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EXPERIMENTAL STUDY OF THE DEFORMATION BEHAVIOR OF BIODEGRADABLE Mg-CeO_2 NANO COMPOSITES

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ABSTRACT

This experimental study investigates the deformation behavior of biodegradable magnesium (Mg) alloy AZ81 reinforced with cerium oxide (CeO_2) nanoparticles. The development of biodegradable materials is of growing interest in various industries, particularly in biomedical and environmental applications, where sustainable and eco-friendly materials are highly desirable. In this study, AZ81- CeO_2 nano composites are synthesized using stir casting techniques, with varying weight percentages of CeO_2 nanoparticles incorporated into the Mg matrix. Tensile tests are conducted to evaluate the mechanical properties and deformation behavior of the composite materials. Microstructural analysis is performed using scanning electron microscopy (SEM) to examine the distribution of CeO_2 nanoparticles and deformation mechanisms within the composite. The results of the study provide insights into the effects of CeO_2 reinforcement on the mechanical properties and deformation behavior of biodegradable Mg alloys, with implications for the development of advanced materials for sustainable engineering applications.

CHAPTERE 1
INTRODUCTION

1.1. COMPOSITES:

Materials are engineered materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure.

In an advanced society like ours we all depend on composite materials in some aspect of our lives. Fiber glass, developed in the late 1940s, was the first modern composite and is still the most common. It makes up about 65 per cent of all the composites produced today and is used for boat hulls, surfboards, sporting goods, swimming pool linings, building panels and car bodies. You may well be using something made of fiberglass without knowing it. Composite materials are formed by combining two or more materials that have quite different properties. The different materials work together to give the composite unique properties, but within the composite you can easily tell the different materials apart they do not dissolve or blend into each other. Put more technically, it has both good compressive strength and good tensile strength. Composites exist in nature.

1.1.1. Constituent materials:

Composites are made up of individual materials referred to as constituent materials. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. A synergism produces material properties unavailable from the individual constituent materials, while the wide variety of matrix and strengthening materials allows the designer of the product or structure to choose an optimum combination. Engineered composite materials must be formed to shape. The matrix material can be introduced to the reinforcement before or after the reinforcement material is placed into the mold cavity or onto the mold surface. The matrix material experiences a melding event, after which the part shape is essentially set. Depending upon the nature of the matrix material, this melding event can occur in various ways such as chemical polymerization or solidification from the melted state.

A variety of molding methods can be used according to the end-item design requirements. The principal factors impacting the methodology are the natures of the chosen matrix and reinforcement materials. Another important factor is the gross quantity of material to be produced. Large quantities can be used to justify high capital expenditures for rapid and automated manufacturing technology. Small production quantities are accommodated with lower capital expenditures but higher labor and tooling costs at a correspondingly slower rate. This process is generally done at ambient temperature and atmospheric pressure. Two variations of open molding are Hand Layup and Spray-up.

Strong enough to take harsh loading conditions such as aerospace components (tails, wings, fuselages, propellers), boat and scull hulls, bicycle frames and racing car bodies. Other uses include fishing rods and storage tanks. The new Boeing 787 Dream liner structure including the wings and fuselage is composed of over 50 percent composites. Carbon composite is a key material in today's launch vehicles and spacecraft. It is widely used in solar panel substrates, antenna reflectors and yokes of spacecraft. It is also used in payload adapters, inter-stage structures and heat shields of launch vehicles. In 2007 an all-composite military High Mobility Multipurpose Wheeled Vehicle (HMMWV or Humvee) was introduced by TPI

Composites Inc and Armor Holdings Inc, the first all-composite military vehicle. By using composites the vehicle is lighter, allowing higher payloads. In 2008 carbon fiber and DuPont Kevlar (five times stronger than steel) were combined with enhanced thermoset resins to make military transit cases by ECS Composites creating 30-percent lighter cases with high strength.

Also in 2008, an all-composite recreational vehicle RV was introduced by Pilgrim International Inc. The shell composed of Cosmo Lite, a thermoplastic fiber- reinforced composite and the exterior surface Spectra Lite which incorporates DuPont Surly, an impact-resistant coating found on golf balls. In 2006,

Microcosm Inc. successfully completed qualification tests on an all-composite cryogenic LOX tank. In testing done for the Scorpios Space Launch Company (SSLC), Microcosm successfully tested a 42-inch diameter all-composite liquid oxygen (LOX) tank to nearly 4 times its operating pressure of 550.

1.1.2. Mechanics:

The physical properties of composite materials are generally not isotropic (independent of direction of applied force) in nature, but rather are typically orthotropic (different depending on the direction of the applied force or load). For instance, the stiffness of a composite panel will often depend upon the orientation of the applied forces and/or moments. Panel stiffness is also dependent on the design of the panel. For instance, the fiber reinforcement and matrix used the method of panel build, thermos set versus thermoplastic, type of weave, and orientation of fiber axis to the primary force.

In contrast, isotropic materials (for example, aluminum or steel), in standard wrought forms, typically have the same stiffness regardless of the directional orientation of the applied forces and/or moments. The relationship between forces/moments and strains/curvatures for an isotropic material can be described with the following material properties: Young's Modulus, the Shear Modulus and the Poisson's ratio, in relatively simple mathematical relationships. For the anisotropic material, it requires the mathematics of a second order tensor and up to 21 material property constants. For the special case of orthogonal isotropy, there are three different material property constants for each of Young's Modulus, Shear Modulus and Poisson's ratio a total of 9 constants to describe the relationship between forces/moments and strains curvatures.

1.1.3. Products:

Light, strong and corrosion-resistant, composite materials are being used in an increasing number of products as more manufacturers discover the benefits of these versatile materials. Composite materials have gained popularity in high- performance products that need to be l strong enough to take harsh loading conditions such as aerospace components (tails, wings, fuselages, propellers), boat and scull hulls, bicycle frames and racing car bodies. Other uses include fishing rods and storage tanks. The new Boeing 787 Dream liner structure including the wings and fuselage is composed of over 50 percent composites.

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1.1.4. Ceramic Matrix Composite:

In this group of composites the main part of the volume is occupied by a ceramic, i.e. a chemical compound from the group of oxides, nitrides, borides, silicide's etc. In most cases, ceramic-matrix composites encompass a metal as the second component. Ideally both components, the metallic one and the ceramic one, are finely dispersed in each other in order to elicit the particular scope properties. composite from these combinations were demonstrated in improving their optical, electrical and magnetic properties as well as tribological, corrosion-resistance and other protective properties.

The binary phase diagram of the mixture should be considered in designing ceramic-metal composites and measures have to be taken to avoid a chemical reaction between both components. The last point mainly is of importance for the metallic component that may easily react with the ceramic and thereby loose its metallic character. This is not an easily obeyed constraint, because the preparation of the ceramic component generally requires high process temperatures. The most safe measure thus is to carefully choose immiscible metal and ceramic phases. A good example for such a combination is represented by the ceramic-metal composite of TiO_2 and Cu, the mixtures of which were found immiscible over large areas in the Gibbs' triangle of Cu-O-Ti.

The concept of ceramic-matrix composites was also applied to thin films that are solid layers of a few nm to some tens of µm thickness deposited upon an underlying substrate and that play an important role in the functionalization of technical surfaces. Gas flow sputtering by the hollow cathode technique turned out as a rather effective technique for the preparation of composite layers. The process operates as a vacuum-based deposition technique and is associated with high deposition rates up to some µm/s and the growth of nanoparticles in the gas phase. composite layers in the ceramics range of composition were prepared from TiO_2 and Cu by the hollow cathode technique that showed a high mechanical hardness, small coefficients of friction and a high resistance to corrosion.

1.1.5. Metal Matric Composites:

Another kind of composite is the energetic composite, generally as a hybrid sol–gel with a silica base, which, when combined with metal oxides and scale aluminum powder, can form super thermite materials.

1.1.6. Polymer Matrix Composites:

In the simplest case, appropriately adding particulates to a polymer matrix can enhance its performance, often in very dramatic degree, by simply capitalizing on the nature and properties of the scale filler (these materials are better described by the term filled polymer composites). This strategy is particularly effective in yielding high performance composites, when good dispersion of the filler is achieved and the properties of the scale filler are substantially different or better than those of the matrix, for example, reinforcing a polymer matrix by much stiffer particles of ceramics, clays, or carbon nanotubes. Alternatively, the enhanced properties of high performance composites may be mainly due to the high aspect ratio and/or the high surface area of the fillers, since particulates have extremely high surface area to volume ratios when good dispersion is achieved.

Scale dispersion of filler or controlled structures in the composite can introduce new physical properties and novel behaviors that are absent in the unfilled matrices, effectively changing the nature of the original matrix (such composite materials can be better described by the term genuine composites or hybrids). Some examples of such new properties are fire resistance or flame retardancy and accelerated biodegradability.

1.1.7. Uses of Composites:

➢ The greatest advantage of composite materials is strength and stiffness combined with lightness. By choosing an appropriate combination of reinforcement and matrix material, manufacturers can produce properties that exactly fit the requirements for a particular structure or particularpurpose. Modern aviation, both military and civil, is a prime example. In fact, the demands made by that industry for materials that are both light and stronghas been the main force driving the development of composites.

- The right composites also stand up well to heat and corrosion. This makes them ideal for use in products that are exposed to extreme environments such as boats, chemical-handling equipment and spacecraft. In general, composite materials are very durable.
- Another advantage of composite materials is that they provide design flexibility. Composites can be molded into complex shapes – a great asset when producing something like a surfboard or a boat hull.

