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ADVANCEMENT IN METALLURGICAL ENGINEERING

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ABSTRACT
Metallugical Engineering is the science and technology of producing, processing and giving proper shape to metals and alloys and other Engineering Materials having desired properties through economically viable process. Metallurgical Engineering has played a crucial role in the development of human civilization beginning with bronze-age some 3000 years ago when tools and weapons were mostly produced from the metals and alloys.Science and technology has matured over millennia and still plays crucial role by supplying materials having suitable properties In the recent decades Scientists and Engineers around the world have been responding to the requirement of high performance materials through innovative material research and engineering. The ever increasing demand on quality and reliability has resulted in some dazzling technological achievements in the area of advanced materials and manufacturing. From gold nano-structure to advanced superalloys that are used not only in a complex structurs such as aeroplanes but also in clinical treatments. Recent Researches in Metallurgical Engineerig, From Extraction to Forming that deals with all sorts of metals-related areas including mineral processing, extractive metallurgy,heat treatment,casting,welding and forming metallugy.

KEYWORDS: Scientists, Engineers, Technological, Manufacturing, Civilization, Extractive, Casting, welding, forming

INTRODUCTION
Metallurgy is a domain of materials science and engineering that studies the physical and chemical behaviour of metallic elements, their intermetallic compounds, and their mixtures, which are called alloys. Metallurgy is also the technology of metals : the way in which science is applied to the production of metals, and the engineering of metal components for usage in products for consumers and manufacturers. The production of metals involves the processing of ores to extract the metal they contain, and the mixture of metals, sometimes with other elements, to produce alloys. Metallurgy is distinguished from the craft of metal working, although metal working relies on metallurgy, as medicine relies on medical science, for technical advancement.

Metallurgy is subdivided into *ferrous metallurgy* and *non-ferrous metallurgy.* Ferrous metallurgy involves processes and alloys based on iron while non-ferrous metallurgy involves processes and alloys based on other metals. The production of ferrous metals accounts for 95 percent of world metal production[1].

HISTORY
The earliest recorded metal employed by humans appears to be gold, which can be found free or "native". Small amounts of natural gold have been found in Spanish caves used during the late Paleolithic period, c. 40,000 BC[2]. Silver, copper, tin and meteoric iron can also be found in native form, allowing a limited amount of metalworking in early cultures[3]. Egyptian weapons made from meteoric iron in about 3000 BC were highly prized as "daggers from heaven"[4].

Certain metals, notably tin, lead and copper, can be recovered from their ores by simply heating the rocks in a fire or blast furnace, a process known as smelting. The first evidence of this extractive metallurgy dates from the 5th and 6th millennia BC[5] and was found in the archaeological sites of Majdanpek, Yarmovac and Plocnik, all three in Serbia. To date, the earliest evidence of copper smelting is found at the Belovode site[6], including a copper axe from 5500 BC belonging to the Vinča culture[7]. Other signs of early metals are found from the third millennium BC in places like Palmela (Portugal), Los Millares (Spain), and Stonehenge (United Kingdom). However, the ultimate beginnings cannot be clearly ascertained and new discoveries are both continuous and ongoing.

These first metals were single ones or as found. About 3500 BC, it was discovered that by combining copper and tin, a superior metal could be made, an alloy called bronze, representing a major technological shift known as the Bronze Age.

The extraction of iron from its ore into a workable metal is much more difficult than for copper or tin. The process appears to have been invented by the Hittites in about 1200 BC, beginning the Iron Age. The secret of extracting and working iron was a key factor in the success of the Philistines[4,8].

Historical developments in ferrous metallurgy can be found in a wide variety of past cultures and civilizations. This includes the ancient and medieval kingdoms and empires of the Middle East and Near East, ancient Iran, ancient Egypt, ancient Nubia, and Anatolia (Turkey), Ancient Nok, Carthage, the Greeks and Romans of ancient Europe, medieval Europe, ancient and medieval China, ancient and medieval India, ancient and medieval Japan, amongst others. Many applications, practices, and devices associated or involved in metallurgy were established in ancient China, such as the innovation of the blast furnace, cast iron, hydraulic-powered trip hammers, and double acting piston bellows[9,10].

