PROSPECTS OF UTILIZING ADVANCED TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT IN DEVELOPING COUNTRIES

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ABSTRACT

Rapid industrialization, export enhancement, self-reliance and minimizing the import could be the basic targets of the developing countries in order to strengthen the economy. However, the engineering industries (automobile, textile, chemical, machine-tools, etc.) have failed to achieve the targets set for deletion of imported parts. The reason for this state of affairs can be attributed to the inability of the local industry to manufacture good-quality products, due to use of out-dated techniques and lack of technical know-how. The situation can be rectified by restoring the production of those engineering-based parts locally. To achieve these targets, capacity-building in science and technology is vital, especially in the developing countries.

This paper describes the imperative technologies in the field of Materials-Science and explains their promising features and optimum utilization for the enhancement of imports-substitution and export of values-added products in the engineering sector.

IDENTIFICATION OF LOW AND HIGH-TECH PROJECTS FOR MATERIALS AND PROCESSES

Industry in the present-day world is the backbone of a country's economy and prosperity. In Pakistan, concerted efforts are being made to develop a self-reliant economy. What it means, in actual terms, is that the agro-based economic system should be changed to an industrial-based system, i.e. we must attain autarky in the field of industrial production.

This simple realization of the ground-reality requires action in certain areas. In fact, we have been exploring ways and means to overcome our technology-problem. But nothing seems to have succeeded so far. The present government has taken steps to strengthen the infrastructure and has set the ball rolling; Industrialization should now be a matter of time only. However, the Government alone cannot succeed in its great leap forward, unless all sections of the society engaged in this process can perform their individual, specific roles properly. We, as scientist, must be able to identify the usefulness and relevance of the technologies that should be adopted or materials to be developed. This is most essential in order to avoid wastage of time, resource and the materials.

Having made this observation, let us proceed on to recognize the fact that, so far, we have not succeeded in building a sound technological set-up based on low-technology. This is not to say that first priority must be given to low-tech. In fact this is not entirely necessary. Now is the time to develop high-technology as quickly as possible. We have to live in the contemporary world and compete with contemporary reality, which is now defined by new and emerging technologies and materials.

The high-technology basically aims at developing materials which are lighter, stronger, more resistant to effects of aggressions of environment; they are longer lasting, they are appealing to the eye and maintain their appeal for longer time. High technology also aims at miniaturization, automation, precision and enhanced productivity.

New and emerging technologies have revolutionized, transport, automation, industrial production, communication, bio-medics, diagnostics of every kind, avionics and space travel, etc. It is really now high time to create these facilities in the developing countries, so that capacity-building in science and technology can be enriched in many ways.

AREAS OF NEW AND EMERGING TECHNOLOGIES

The specific areas of the new and emerging technology that need our immediate attention pertain to the following specific fields.

i Powder Metallurgy And Metal Matrix Composites
ii Composite Materials And Engineering Ceramics

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iii Shape Memory Alloys
iv Single Crystals
v Materials For Defence
vi Special Alloys For Surgical And Biomedical Use
vii High-Temperature Alloys
viii Plastics, Composite Plastics And Ceramic Polymers
ix Materials For Sports Industry
x New Magnetic Materials & Ceramic Magnets
xi Surface Modification By Plasma, CVD And PVD Techniques
xii Nano-Technology, With Special Emphasis On Nano-Materials And Their Characterization For Engineering Industrial Applications.

In the light of the abvoe list, projects/schemes of short and long-term duration in the following fields are recommended to be undertaken.

Powder Metallurgy And Metal Matrix Composites

The techniques utilize compaction of powder mixtures, composite powders and/or pre-alloyed powders, followed by sintering and coining for the production of complex shapes, such as gears, pistons and bush bearings. The technique is now being employed for the production of new magnets, ceramics magnets, engineering ceramics, hard metals, refractory metals, etc. The materials are intensively being used in the automobile industry, electronics, avionics and space-research.

Similarly, Metal matrix composites have achieved considerable attention in the developed countries, due to high strength, high specific modulus, high-temperature properties and lower expansion-coefficient. MMCs have wide industrial applications in aerospace, auto and defence industry.

In Pakistan, powder metallurgy and Metal matrix composite posses great potential for industrial applications.

Composite Materials And Engineering Ceramics

Composite materials can be classified into metal-matrix composites and ceramic-matrix composites. These materials, due to light weight and high strength along with ability to withstand high temperatures, have properties that render them highly useful in a variety of applications i.e. electronics, automobiles, space craft, biomedical and tribological applications.

Glass-reinforced thermosetting plastics are presently competing with both steel-sheet and zinc die-casting. The use of low-cost composites in the automotive industry has already reached impressive performance.