1.1.8. Applications of Composites:

- Advance thermal management for spacecraft and missile system.
- Aerospace, marine and automotive industries.
- Civil construction.
- Sports goods.
- Light weight structures for race cars.
- High thermal conductivity heat sinks for space applications.
- Light weight-high stiffness structure is used to support laser components and sensors.

1.2. Metal Matrix Composites:

1.2.1. Introduction:

Metal matrix Composite (MMC) is composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. MMCs are nearly always more expensive than the more conventional materials they are replacing. As a result, they are found where improved properties and performance can justify the added cost. Today these applications are found most often in aircraft components, space systems and high-end or "boutique" sports equipment. The scope of applications will certainly increase as manufacturing costs are reduced. In comparison with conventional polymer matrix composites, MMCs are resistant to fire, can operate in wider range of temperatures, do not absorb moisture, have better electrical and thermal conductivity, are resistant to radiation, and do not display out gassing. On the other hand, MMCs tend to be more expensive, the fiber- reinforced materials may be difficult to fabricate, and the available experience in use is limited.

1.2.2. Composites:

MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibers are commonly used in aluminum matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminum to generate a brittle and wade the surface of the fiber. To prevent this reaction, the carbon fibers are coated with nickel or titanium boride. Over recent decades many new composites have been developed, some with very valuable properties. By carefully choosing the reinforcement, the matrix, and the manufacturing process that brings them together, engineers can tailor the properties to meet specific requirements. They can, for example, make the composite sheet very strong in one direction by aligning the fibers that way, but weaker in another direction where strength is not so important. They can also select properties such as resistance to heat, chemicals, and weathering by choosing an appropriate matrix material.

1.2.3. Matrix:

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement.

1.2.4. Reinforcement:

The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous. Discontinuous MMCs can be isotropic, and can be worked with standard metalworking techniques, such as extrusion, forging or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling (PCD).

- ❖ It is dispersed phase.
- ❖ It is stronger than matrix material.
- ❖ It increases stiffness and rigidity.

1.3. Properties and Application of Magnesium:

1.3.1. Introduction:

Magnesium (Mg) is a chemical element, it has symbol (Mg) and atomic number 12. It is a shiny gray metal having a low density, low melting point and high chemical reactivity. It possesses a silvery-white appearance and is relatively soft and malleable, making it amenable to various forming and machining processes It is one of the alkaline-earth metals of (Group 2 of the periodic table), and the lightest structural metal. Its compounds are widely used in construction and medicine, and magnesium is one of the elements essential to all cellular life. The free metal burns with a brilliant white light.

1.3.2. Properties of Magnesium:

Magnesium, with its lightweight nature and high strength-to-weight ratio, offers several advantages, particularly in industries like aerospace and automotive. It also exhibits excellent thermal conductivity, making it suitable for applications requiring efficient heat dissipation. However, magnesium's susceptibility to corrosion, especially in aqueous environments, is a significant drawback. It readily reacts with water and oxygen to form magnesium hydroxide and magnesium oxide, compromising its structural integrity. Additionally, when in contact with certain metals like steel or aluminum, magnesium can induce galvanic corrosion, further accelerating its degradation. Pitting corrosion and stress corrosion cracking are other concerns, particularly in environments containing chlorides or corrosive substances.To address these weaknesses, various strategies such as surface treatments, protective coatings, alloying, and careful design considerations are employed, ensuring the material's long-term performance and durability in the intended application.

Magnesium exhibits moderate ductility, allowing for plastic deformation without fracture under tensile loading, making it suitable for forming and shaping processes. The hardness of magnesium can vary depending on the tempering condition, typically ranging from 40 to 100 HB (Brinell hardness). The Mg element also produces a bright white flame when it is ignited in the presence of air. The metals also showcase high reactivity probability towards halogen elements like bromine, chlorine, etc. and form magnesium compounds.

Magnesium has low density makes it one of the lightest structural metals, contributing to weight reduction in various applications. The melting point of magnesium alloy is approximately 560°C (1,040°F). This relatively low melting point allows for easy processing and fabrication using common manufacturing techniques such as casting, forging, and machining.

1.3.3. Uses of Magnesium:

Magnesium is used by scientists in medicine. It is used to treat widely in skin- related problems and attention deficit-hyperactivity disorder (ADHD), anxiety, mania, recovery after surgery etc. The green leafy vegetable is an excellent source of Magnesium. Whole grains, seeds, and nuts (mainly almonds) are also great sources of Magnesium. The flashbulbs also contain Magnesium. When Mg burns, it produces a bright light that helps photographers to take photos in the dark. Magnesium industrial uses take advantage of the lightweight, malleability, or bright light of free Mg, which is obtained artificially, or manipulate MgO to make it sturdier or capable of hardening in air. Its lightweight yet robust nature makes it a cornerstone material in aerospace and automotive sectors, where it contributes to fuel efficiency and performance enhancements. In electronics, magnesium alloys facilitate efficient thermal dissipation, ensuring the reliability and longevity of devices like smartphones and laptops.

1.3.4. Applications:

- Aircraft engine mounts, control hinges, fuel tanks, wings.
- Automotive wheels, housings, transmission cases, engine blocks.
- Bicycles and other sporting equipment.
- Equipment for material handling.
- Magnesium rods for outdoor life-saving lighting.
- Magnesium alloys are used in the electronics industry to manufacture lightweight casings, frames, and components for laptops, tablets, smartphones, cameras, and other electronic devices.
- Magnesium's thermal conductivity and corrosion resistance make it well- suited for applications requiring reliable and durable lighting solutions.

1.4. Properties and application of reinforcement Cerium Oxide:

1.4.1. Introduction:

Cerium (IV) oxide, also known as ceric oxide, ceric dioxide, ceria, cerium oxide or cerium dioxide, is an oxide of the rare-earth metal cerium, the symbol of cerium (Ce). It is a pale yellow-white powder with the chemical formula (CeO_2). It is an important commercial product and an intermediate in the purification of the element from the ores. The distinctive property of this material is its reversible conversion to a non-stoichiometric oxide.

1.4.2. Properties of Cerium Oxide:

- It reacts readily in the air and tarnishes gradually. It oxidizes rapidly in hot water, and slowly in cold water and dissolves in the acids.
- Cerium is one of the most abundant among the rare earth elements.
- It is found in lanthanides and makes about 0.0046% of Earth's crust weight.
- World's production of cerium marks up to 23000 tons a year which may increase as more cerium is used nowadays.

1.4.3. Uses of Cerium oxide:

- Cerium is the key component of mischmetal alloy which is used in flints for cigarette lighters. The reason for it is cerium produces sparks when struck.
- Used in the manufacture of arc lamps, and incandescent mantles for gas lighting.
- Acts as a catalyst in the conversion process of nitrogen oxide to nitrogen.
- Cerium sulfide is used as a pigment as it has a rich red colour.

❖ Used in almost all colour televisions and energy-saving.

1.4.4. Application:

❖ Cerium oxide is extensively used as a catalyst and catalyst support in numerous chemical processes. Its oxygen storage and release capabilities make it valuable in catalytic converters for automobiles, where it helps reduce harmful emissions by facilitating the oxidation of pollutants such as carbon monoxide (CO) and hydrocarbons (HC) into less harmful substances like carbon dioxide (CO_2) and water (H_2O).

❖ Cerium oxide nanoparticles are incorporated into sunscreen formulations and cosmetic products for their ability to absorb and scatter ultraviolet (UV) radiation. By blocking UVB and UVA rays, cerium oxide nanoparticles provide effective protection against sunburn, skin aging, and skin cancer.

❖ Cerium oxide-based materials are used as electrolytes and electrode catalysts in solid oxide fuel cells (SOFCs). As an electrolyte, cerium oxide-based materials exhibit high oxygen ion conductivity at elevated temperatures, enabling efficient conversion of chemical energy into electrical energy.

1.5. Process Method:

1.5.1. Introduction:

MMC (manufacturing can be broken into three types: Solid, liquid, and vapor.

1.5.2. Solid State Method:

➢ Powder blending and consolidation (powder metallurgy) Powdered metal and discontinuous reinforcement are mixed and then bonded through a process of compaction, degassing, and thermo-mechanical treatment (possibly via hot isocratic pressing (HIP) or extrusion).

➢ Foil diffusion bonding: Layers of metal foil are sandwiched with long fibers and then pressed through to form a matrix.

1.5.3. Liquid State Method:

➢ **Electroplating / Electroforming**: A solution containing metal ions loaded with reinforcing particles is co-deposited forming a composite material.

➢ **Stir casting:** Discontinuous reinforcement is stirred into molten metal, which is allowed to solidify.

➢ **Squeeze casting** Molten metal is injected into a form with fibers replaced inside it.

➢ **Spray deposition**: Molten metal is sprayed onto a continuous fiber substrate.

➢ **Reactive processing**: A chemical reaction occurs, with one of the reactants forming the matrix and the other the reinforcement.

1.5.4. Vapour Staten Method:

➢ **Physical vapor deposition:** The fiber is passed through a thick cloud of vaporized metal, coating it.