A 16th century book by Georg Agricola called *De re metallica* describes the highly developed and complex processes of mining metal ores, metal extraction and metallurgy of the time. Agricola has been described as the "father of metallurgy[11]".

EXTRACTION

Extractive metallurgy is the practice of removing valuable metals from an ore and refining the extracted raw metals into a purer form. In order to convert a metal oxide or sulfide to a purer metal, the ore must be reduced physically, chemically, or electrolytically.

Extractive metallurgists are interested in three primary streams: feed, concentrate (valuable metal oxide/sulfide), and tailings (waste). After mining, large pieces of the ore feed are broken through crushing and/or grinding in order to obtain particles small enough where each particle is either mostly valuable or mostly waste. Concentrating the particles of value in a form supporting separation enables the desired metal to be removed from waste products.

Mining may not be necessary if the ore body and physical environment are conducive to leaching. Leaching dissolves minerals in an ore body and results in an enriched solution. The solution is collected and processed to extract valuable metals.

Ore bodies often contain more than one valuable metal. Tailings of a previous process may be used as a feed in another process to extract a secondary product from the original ore. Additionally, a concentrate may contain more than one valuable metal. That concentrate would then be processed to separate the valuable metals into individual constituents.

Materials selection was much easier in 1901. The steel age had become dominant because of the availability of cheap steel produced by the Bessemer & Open-Hearth Processes in the later part of the 19th century. Mild steel, in particular enabled the construction of large bridges, oceans liners, trains and then the motorcar. Already a country's annual steel production was being used as a quick indicator of its industrial strength, a criterion that persisted for much of insuring century. The world production of steel had riched some 1670.1 million metric tones by 2014 which compared with 10,536,000 thousand tones of lead the next most used metal and around 18,500 and 11,200 thousand tones copper and zinc respectively . Apart from the precious metals, tin was the only other base metal having significant industrial importance. Polymer science and Technology was in its

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infancy, with "celluloid" (cellulose nitrate softened with camphor oil) being the only synthetic plastics so far invented. Ceramics were confined essentialy to pottery and building materials.

ALLOYS

Common engineering metals include aluminium, chromium, copper, iron, magnesium, nickel, titanium and zinc. These are most often used as alloys. Much effort has been placed on understanding the iron-carbon alloy system, which includes steels and cast irons. Plain carbon steels (those that contain essentially only carbon as an alloying element) are used in low-cost, high-strength applications where weight and corrosion are not a problem. Cast irons, including ductile iron, are also part of the iron-carbon system.

Stainless steel or galvanized steel are used where resistance to corrosion is important. Aluminium alloys and magnesium alloys are used for applications where strength and lightness are required.

Copper-nickel alloys (such as Monel) are used in highly corrosive environments and for non-magnetic applications. Nickel-based superalloys like Inconel are used in high-temperature applications such as gas turbines, turbochargers, pressure vessels, and heat exchangers. For extremely high temperatures, single crystal alloys are used to minimize creep.

RECENT ADVANCES IN 3D PRINTING OF BIOMATERIALS

Biomaterials for medical use have been developed in accordance with progress of the fields of medicine, biochemistry, material science, and pharmaceutics. Advances in the medicine have changed the concept of surgery from the deletion of damage tissue for the preservation of the remaining healthy tissue to the reconstruction or replacement of damaged tissue by promoting regeneration of the natural tissue. All the materials used in medicine should be biocompatible. Conventional materials such as metals, ceramics, and synthetic polymers are usually bioinert and support the structural defects. But recently introduced biomaterials are designed to provide biological functions as much as possible by mimicking natural tissue structures.

