complete facilities to forge and heat-treat the gun-barrel blanks. These include a 3150 -ton press, the biggest in the country even today, pit furnaces (probably the deepest in the country) and similar associated facilities. The major missing step in the complete indigenization was the facility to produce materials of high purity.

With the rehabilitation and modernization of Peoples Steel Mills (PSM), the problem could be addressed. The hierarchy at KRL decided to coordinate with PSM, HMC and HIT, to bring the theoretical possibility of local manufacture of the barrel into a reality. A team of KRL experts was involved throughout the production cycle and the subsequent testing of the barrel.

By any criterion, the barrel exhibited promising results. The accuracy, muzzle-velocity and wear-resistance are comparable to any standard. The life of the barrel was predicted, based on the wear data. The Pakistani barrel, with the grace of Allah, is second to none in its performance.

Collaboration with Pakistan Air Force

The interaction with Pakistan Air Force started in the 90’s, when repeated accidents of our aircrafts occurred. Since then, we have conducted numerous failure-studies and are working on development of critical components.

Collaboration with Pakistan Navy

The interaction with Pakistan Navy exists in different projects, which include sea- water analysis, development of composite-seal, made of bronze graphite, development of different components of sensitive nature, but the most noteworthy project was Sonar Hydrophones refurbishment.

POTENTIAL FOR SUSTAINABLE HIGH-TECHNOLOGY PROJECTS

The division has the potential to promote some mega-projects in the country. These include state-of-the-art Sonar laboratory for design and development of sonars according to our requirement. The other important field in which we can venture is the establishment of units to repair and develop components for high- tech aerospace applications.

In principle, the Metallurgy Division, KRL, foresees a broad potential of cooperation with other public and private-sector organizations in the country. There is sufficient potential for the enhancement of activities in the field of high-technology materials.