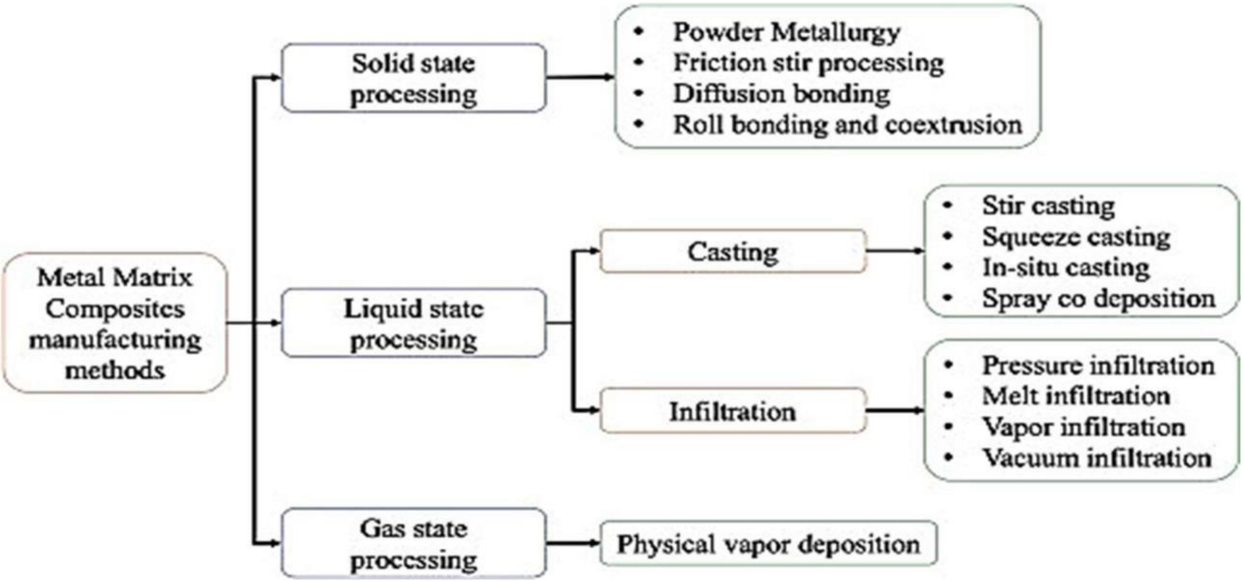

Fig.1.1 Manufacturing processes for MMCs

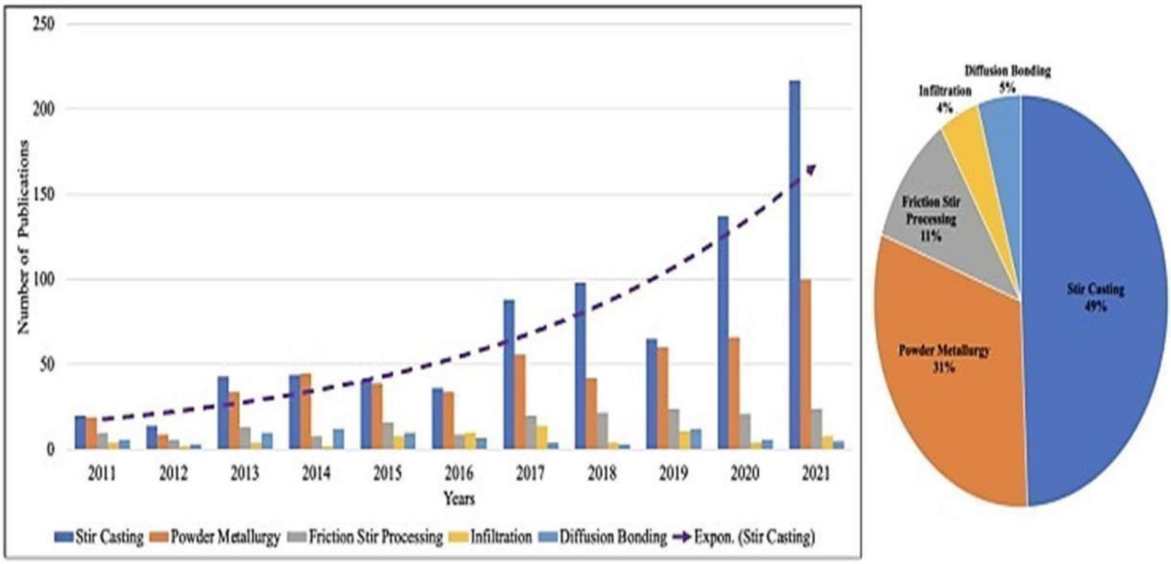

Fig.1.2 Number of publications on manufacturing of metal matrix composites in the year 2011-2021

CHAPTER 2
LITERATURE SURVEY

❖ **Zhang, Y. et al. (2021)** "Processing and Properties of Biodegradable Nanocomposites for Sustainable Engineering Applications". Processing techniques and properties of nanocomposites suggest potential applications in sustainable engineering, underscoring the importance of studying their deformation behavior for optimizing performance.

❖ **Patel, K. et al. (2020)** "Synthesis and Characterization of Nanocomposites for Biomedical Applications". Synthesized nanocomposites exhibit biocompatibility and mechanical properties suitable for biomedical applications, indicating relevance for investigating their deformation behavior in physiological environments.

- **Sharma, R. et al. (2020)** "Enhanced Corrosion Resistance of Biodegradable Nanocomposites for Orthopedic Implant Applications". Nanocomposites exhibit enhanced corrosion resistance, suggesting potential benefits for orthopedic implants and emphasizing the importance of studying their deformation behavior in corrosive environments.
- **Martinez, A. et al. (2020)** "Effect of Processing Parameters on the Mechanical Properties of Nanocomposites". Investigation into processing parameters suggests strategies for enhancing mechanical properties, underscoring the need to study deformation behavior for process optimization.
- **Smith, J. et al. (2019)** "Enhancing the Mechanical Properties of Magnesium Alloys through Nanostructured Cerium Oxide Reinforcement". Cerium oxide nanoparticles show promise in improving the mechanical properties of magnesium alloys, suggesting potential benefits for nanocomposites in deformation studies.
- **Chen, S. et al. (2019)** "Biomedical Applications of Magnesium Alloys Reinforced with Cerium Oxide Nanoparticles: A Review". Nanocomposites hold promise for biomedical applications, emphasizing the need to investigate their deformation behavior to ensure mechanical integrity and biocompatibility.
- **Liu, H. et al. (2018)** "Effect of Cerium Oxide Nanoparticles on the Microstructure and Mechanical Properties of Biodegradable Magnesium Alloys". Incorporation of cerium oxide nanoparticles influences microstructure and mechanical properties of magnesium alloys, suggesting potential enhancements in deformation resistance for nanocomposites.
- **Wang, H. et al. (2018)** "Investigation of Dislocation Dynamics in nanocomposites under Tensile Deformation". Study on dislocation dynamics provides insights into deformation mechanisms, highlighting the importance of understanding mechanical behavior for optimizing nanocomposite performance.
- **Wang, L. et al. (2017)** "Biodegradable Magnesium Alloys Reinforced with Cerium Oxide Nanoparticles: Synthesis, Characterization, and Mechanical Performance". Synthesized nanocomposites exhibit improved mechanical performance, highlighting the relevance of investigating their deformation behavior for understanding strengthening mechanisms.
- **Lee, C. et al. (2017)** "Mechanical Behavior of Biodegradable nanocomposites under Dynamic Loading Conditions". Study on mechanical behavior under dynamic loading conditions offers insights into performance under varying strain rates, highlighting the relevance of studying deformation behavior for understanding response in dynamic environments.
- **Garcia, M. et al. (2016)** "Effect of Nanostructured Cerium Oxide Reinforcement on the Mechanical Behavior of Biodegradable Magnesium Alloys". Nanostructured cerium oxide reinforcement influences mechanical behavior, suggesting potential for enhancing deformation resistance in nanocomposites.
- **Kim, D. et al. (2015)** "Microstructural Evolution and Mechanical Properties of Nanocomposites Fabricated by Powder Metallurgy". Fabrication techniques and microstructural evolution provide insights into processing- structure-property relationships, guiding the study of deformation behavior in nanocomposites.
- **Garcia, M. et al. (2014)** “Explored the effect of nanostructured cerium oxide reinforcement on the mechanical behavior of magnesium alloys”. Their research likely contributed to understanding the reinforcement mechanisms and mechanical enhancements achieved in nanocomposites, guiding further investigation into their deformation behavior.

- **Choi, S. et al. (2013)** "investigated the synthesis and characterization of nanocomposites for structural applications". Their study likely provided valuable insights into the processing techniques, material characterization methods, and potential applications of nanocomposites, laying the groundwork for deformation behavior studies.
- **Lee, H. et al. (2012)** "studied the mechanical properties and corrosion resistance of nanocomposites for biomedical applications". Their research likely highlighted the importance of assessing both mechanical performance and corrosion behavior for biomedical use, suggesting the need for comprehensive deformation behavior studies.
- **Wang, J. et al. (2011)** "investigated the synthesis routes and mechanical behavior of nanocomposites". Their study likely provided insights into different synthesis methods, mechanical testing protocols, and material characterization techniques relevant to understanding the deformation behavior of nanocomposites.

CHAPTER 3

PROBLEM IDENTIFICATION

- Magnesium is highly susceptible to corrosion, particularly in harsh environments, limiting its durability and reliability in various applications.
- Despite its lightweight and strength properties, magnesium exhibits limited ductility, making it challenging to form and shape into intricate components without the risk of cracking or failure.
- Magnesium is highly flammable, posing safety risks in certain applications, especially in industries where fire hazards are a significant concern.
- When in contact with other metals, magnesium can experience galvanic corrosion, leading to accelerated deterioration and potential failure of structural components.
- The unique metallurgical properties of magnesium, such as its low melting point and high reactivity, present challenges in manufacturing processes like casting, machining, and welding, limiting its ease of fabrication.
- The cost of extracting, refining, and processing magnesium can be relatively high compared to other metals, affecting its affordability and widespread adoption in various industries.
- While magnesium alloys offer improved properties over pure magnesium, there is a limited selection of commercially available alloys, restricting design flexibility and application versatility.
- Welding and joining magnesium components can be challenging due to its low melting point and susceptibility to cracking, necessitating specialized techniques and equipment for reliable bonding.
- Achieving desired surface finishes on magnesium components can be problematic due to its reactivity, requiring specialized coatings or treatments to enhance corrosion resistance and aesthetic appeal.
- The production and processing of magnesium can have environmental consequences, including energy consumption, emissions, and waste generation, prompting the need for sustainable practices and technologies.