Three Dimensional Printing (3DP) fabricates 3D structures by inkjet printing liquid binder solution onto a powder bed[13-15]. A wide range of materials has been utilized in printing since most biomaterials exist in either a solid or liquid state.

RECENT ADVANCES IN FERROUS POWDER METALLURGY

Ferrous Powder Metallurgy (P/M) has advanced significantly over the past thirty years in providing opportunity for a parts designer and producer to make high strength net shape parts. Currently, for example, transmission gears in U.S. build cars use P/M parts. This review addresses recent advances in the area of ferrous powder for the P/M industry. Development of molybdenum prealloyed powder for increased density. Cr-Mn containing powder for through hardenability and improved wear resistance, binder treated powders for higher control of alloying ingredients and increasing compaction rates are presented. Two major innovations, namely achievement of higher compaction densities through warm compaction and improved magnetic properties by dielectric coating on iron powders

Metalworking processes

Metals are shaped by processes such as:

- Casting – molten metal is poured into a shaped mold. Various forms of casting exist in industry and academia. These include sand casting, investment casting / lost wax process ,die casting, and continuous casting.
- Forging – a red-hot billet is hammered into shape.
- Rolling – a billet is passed through successively narrower rollers to create a sheet.
- Laser cladding – metallic powder is blown through a movable laser beam (e.g. mounted on a NC 5-axis machine). The resulting melted metal reaches a substrate to form a melt pool. By moving the laser head, it is possible to stack the tracks and build up a three-dimensional piece.

- Extrusion – a hot and malleable metal is forced under pressure through a die, which shapes it before it cools.
- Sintering – a powdered metal is heated in a non-oxidizing environment after being compressed into a die.
- Machining – lathes, milling machines, and drills cut the cold metal to shape.
- Fabrication – sheets of metal are cut with guillotines or gas cutters and bent and welded into structural shape.
- 3D printing – Sintering or melting powder metal in a very small point on a moving 'print head' moving in 3D space to make any object to shape.

Cold-working processes, in which the product's shape is altered by rolling, fabrication or other processes while the product is cold, can increase the strength of the product by a process called work hardening. Work hardening creates microscopic defects in the metal, which resist further changes of shape.

Heat treatment
Metals can be heat-treated to alter the properties of strength, ductility, toughness, hardness and/or resistance to corrosion. Common heat treatment processes include annealing, precipitation strengthening, quenching, and tempering[12]. The **annealing** process softens the metal by heating it and then allowing it to cool very slowly, which gets rid of stresses in the metal and makes the grain structure large and soft-edged so that when the metal is hit or stressed it dents or perhaps bends, rather than breaking; it is also easier to sand, grind, or cut annealed metal. **Quenching** is the process of cooling a high-carbon steel very quickly by dipping in liquid ,oil or fused salts after austenetic temperature heating, thus after"quenching" the steel's, a very hard martensite form, which makes the metal harder. There is a balance between hardness and toughness in any steel; the harder the steel, the less tough or impact-resistant it is, and the more impact-resistant it is, the less hard it is. **Tempering** relieves stresses in the metal that were caused by the hardening process; tempering makes the metal less hard while making it better able to sustain impacts without breaking.

Often, mechanical and thermal treatments are combined in what are known as thermo-mechanical treatments (TMT) for better properties and more efficient processing of materials. These processes are common to high-alloy special steels, super alloys and titanium alloys.

LATEST ADVANCES OF WELDING TECHNOLOGY

Demands for properties of materials used in structures include many things such as strength, toughness, fatigue property, corrosion resistance and heat resistance, and these become to be higher level. On the other hand, demands for welding technologies become to be severe with these demands for properties, and these are wide variety such as high efficiencies, high qualities labor saving and low cost.