Carbon fibers have emerged as the main reinforcement-fibre for high-performance composite materials. The development of strong and stiff carbon-fibres for a wide range of industrial applications and their use in lightweight structural parts are among the principal technological achievements of this period. High strength and stiffness, light weight, improved fatigue-resistance, corrosion-resistance, good friction and wear-qualities are promising features of this material. Moreover, low thermal expansion and thermal and electrical conductivity combine to make these composites an attractive substitute for various metals, special alloys and other materials [1].

In recent years, there has been a marked improvement and growth in the engineering materials. This is manifest in the development of various high-performance smart engineering materials. These advanced engineering composites, because of their unique and promising features, are replacing the traditional materials.

Keeping in view these factors, advanced composites materials possess a great potential for a wide range of industrial applications in auto, textile, and chemical and petrochemical, dentistry fields.

Shape-Memory Alloys

[So called because they return to original shape after the constraint (heat or stress) has been removed].

Those alloys, which exhibit thermo-elastic martensitic transformation properties, are called shape-memory alloys. These alloys can be divided into ferrous and non-ferrous categories. These alloys are useful in a variety of applications like pipe-coupling, electrical connectors and thermo-elastic switches for automations of industrial plants, communications, avionics and space crafts applications. These alloys are also employed for medical applications (bone plates, catheter bends etc.)

Single-Crystal Alloys

Single-crystal alloys have assumed enormous importance for research and technology, especially in the fields of electronics, electro-optics, metal corrosion, semi-conductors and magnetic bubbles materials.

Materials For Defence

For defence we need a wide range of materials, which includes the following:

- Special alloy steel
- SG Iron
- Precision casting alloys
- LM, 2000, 6000 and 7000 Aluminum series, cast and wrought alloys.
- Advanced engineering composites. i.e. carbon fiber, metal matrix and MMC composites.
- Engineering Polymers
- Plasma coatings of ferrous, non-ferrous, cermits, ceramics coatings.
- Thermal barrier coatings [TBC]. (Zirconia with additives) for high-temperature application.
- CVD and PVD surface-coatings techniques.
- Heat-treatment salts and chemicals
- Transfer of high-tech technologies
- Engineering ceramics etc.

Special Alloys For Surgical And Biomedical Uses

Surgical instruments are one of the major source of export-oriented products in the country. Major part of these alloys is being imported from different countries like Japan, France and Germany; however, about thirty thousand ton of stainless steel of surgical grades, along with twenty-five to thirty tons per day of stainless steel, is being locally re-melted/produced by different small units, especially in Gujranwala and vicinity areas [2]. The re-melting units in these industrial areas are producing generally disposable type of cheap stainless-steel products. However, the castings required for various grades of surgical stainless steel must conform to the standard specifications requiring high quality. The local industry, without possessing relevant abilities, can't produce these grades of high quality. Therefore, local efforts to produce these grades of stainless steel are vital to get a major share of export. We really have to create facilities to produce these materials, along with human-resource development in these fields, to meet the future requirements.

Orthopaedic Implants

In Pakistan, every year the Government spends million of dollars for the imports of various orthopedic implants. However, in the country there are a few companies in Gujranwala who are manufacturing (remelting) these implants locally. It has been practically observed that the quality of these implants is so inferior that if subsequently caused severe damage and even loss of life. These implants of proper quality can be locally manufactured in developing countries by employing standard techniques and the surface can be modified by plasma sprayed with titanium, which not only improves wear-resistance and life but also their bio-compatibility with human body.

High-Temperature Alloys

High-temperature alloys can withstand high temperatures without any physical and mechanical change in materials. Therefore due to these characteristics, these possess large number of applications in aerospace, refineries, high-temp. furnaces and kilns, turbines, high-temp. Creep and fatigue-resistant materials.

Polymers (New And Super)

The term polymer – polymer composites refers to a materials in which rigid, rod-like polymer molecules are dispersed at molecular level in a flexible coil-like polymer of similar chemical composition. With dispersion at this level, the materials are sometimes also known as molecular composites. Polymer composites offers three advantages over polymer-fiber reinforced polymers. Firstly, because of flaws and imperfect alignment of chains with in fibers, the strength of an isolated polymer molecule exceeds, by an order of magnitude or more, the strength of fibers produced from the same polymers. Secondly, fiber-reinforced composites can present adhesion problems at fiber–matrix interface, leading to loss of strength. Thirdly, due to the stress-transfer region at fiber ends, it is only when the axial ratio is high enough that the full reinforcement of the fiber is realized.

These new materials possess great industrial potential in the industry, especially in developing countries.

Materials For Sports Industry

More advanced composite materials are being used in sports industry due to high strength, high stiffness and low weight. When we see the comparative stiffness of steel wire, glass and pitch-based carbon fibers, it shows the carbon-fibers as the stiffest one; this anisotropy of the properties of advanced fiber-composites represents a completely new feature.