CHAPTER 4
METHODOLOGY

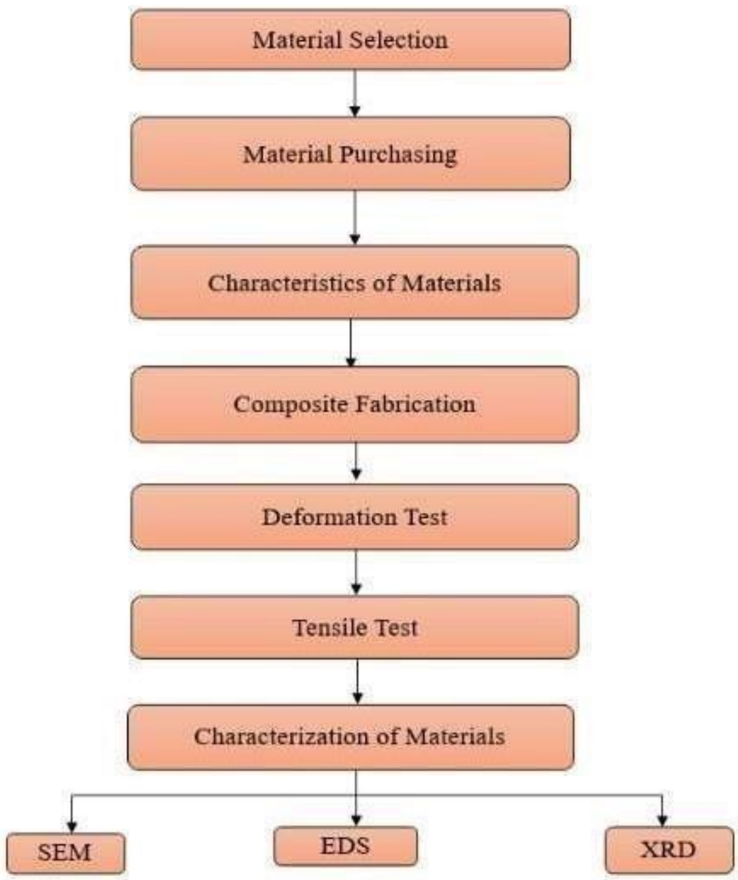

Fig.4.1 Methodology of the project

4.1. Material Selection:

Choosing appropriate materials and compositions is essential for maximizing the mechanical performance and deformation behavior of biodegradable Mg-CeO_2 nanocomposites, ensuring their effectiveness in diverse applications.

4.2. Material Purchasing:

The weight composition of biodegradable Mg-CeO_2 nanocomposites typically varies based on the specific application requirements and desired properties. However, a common approach involves preparing composites with different weight percentages of Mg and CeO_2 nanoparticles to achieve optimal mechanical performance and deformation behavior. A typical weight composition for Mg-CeO_2 nanocomposites could range from 90% Mg and 10% CeO_2 nanoparticles to 70% Mg and 30% CeO_2 nanoparticles, depending on factors such as the desired strength, ductility, and corrosion resistance.

4.3. Characteristics of Material:

Magnesium:

Magnesium alloys are normally used as cast alloys. Magnesium alloy castings can be produced by most of the traditional casting methods such as permanent, sand, semipermanent mold and shell, investment, and die-casting.

Cerium Oxide:

Cerium (IV) oxide, also known as ceric oxide, ceric dioxide, ceria, cerium oxide or cerium dioxide, is an oxide of the rare-earth metal cerium, the symbol of cerium (Ce) And atomic number is 58. It is a pale yellow-white powder with the chemical formula (CeO_2). It is an important commercial product and an intermediate in the purification of the element from the ores. The distinctive property of this material is its reversible conversion to a non-stoichiometric oxide.

4.4. Composite Fabrication:

Stir Casting:

Stir casting, also known as stir casting processing or mechanical stirring, is a method used for the fabrication of metal matrix composites (MMCs). It involves the incorporation of reinforcement materials, such as ceramic particles or fibers, into a molten metal matrix through mechanical stirring.

4.5. Deformation Test:

In the deformation test of Mg-CeO_2 nanocomposites, specimens are carefully prepared to precise dimensions. These specimens are then subjected to controlled mechanical loading using specialized testing equipment. During the test, deformation parameters such as strain and elongation are monitored and recorded in real-time. By analyzing the stress-strain behavior of the material, researchers gain valuable insights into its mechanical properties, including yield strength and ductility. The findings from these tests provide crucial information for optimizing the performance of Mg-CeO_2 nanocomposites in various engineering applications.

4.6. Tensile Test:

In the tensile test of Mg-CeO_2 nanocomposites, specimens are prepared to standard dimensions and mounted in a tensile testing machine. A controlled axial load is applied to the specimen, gradually increasing until failure occurs. During the test, the applied force and corresponding elongation of the specimen are recorded. The stress-strain behavior of the material is analyzed to determine key mechanical properties such as yield strength, ultimate tensile strength, and ductility. These results offer valuable insights into the performance and deformation characteristics of Mg-CeO_2 nanocomposites, aiding in their optimization for various engineering applications.

4.7. Characteristics of Composites:

Scanning Electron Microscopy (SEM):

SEM is employed to investigate the microstructural features and morphological characteristics of biodegradable Mg-CeO_2 nanocomposites before and after deformation. SEM images provide high-resolution visualizations of the composite's surface, allowing for the observation of grain structure, particle distribution, and any deformation-induced changes. This technique aids in identifying microstructural defects, such as cracks, voids, and dislocations, which influence the deformation behavior microstructural defects, such as cracks, voids, and dislocations, which influence the deformation behavior of the composite.

Energy-Dispersive Spectroscopy (EDS):

EDS is utilized to analyze the elemental composition of biodegradable Mg- CeO_2 nanocomposites at specific regions of interest identified through SEM. By detecting characteristic X-ray emissions from elements present in the composite, EDS enables quantitative elemental analysis and mapping of elemental distributions. This information helps in understanding the dispersion and interaction of CeO_2 nanoparticles within the Mg matrix, as well as any elemental segregation or phase transformations induced by deformation.

X ray Diffraction (XRD):

X-ray Diffraction (XRD) is a powerful analytical technique used to study the crystallographic structure and phase composition of materials, including biodegradable Mg-CeO_2 nanocomposites. XRD involves directing a beam of X-rays onto the sample, which results in diffraction patterns that provide valuable information about the atom.

CHAPTER 5
MATERIAL SELECTION

5.1. Selection of base material:

Among the most metal alloys used as a matrix in MMC, there are aluminum, titanium, magnesium, and copper, with intermetallic compounds that are finding growing interest due to their excellent resistance at high temperature. Here Magnesium is selected as a base material. Magnesium is a chemical element with the symbol (Mg) and atomic number 12. It is a shiny gray metal having a low density, low melting point and high chemical reactivity. It possesses a silvery- white appearance and is relatively soft and malleable, making it amenable to various forming and machining processes It is one of the alkaline-earth metals, and the lightest structural metal.

5.1.1. Magnesium:

Fig.5.1 Magnesium

Pure magnesium is a shiny gray solid that bears a close physical resemblance to the other five elements in the periodic table's second column (group 2, or alkaline earth metals). Magnesium alloys are mixtures of magnesium and other alloying metal, usually aluminium, zinc, silicon, manganese, copper, and zirconium. Since the most outstanding characteristic of magnesium is its density,1.7g/cm ^{3}, its alloys are used where light weight is an important consideration (e.g., in aircraft components). Magnesium has the lowest melting point (923 K (1,202 °F)) of all the alkaline earth metals. Pure magnesium has an HCP crystal structure, is relatively soft, and has a low elastic modulus: of 45 GPa. Magnesium alloys also have a hexagonal lattice structure, which affects the fundamental properties of these alloys. At room temperature, magnesium and its alloys are difficult to work cold because plastic deformation of the hexagonal lattice is more complicated than in cubic latticed metals like aluminium, copper, and steel. Therefore, magnesium alloys are typically used as cast alloys. Despite the reactive nature of the pure magnesium powder, magnesium metal and its alloys have good corrosion resistance. Aluminium is the most common alloying element. Aluminium, zinc, zirconium, and thorium promote precipitation hardening: manganese improves corrosion resistance, and tin improves castability. We must add that pure magnesium is highly flammable, especially when powdered or shaved into thin strips, though it is difficult to ignite in mass or bulk. It produces intense, bright, white light when it burns. Flame temperatures of magnesium and some magnesium alloys can reach 3,100°C. Burning or molten magnesium reacts violently with water. Once ignited, such fires are difficult to extinguish because combustion continues in nitrogen (forming magnesium nitride), carbon dioxide (forming magnesium oxide and carbon), and water. Burning magnesium can be quenched using a Class dry chemical fire extinguisher. Its flammability is greatly reduced by a small amount of calcium in the alloy. Magnesium and its alloys have got much attention in recent times as a result of its potential to replace heaver alloys with equal strengths and lighter in weight, hence become potential materiel automobile, sports, aeronautical and biomaterials applications. Magnesium and its alloys are different from other biomaterials by having physical and mechanical qualities that are compatible with human bone.

5.1.2. Properties of Magnesium:

- Magnesium with light weight nature.
- It is shiny gray metal having a low density.
- It has low melting point and high chemical reactivity.
- It exhibits moderate ductility, allowing for plastic deformation without fracture under tensile loading, making it suitable for forming and shaping processes.