Welding has been developing and evolving more quickly than ever before. New technology breakthroughs have made welding more accurate, efficient and cost-effective[16]. Below is how they are revolutionizing welding;

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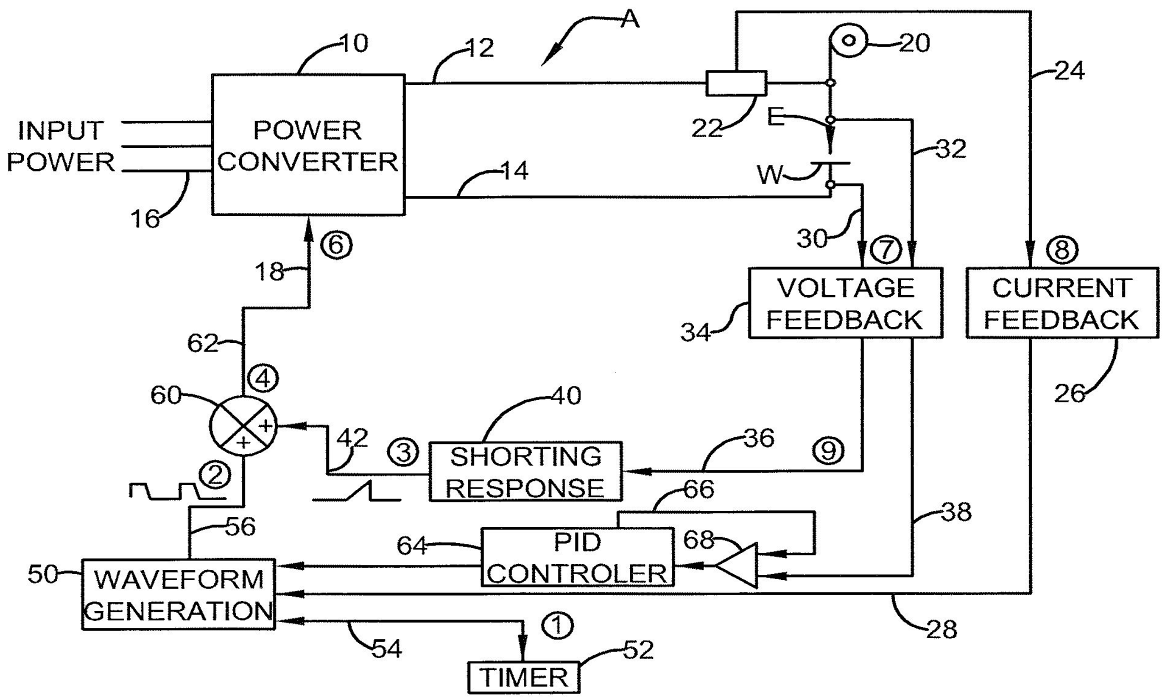
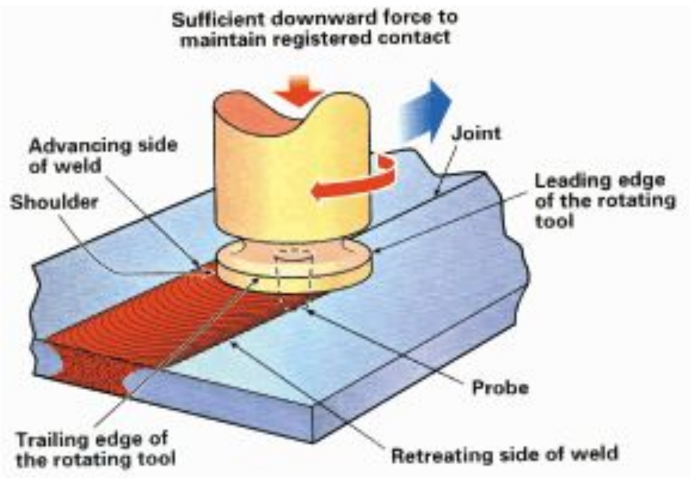
1. **Surface tension transfer process**



Surface tension transfer process (STT) developed and patented by Lincoln Electric is intended for boosting productivity by replacing such older welding methods as gas metal arc welding, gas tungsten arc welding. The benefits of this process include : reducing welding fumes and typical spatters, decreasing amount of time spent to train someone in welding technology, and increasing speed. STT welding is ideal when working with stainless steels and galvanized steel.