The utilization of carbon-fiber reinforced plastics for sports goods has a wide range of application, like fishing rods, golf-club skillets, bicycles and structural members of racing kayaks and yachts. High strength and stiff, light weight with improved fatigue resistance, corrosion resistance, good friction and wear, combine to make carbon-fiber an attractive substitute for various metals, special alloys and wood [1].

Consumers now prefer to buy light-weight, high-strength, better stiffness and fatigue-strength materials as compared to the conventional wooden items. This trend has shown an adverse effect on the export of sports items from Pakistan. Therefore, it is important that to enhance our export, we must focus our attention for the development of carbon-fiber sports items, along with other composites for wide variety of its applications in Pakistan.

Magnetic Materials *(Permanent And Non-Permanent)*

New emerging magnetic materials, like Nd-Fe-B, could be utilized as magnetic materials due to their better magnetic properties. These materials are being extensively used in electronic, communications and avionics industries.

Surface-Modification of Engineering-Based Materials By Plasma Spraying

The Surface modification is a valuable technique that makes it possible to add new properties, only on the top of the surface, irrespective of its internal characteristics; this is most commonly done by coating. Generally, the following techniques are in practice in order to produce various kinds of coatings on industrial scale: evaporation, plasma spray, sputtering, chemical vapour deposition and PVD etc. [3].

Plasma spraying is emerging as an excellent technique to produce a wide variety of coatings on an industrial scale [4]. These coatings are quite useful for corrosion or erosion resistance, thermal barrier for high temperature or for dimensional-accuracy industrial and high-tech applications [5].

Pakistan is one of the major exporters of various textile items in the world. Our economy is mainly based on the export of these textile products. There is no proper scientific research and development for the development of textile parts, its repair and local deletion. These textile industries spend billions of rupees for the import of various textile parts, causing a staggering effect on the economy. The situation can be rectified considerably by restoring to production and repair of these parts locally. Same situation exists for automobile, chemical, petrochemical, defence, power-generation, and fertilizers industries. So plasma spraying is an answer to produce and reclaim worn out parts for a wide variety of industrial coatings.

Future R&D Programme

These techniques possess a wide range of industrial and R&D applications in the industry. Therefore, a wide range of long and short-term projects can be prepared according to industrial demands for high wear- resistance, corrosion and erosion resistance, production of high-temperature coatings and reclamation of worn-out industrial parts. A huge amount of foreign exchange can be saved for textile, chemical, petrochemical, auto industries in developing countries.

Nano-Technology With Special Emphasis On Nano-Materials And Their Characterization For Engineering Industrial Applications

Nano-scale science and technology enables controlled component design and fabrication, on atomic and molecular scales. Nano-related R&D units, findings and processes from biotechnology and genetic engineering, with chemistry, Physics, electronics and Materials science, with the aim of manufacturing cost-effective innovative products are now coming up, as below:[6].

Industrial Applications

- Biomedical
- Nano tribology
- Nano-mechanical system
- Nano-machining
- Nano thin films
- Nano-scale technologies to produce miniaturized and inexpensive electronic, sensing and actuator system.
- Chemical, biological and drug sensors
- Nano-scale powders for specific industrial application

Development Of Nano-Powder In Pakistan

These powders have got considerable industrial potential and applications can be summarized as follows:

- Conductive coating and paste
- Electrode for MLCC (multi-layer chip condenser)
- EMI shielding coatings
- Dielectric and piezoelectric
- Hi-Tech microwave filter
- Transducer
- Anti-static coatings on plastic sheets

Nano-structured Materials

The world-market for materials is estimated almost $10 billion per annum and this demand is growing rapidly. More recently, with the advent of the tools of Nano-technology, materials-science has been transformed to a point that the relationship between the structure of a material and its properties can now be controlled.

Materials possess very promising and different properties when nanostructured. The much finer grain-size can be used to produce denser materials, with greatly improved mechanical properties. Aerospace and defence will also benefit from the new lightweight, high-strength nano-composite materials and even ceramics, as well biomedicine in stronger hip-prostheses.

CONCLUSIONS

The current import-bill for auto, textile and orthopedic implants and engineering goods in the developing countries is running into hundreds of billions p.a., causing a staggering effect on the economy. This situation can be rectified by resorting to production of these engineering based parts locally; which requires:

a. Up-gradation and improvement of technological set up
b. Enhancement of technical skill and manpower
c. Improvement of product-quality, through R&D inputs.
d. Export enhancement of value-added products

These measures are key-factors to more rapid industrialization, export enhancement, self-reliance and minimize the import in the developing countries. However, local efforts, especially R&D input pertaining to material technology, are necessary for the sake of production and development of these advanced materials locally, to meet the challenge of 21st century's demand for low-cost and efficient materials.

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