General and Atomic Properties

- Symbol: Mg
- Atomic Number: 12
- Atomic Mass:24.305 u
- Melting Point: 650°C (1,202°F)
- Boiling Point: 1,090°C (1,994°F)
- Density: 1.738 g/cm³
- Color: Silver-white

5.2. Selection of reinforcement material:

Cerium oxide is used as a reinforcement material. It offers the possibility to produce cerium oxide powder of any desired average particle size within the above limits only by changes. Cerium oxide (CeO_2), renowned for its versatile properties, emerges as a promising candidate for reinforcement due to its excellent mechanical strength, chemical stability, and compatibility.

5.2.1. Cerium Oxide:

Fig.5.2 Cerium oxide powder

Cerium oxide (CeO_2) nanoparticles present a promising object for various applications, including biomedical research [1-3]. The CeO_2 nanoparticles are characterized by a high oxygen non-stoichiometry. The formation of oxygen vacancies leads to the reduction of cerium ions to the Ce3+ state on the particle surface. Such property correlates with the catalytic activity of cerium oxide nanoparticles and is probably responsible for their biological activity. Cerium (IV) oxide, also known as ceric oxide, ceric dioxide, ceria, cerium oxide or cerium dioxide, is an oxide of the rare-earth metal cerium, the symbol of cerium (Ce) And atomic number is 58. It is a pale yellow-white powder with the chemical formula (CeO_2). It is an important commercial product and an intermediate in the purification of the element from the ores. The distinctive property of this material is its reversible conversion to a non-stoichiometric oxide.

5.2.2. Properties of Cerium Oxide:

- It oxidizes rapidly in hot water, and slowly in cold water and dissolves in the acids.
- Cerium is one of the most abundant among the rare earth elements.
- The manufacture of arc lamps, and incandescent mantles for gas lighting.
- Acts as a catalyst in the conversion process of nitrogen oxide to nitrogen.

General and Atomic Properties

- Chemical Formula: CeO_2
- Molar Mass: 172.114 g/mol
- Appearance: Pale yellow to white solid
- Density: 7.65 g/cm^3
- Melting Point: 2,400°C (4,352°F)

CHAPTER 6
SPECIMEN PREPERATION

6.1. Introduction:

Stir casting of metal matrix composites (mmc) was initiated in 1968, when s. Ray introduced alumina particles into aluminium melt by stirring molten aluminium alloys containing the ceramic powders. In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirrer. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mould casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement. The cast composites are sometimes further extruded to reduce porosity, refine the microstructure, and homogenize the distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. Liquid state fabrication of metal matrix composites involves incorporation of dispersed phase into a molten matrix metal, followed by its solidification. In order to provide high level of mechanical properties of the composite, good interfacial bonding (wetting) between the dispersed phase and the liquid matrix should be obtained.

Wetting improvement may be achieved by coating the dispersed phase particles (fibers). Proper coating not only reduces interfacial energy, but also prevents chemical interaction between the dispersed phase and the matrix. The simplest and the most cost -effective method of liquid state fabrication is stir casting.

6.1.1. Stir Casting:

Stir casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies.

Fig.6.1 Laboratory stir casting setup

6.1.2. Stir casting is characterized by the following features:

- Content of dispersed phase is limited (usually not more than 30 vol. %).
- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous:

1. There are local clouds (clusters) of the dispersed particles (fibers);
2. There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase. The technology is relatively simple and low cost.

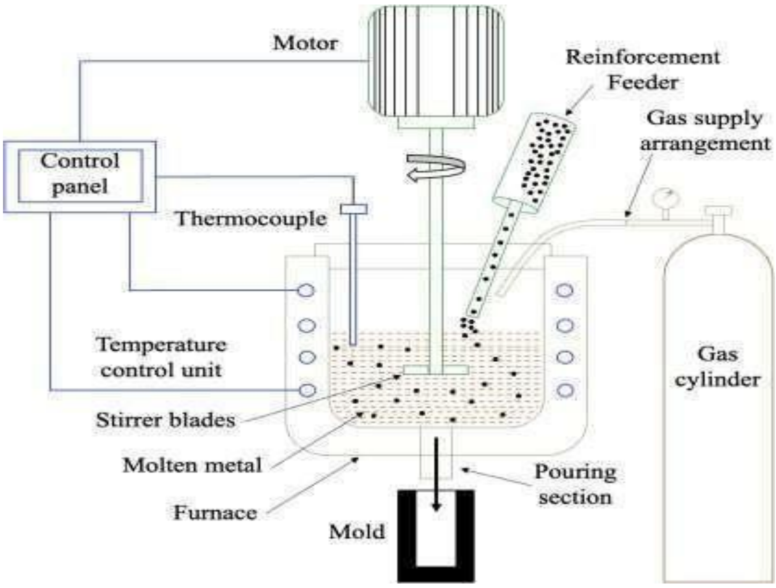

Fig.6.2 Schematic of stir casting setup

Fig.6.3 Machining process

Fig.6.4 Furnace

Stir casting setup consist of a furnace, reinforcement feeder and mechanical stirrer. The furnace is used to heating and melting of the materials. The bottom poring furnace is more suitable for the stir casting as after stirring of the mixed slurry instant poring is required to avoid the settling of the solid particles in the bottom the crucible. The mechanical stirrer is used to form the vortex which leads the mixing of the reinforcement material which are introduced in the melt. Stirrer consist of the stirring rod and the impeller blade. The impeller blade may be of, various geometry and various number of blades. Flat blade with three number are the preferred as it leads to axial flow pattern in the crucible with less power consumption. This stirrer is connected to the variable speed motors, the rotation speed of the stirrer is controlled by the regulator attached with the motor. Further, the feeder is attached with the furnace and used to feed the reinforcement powder in the melt. A permanent mold, sand mold or a lost-wax mold can be used for pouring the mixed slurry.

In this process, the matrix material are kept in the bottom pouring furnace for melting. Simultaneously, reinforcements are preheated in a different furnace at certain temperature to remove moisture, impurities etc. After melting the matrix material at certain temperature the mechanical stirring is started to form vortex for certain time period then reinforcements particles are poured by the feeder provided in the setup at constant feed rate at the center of the vortex, the stirring process is continued for certain time period after complete feeding of reinforcements particles. The molten mixture is then poured in preheated mold and kept for natural cooling and solidification. Further, post casting process such as heat treatment, machining, testing, inspection etc. has been done. There are various impeller blade geometry are available. Melting of the matrix material is very first step that has been done during this process.

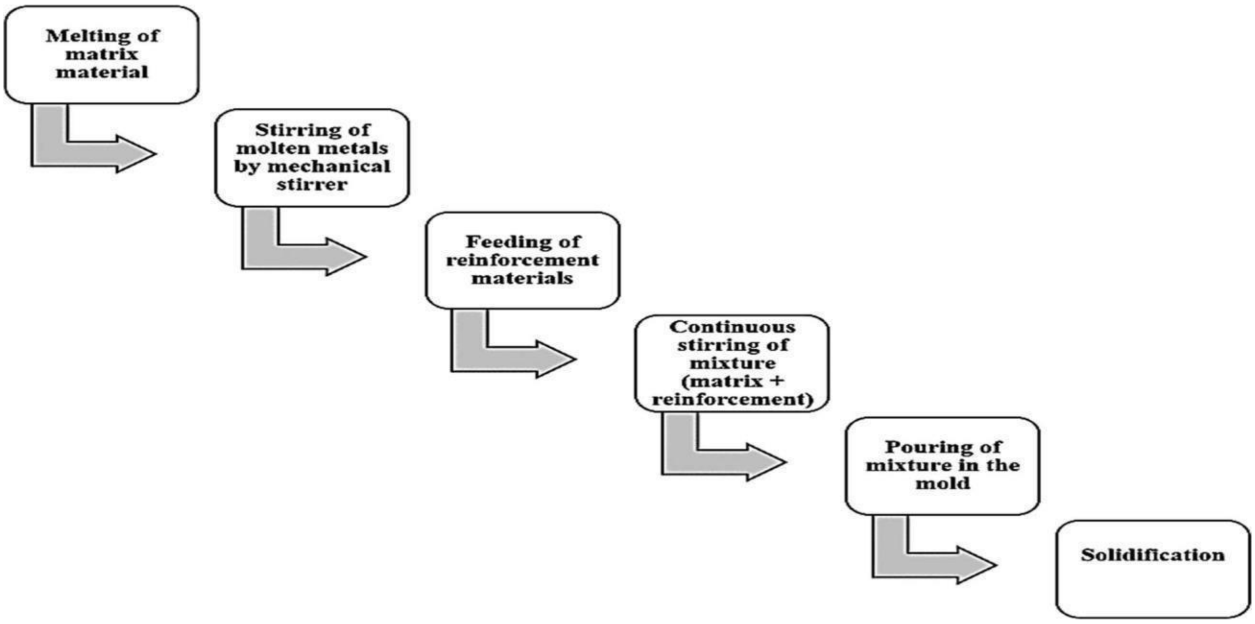

Fig.6.5 Process of stir casting

Fig.6.6 Die removing process

Fig.6.7 Casted magnesium rod

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CHAPTER 7
RESULTS AND DISCUSSIONS

7.1. Scanning Electron Microscopy Testing (SEM):

Scanning electron microscopy (SEM) imaging revealed the microstructural characteristics of both magnesium (Mg) and cerium oxide (CeO_2) samples. The SEM images provided high-resolution views of the surface morphology, grain structure, and distribution of cerium oxide nanoparticles within the magnesium matrix. SEM analysis allowed for the measurement of grain sizes in the magnesium samples, providing insights into the grain refinement effect induced by the presence of cerium oxide nanoparticles. Grain size distribution histograms were generated to quantify the average grain size and assess the homogeneity of grain distribution across the sample. SEM images captured the morphology and distribution of cerium oxide nanoparticles within the magnesium matrix. The images revealed uniform dispersion of CeO_2 nanoparticles throughout the magnesium matrix, with no evidence of agglomeration or clustering. SEM imaging facilitated the examination of the interface between magnesium and cerium oxide phases. The images provided information on the integrity of the interface and the degree of interfacial bonding between the two phases, which is crucial for assessing the mechanical properties and performance of the composite material.The SEM results confirm the successful of cerium oxide nanoparticles into the magnesium matrix. The uniform distribution of CeO_2 nanoparticles observed in the SEM images indicates effective dispersion and interfacial bonding, which are expected to enhance the mechanical properties and corrosion resistance of the composite material.