2. **Friction stir welding**

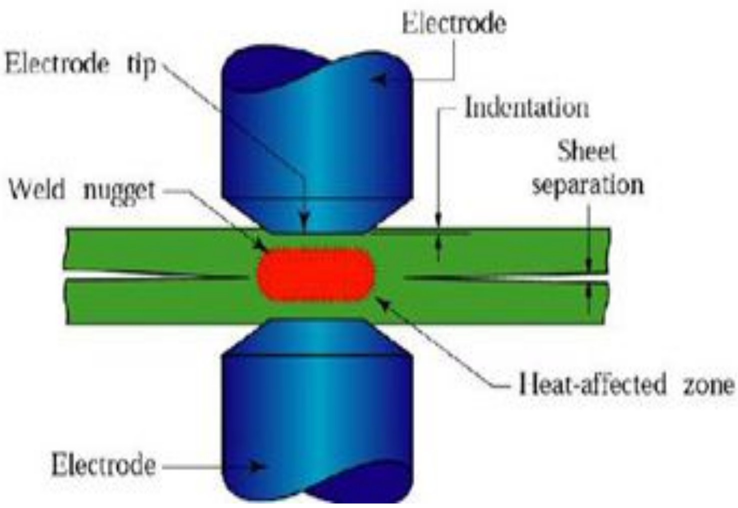


Automakers around the world are continuously looking for new ways to reduce manufacturing costs without scarifying quality and automotive safety. By using new innovated method of friction stir welding a lower cost material like aluminium can be welded easily with steel. This process of joining aluminium and steel is simple and safe. This new method helps generate more stable, secure bond between two materials by moving a rotating tool on the top of aluminium, which is then bounded to steel. By replacing the conventional steel sub-frame with one comprising aluminium and steel can reduce body weight 25%. This highly efficient method also helped in reducing electricity cost up to 50% during the welding process.

3. **Laser welding**

Laser welding is quite new technique that involves conversing light energy into heat energy. The radiation emitted through laser welding allows beams to travel larger distances with suffering considerable loss of quality. Though initial costs for laser welding is higher than conventional spot welding methods, a significant reduction in cycle time eventually makes laser welding more efficient option[17].

4. **Resistance spot welding**



Resistant spot welding has to do with direct application of opposing forces using the pointed-tip electrodes. Engineers has availed this technique in producing lighter weight, more fuel-efficient vehicles from aluminum.

By getting rid of about 2 pounds of rivets from the vehicles hood, doors and lift gates, engineers can utilize that surplus weight in other areas of vehicle , if necessary. Thanks to the resistance spot welding technology, aluminum pieces can be directly welded together using a multi-ringed dome electrode.

PLATING

Electroplating is a chemical surface-treatment technique. It involves bonding a thin layer of another matal such as gold, silver, chromium or zinc to the surface of the product. It is used to reduce corrosion as well as to improve the product's aesthetic appearance.

THERMAL SPRAYING

Thermal spraying techniques are another popular finishing option, and often better high temperature properties than electroplated coatings.

RECENT DEVELOPMENT IN CORROSION RESISTANCE OF STEEL

With the comong of the 21st century, a mission required for the industries has greatly changed with strong demands of structuring a recycle-oriented society, and preventing the global warming. Steel products are used extensively as the important raw material of consumption and capital goods, and therefore expected to make a technical contribution toward the accomplishment of the above mission. Corrosion-resistant steel is widely used in the places where the working conditions and requirement for corrosion resistance are ramified. Corrosion is a destruction of materials by a chemical or electrochemical reaction in all environment at any temprature. Corrosion is an intrinsic problem for utility metals. In case of steel, stainless steel, galvanized, electro galvanized, and weathering steel of which corrosion can be prevented or moderated have been put to practical use. This has led to an increase in the volume of steel used along with the improvement in performance for corrosion resistance.