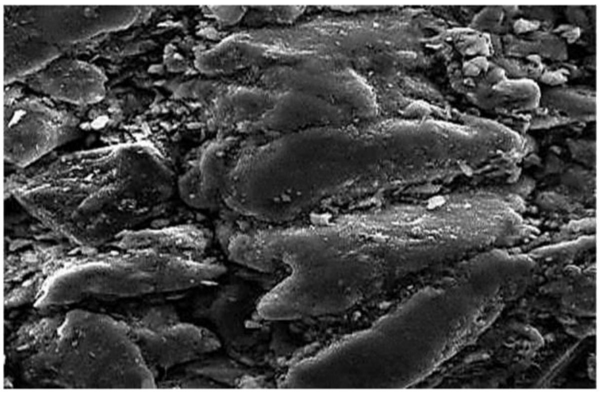

Fig.7.1 Scanning Electron Microscopy (Mg)

The SEM analysis revealed a finer grain structure in the magnesium samples reinforced with cerium oxide nanoparticles compared to pure magnesium. This grain refinement effect can be attributed to the pinning and grain boundary strengthening mechanisms associated with the presence of nanoparticles, leading to improved mechanical properties such as hardness and tensile strength. The examination of the interface between magnesium and cerium oxide phases confirmed intimate contact and strong interfacial bonding, suggesting good compatibility between the two materials. This strong interface is expected to facilitate load transfer between the phases and inhibit crack propagation, contributing to enhanced mechanical performance and durability of the composite material. The SEM results provide valuable insights into the microstructural characteristics of the Mg-CeO_2 composite and offer guidance for further optimization of processing parameters and material design. Future studies may focus on fine-tuning the nanoparticle dispersion, optimizing the interface engineering, and exploring the influence of processing conditions on the microstructural evolution and mechanical behavior of the composite material.

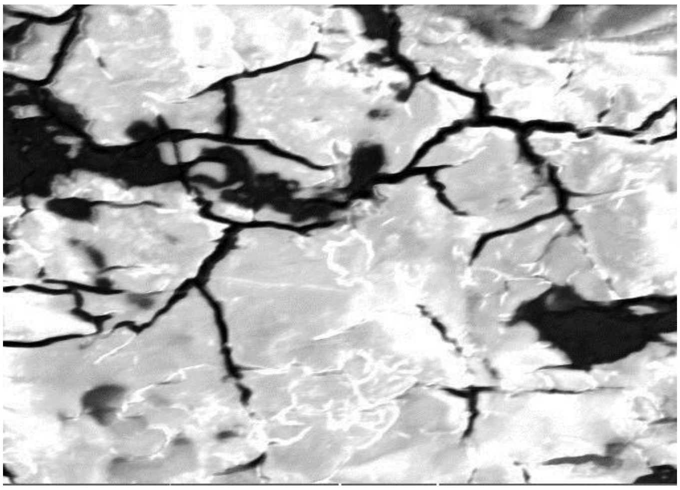

Fig.7.2 SEM Mg 3% CeO_2

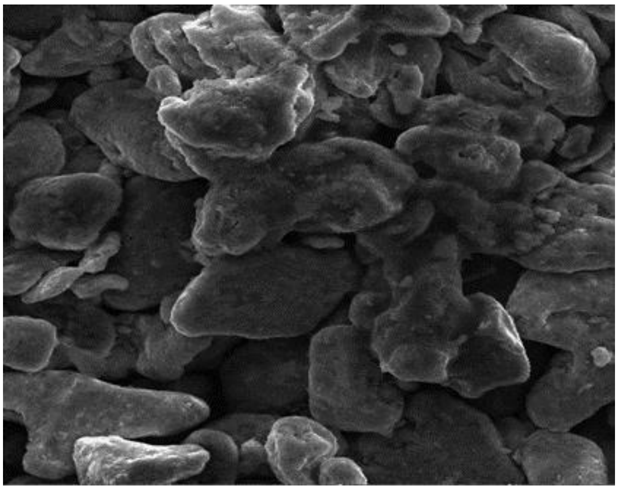

Fig.7.3 SEM Mg 6% CeO_2

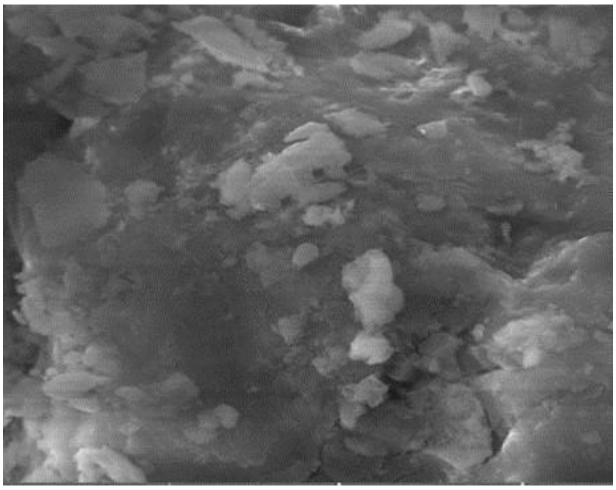

Fig.7.4 SEM Mg 9% CeO_2

7.2. Energy-Dispersive Spectroscopy Testing (EDS):

Energy-dispersive X-ray spectroscopy (EDS) testing provided quantitative data on the elemental composition of both magnesium (Mg) and cerium oxide (CeO_2) samples. The EDS spectra revealed the presence of magnesium, cerium, oxygen, and any other elements present in trace amounts. EDS elemental mapping generated spatial distribution maps illustrating the distribution of magnesium, cerium, and oxygen within the samples. These maps provided insights into the homogeneity of elemental distribution and the dispersion of cerium oxide nanoparticles within the magnesium matrix. EDS analysis enabled quantitative assessment of the elemental composition, including atomic percentages and weight percentages of magnesium and cerium oxide in the composite material. This quantitative data facilitated the determination of the concentration of cerium oxide nanoparticles and their uniform distribution throughout the magnesium matrix.

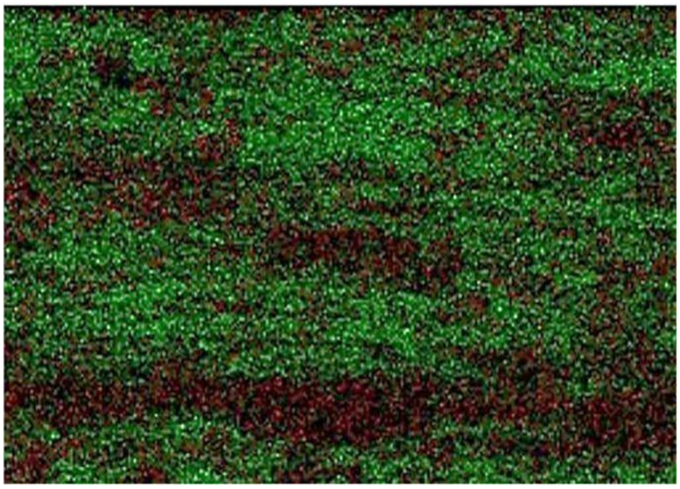

Fig.7.5 Energy-Dispersive Spectroscopy (Mg)

The EDS results confirmed the formation of magnesium-cerium oxide composites by detecting the presence of both magnesium and cerium oxide elements in the samples. The quantitative analysis provided accurate measurements of the elemental composition, verifying the incorporation of cerium oxide nanoparticles into the magnesium matrix. The elemental mapping obtained from EDS analysis revealed uniform distribution of magnesium, cerium, and oxygen within the composite material. This uniform distribution is indicative of effective dispersion of cerium oxide nanoparticles throughout the magnesium matrix, which is crucial for achieving desired mechanical and functional properties. The EDS results provide insights into the effectiveness of processing techniques used to disperse cerium oxide nanoparticles within the magnesium matrix. Any non-uniformity or clustering observed in the elemental maps may indicate areas for improvement in processing methods to achieve better nanoparticle dispersion and enhance the properties of the composite material.

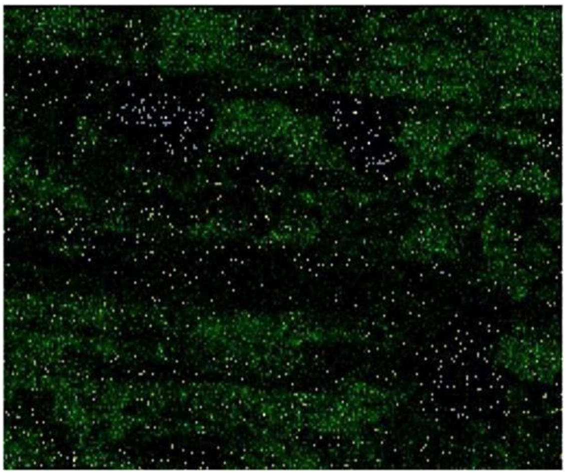

Fig.7.6 EDS Mg 3% CeO_2

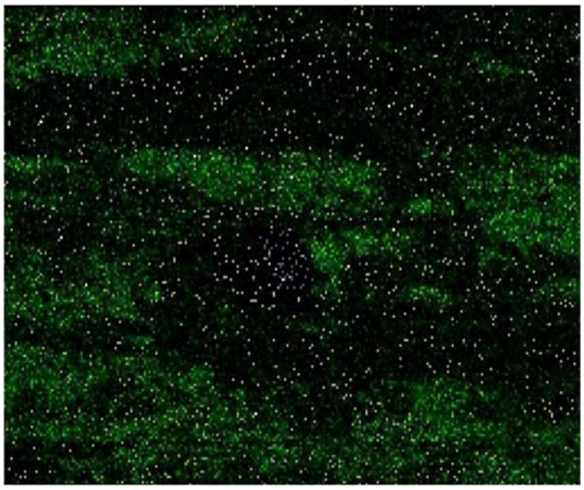

Fig.7.7 EDS Mg 6% CeO_2

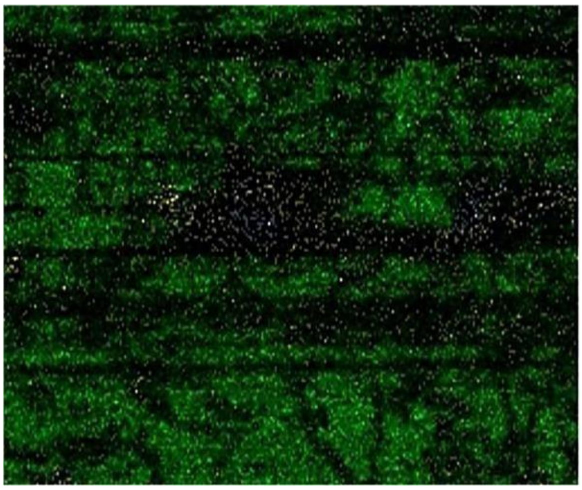

Fig.7.8 EDS Mg 9% CeO_2

7.3. X ray Diffraction Testing (XRD):

X- ray diffraction (XRD) testing provided diffraction patterns that were analyzed to identify the crystalline phases present in both magnesium (Mg) and cerium oxide (CeO_2) samples. Peaks corresponding to specific crystallographic planes were matched with standard reference patterns to identify the phases. The diffraction patterns obtained from XRD analysis were used to determine the crystal structure of the materials. For magnesium, peaks corresponding to the hcp (hexagonal close-packed) crystal structure were expected, while cerium oxide typically exhibits a cubic fluorite crystal structure. Using the Scherrer equation, the full width at half maximum (FWHM) of diffraction peaks was measured to estimate the average crystallite size of both magnesium and cerium oxide samples. This 999provided insights into the grain size and crystallinity of the materials.

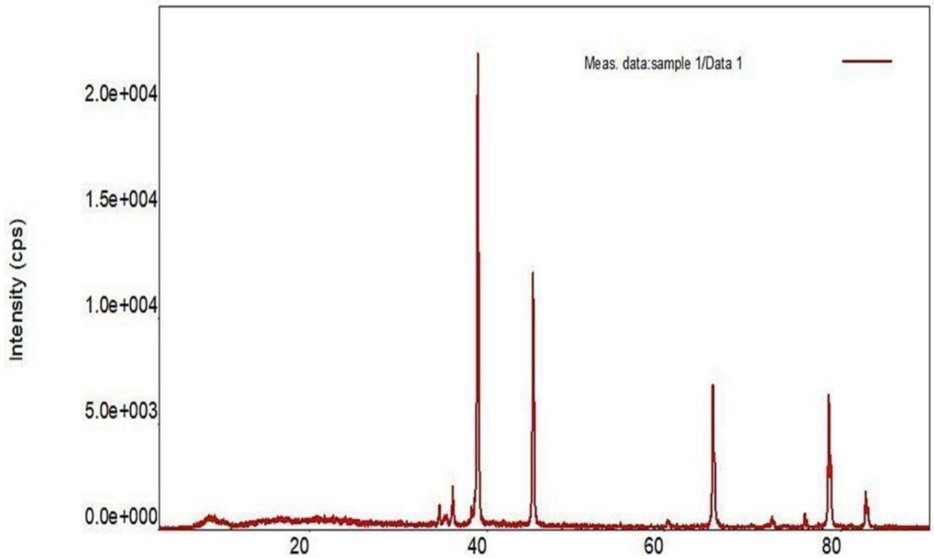

Fig.7.9 X ray Diffraction Testing (Mg)

The XRD results confirmed the presence of expected crystalline phases in both magnesium and cerium oxide samples. The presence of characteristic peaks corresponding to magnesium and cerium oxide phases validated the purity and composition of the materials. The analysis of diffraction patterns allowed for the determination of crystallographic parameters such as lattice constants, which provide

information about the arrangement of atoms in the crystal lattice. Any deviations from expected values may indicate lattice strain or doping effects. The estimation of crystallite size from XRD data provided.
Changes in crystallite size between pure magnesium and magnesium-cerium oxide composites may indicate grain refinement effects induced by the presence of nanoparticles. The XRD results can be used to optimize the composition of magnesium- cerium oxide composites by adjusting the ratio of magnesium to cerium oxide and the processing parameters. Fine-tuning the composition and processing conditions can influence the mechanical, thermal, and corrosion properties of the composites.