Cathodic protection is an electrical technique for preventing the rusting of iron and steel, a phenomenon which is usually considered a chemical reaction. Because of this the subject advances hand in hand with developments in electrical engineering and in the electrochemical industry and is modified in conjunction with advances in the chemical techniques for preventing corrosion. Magnesium, aluminium and zinc can be used as sacrificial anodes to provide cathodic protection and the greatest advance in this field has been the discovery of a new series of aluminium alloys which in sea-water become a permanent anode and the plating of a very thin film of platinum on to a titanium substrate has been found to make an ideal anode. Much of the exploitation of this anode has taken place with new electrical techniques such as automatic control, the individual adjustment of anode current and a considerable improvement in the instrumentation.

Table-1 shows some steel corrosion problems in the corrosion-resistant steel materials and coated steel sheets.

Table 1 Research and problems about steel[18].

	Construction/civil engineering	Energy/chemical	Automobile	Household electric appliances/ electronic equipment	Offshore structure
Corrosion condition	*Atmospheric corrosion, *Freshwater corrosion, *Salt damage corrosion	*Acid and alkali, *Salts, *High-temperature gas corrosion, *Hot water corrosion	*Atmospheric corrosion, *Salt damage corrosion, *Fuel tank corrosion	*Atmospheric corrosion, *Freshwater corrosion, *Salt damage corrosion	*Seawater corrosion, *Salt damage corrosion
Problems and antirust technology	*Security of social infrastructure, *Security of long	*Measures against acid and alkali corrosion,	*Simultaneous security of anti-corrosiveness,	*Techniques against corrosion free of	*Measures against seawater corrosion,

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	service life, *coated steel sheet	*Measures against high temperature corrosion, *Measures against stress corrosion cracking	drawability, *Technique against corrosion free of environmental load	environmental load	*Measures against seawater corrosion, *Security of long service life
Newly developed steel and corrosion resistant technology	*Costal weathering steel for bridges, *Technique of predicting weathering steel corrosion, *Highly corrosion-resistant stainless steel	*Zn-Mg-coated steel sheet for tank, *Water corrosion proof element steel sheet	*Zn-Al coated steel sheet, *Various high tensile coated steel sheets, *Stainless steel for exhaust system	*Lead-free coated steel sheet, *Chromate-free coated steel sheet, *Pre-coated steel sheet	*High performance of line-pipe

MICROSTRUCTURE

Metallurgists study the microscopic and macroscopic properties using metallography, a technique invented by Henry Clifton Sorby. In metallography, an alloy of interest is ground flat and polished to a mirror finish. The sample can then be etched to reveal the microstructure and macrostructure of the metal. The sample is then examined in an optical or electron microscope, and the image contrast provides details on the composition, mechanical properties, and processing history.

Crystallography, often using diffraction of x-rays or electrons, is another valuable tool available to the modern metallurgist. Crystallography allows identification of unknown materials and reveals the crystal structure of the sample. Quantitative crystallography can be used to calculate the amount of phases present as well as the degree of strain to which a sample has been subjected.

CONCLUSION

Technological advancements which have shown a substential growth concerned with each and every field of metallurgy. Advancement in metallurgy occured by chance early in the 20th century now the understanding of metallurgy has advanced to a stage whereby it is becoming possible to design in different field of metallurgy like manufacturing technology, casting technology, corrosion technology, alloying, welding technology etc. that closely match with the different properties of materials and their service requirements. In retrospect 20th century will be seen as the golden age of metallurgical development. Special achievement have been a more precise understanding of the actual role of different metallurgical processes and ability to closely control their parameters. For the 21st century it is to be hoped that new development in the field of metallurgy specially in manufacturing technology, casting technology, refining, welding etc. will be stimulated more by economic, social and environmental needs.

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