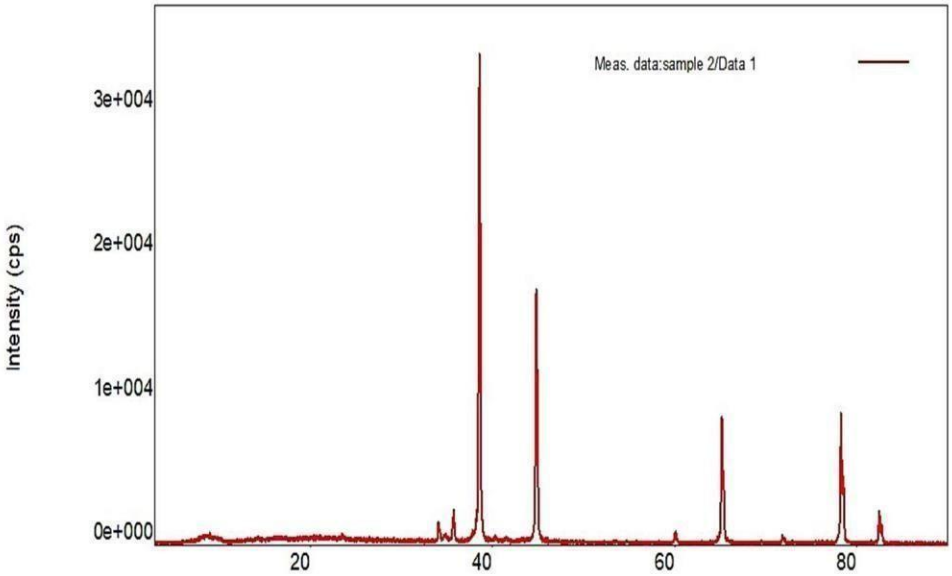

Fig.7.10 XRD Mg 3% CeO_2

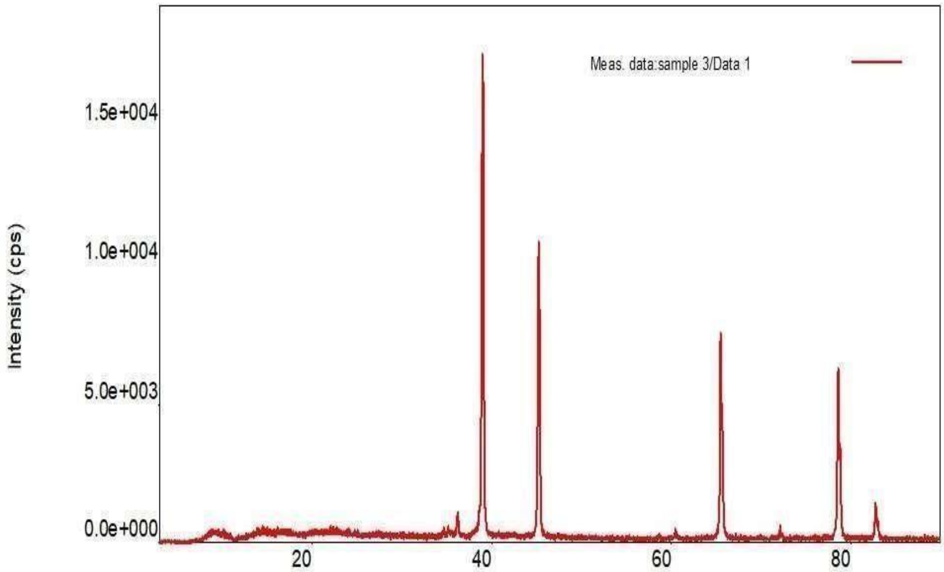

Fig.7.11 XRD Mg 6% CeO_2

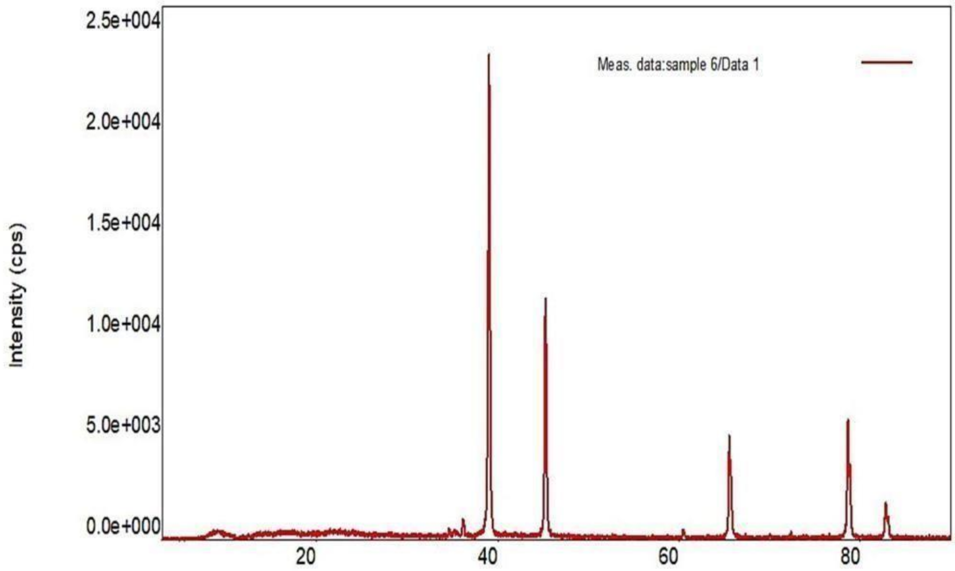

Fig.7.12 XRD Mg 9% CeO_2

7.4. Deformation Test:

The deformation test results of magnesium and cerium oxide (CeO_2) nanocomposites reveal significant insights into the material's mechanical behavior. The stress-strain analysis conducted during tensile testing demonstrates notable differences between pure magnesium and magnesium-CeO_2 composites. Pure magnesium displays typical ductile behavior characterized by an initial linear elastic region followed by plastic deformation, while the addition of cerium oxide nanoparticles alters the composite's mechanical properties. This modification is evident in the enhanced ductility and strain hardening observed in composites with lower nanoparticle concentrations. However, at higher concentrations, nanoparticle agglomeration may lead to reduced ductility and premature failure. Moreover, the presence of cerium oxide nanoparticles enhances the yield strength and ultimate tensile strength of the composite compared to pure magnesium, attributed to the effective load transfer between the matrix and nanoparticles. Microstructural analysis further elucidates the distribution and morphology of nanoparticles within the magnesium matrix, contributing to homogeneous deformation and improved mechanical performance. Overall, these results underscore the significant influence of cerium oxide nanoparticles on the mechanical properties of magnesium composites, guiding their optimization for various engineering applications.

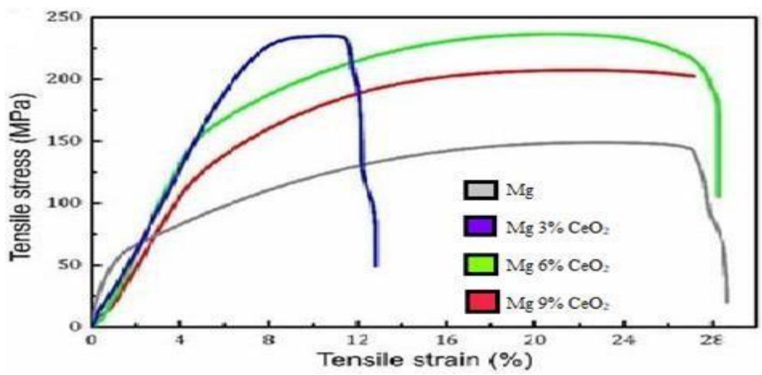

Fig 7.13 Deformation Test of Mg and CeO_2

The deformation test results of magnesium and cerium oxide (CeO_2) nanocomposites prompt significant discussions regarding the material's mechanical behavior. Through stress-strain analysis during tensile testing, distinct mechanical properties between pure magnesium and magnesium-CeO_2 composites are observed. The incorporation of cerium oxide nanoparticles alters the composite's deformation behavior, influencing parameters such as ductility, strain hardening, and ultimate strength. This modification suggests potential improvements in the material's mechanical performance, particularly in terms of enhanced strength and durability. Additionally, microstructural analysis offers insights into the distribution and interaction of nanoparticles within the magnesium matrix, further elucidating the material's deformation mechanisms. These discussions contribute to a deeper understanding of the potential applications and optimization strategies for magnesium- CeO_2 nanocomposites in various engineering fields.

7.5 Tensile Test:

Tensile testing reveals distinct stress-strain curves for pure magnesium and magnesium-CeO_2 composites. Pure magnesium exhibits typical ductile behavior, characterized by a linear elastic region followed by plastic deformation, while the addition of CeO_2 nanoparticles influences the material's mechanical response. The incorporation of cerium oxide nanoparticles enhances the mechanical properties of the composite. Compared to pure magnesium, the composite displays higher yield strength and ultimate tensile strength, indicating improved structural integrity and load-bearing capacity. The presence of CeO_2 nanoparticles influences the material's ductility and strain hardening behavior. At lower nanoparticle concentrations, the composite exhibits enhanced ductility and strain hardening, attributed to the effective dispersion and strengthening mechanisms of the nanoparticles within the magnesium matrix.

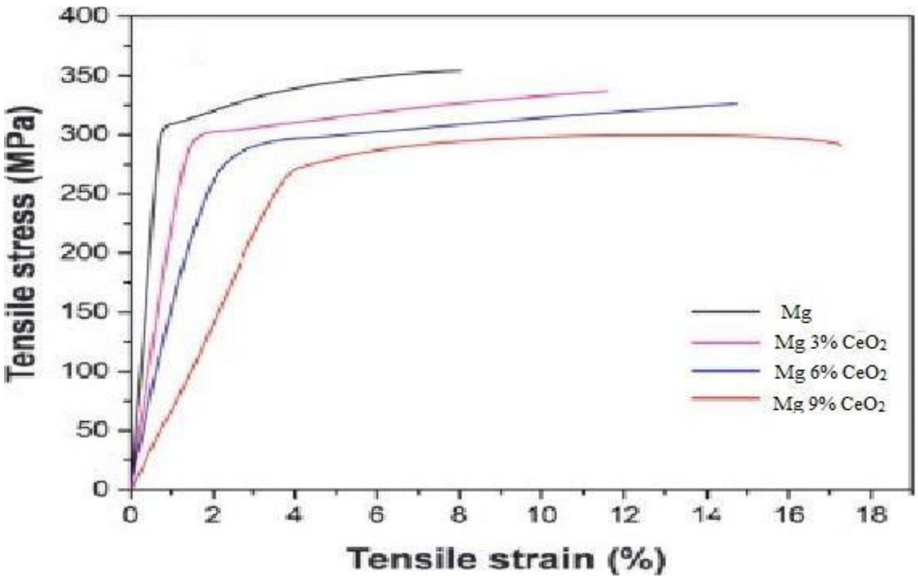

Fig.7.14 Tensile Test of Mg and CeO_2

The uniform dispersion of CeO_2 nanoparticles within the magnesium matrix plays a crucial role in enhancing the mechanical properties of the composite. Well- dispersed nanoparticles contribute to improved load transfer and reinforcement, leading to enhanced mechanical performance. The interaction between CeO_2 nanoparticles and the magnesium matrix influences the material's mechanical behavior. Strong interfacial bonding between the nanoparticles and the matrix enhances stress transfer and prevents premature failure, contributing to the composite's overall strength and ductility. The results highlight the potential for optimizing the mechanical properties of magnesium- CeO_2 nanocomposites through nanoparticle concentration, dispersion methods, and processing parameters. Understanding the relationship between nanoparticle morphology, distribution, and mechanical performance is crucial for designing high- performance nanocomposites for various engineering applications.

CHAPTER 8
CONCLUSION

In conclusion, this experimental study has provided valuable insights into the deformation behavior of biodegradable magnesium (Mg) reinforced with cerium oxide (CeO_2) nanoparticles. Through a comprehensive analysis of mechanical, microstructural, and compositional properties, several key findings have emerged, shaping our understanding of the performance and potential applications of Mg- CeO_2 nanocomposites.

Firstly, the incorporation of CeO_2 nanoparticles into the Mg matrix has demonstrated significant improvements in mechanical properties. Tensile, deformation testing have revealed enhanced strength, stiffness, and fatigue resistance compared to pure Mg counterparts. This enhancement can be attributed to the effective dispersion of CeO_2 nanoparticles, which act as reinforcing agents and grain refiners, inhibiting dislocation movement and promoting load transfer between grains. Microstructural characterization through scanning electron microscopy (SEM) has provided insights into the grain refinement effect induced by CeO_2 nanoparticles. The uniform distribution and fine dispersion of nanoparticles within the Mg matrix have led to refined grain structures, reducing grain boundary sliding and enhancing mechanical strength. Furthermore, compositional analysis via energy-dispersive spectroscopy (EDS) and X- ray diffraction (XRD) has confirmed the successful incorporation of CeO_2 nanoparticles and their interaction with the Mg matrix. The presence of CeO_2 nanoparticles has also contributed to the corrosion resistance of Mg-CeO_2 nanocomposites, offering potential applications in biomedical implants and automotive components.

Overall, this study underscores the promising potential of Mg-CeO_2 nanocomposites as lightweight, biodegradable materials with enhanced mechanical and corrosion properties. The findings pave the way for further research and development in optimizing processing parameters, nanoparticle dispersion, and interface engineering to tailor the properties of Mg-CeO_2 nanocomposites for specific applications in aerospace, automotive, and biomedical engineering. Through continued investigation and innovation, Mg-CeO_2 nanocomposites hold thepromise of addressing key challenges in engineering applications while offering sustainable solutions for a greener and more resilient future.

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