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An Examination of the Powder-based Additive Manufacturing Process and the Chassis of the Underwater Robot

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Abstract

This study includes a brief overview on nanoscale materials. and the evaluation of several nanomaterials in contrast to zirconium. Zirconium was chosen, separated from hafnium, and Its structural load bearing ability, electrical conductivity, self-healing capabilities, and corrosive characteristics were investigated. Ansys 15.0 is then used to analyse the model. On the model, pressure conditions were imposed, which was then subjected to structural analysis of the chassis for an underwater robot. The study was completed, and the results are reported in the sections that follow this one. investigation of several additive manufacturing methods Our primary attention is on laser cladding and selective laser sintering, which have both been evaluated for layering zirconium on robot chassis. Because hafnium has explosive properties, this research first examines how zirconium is removed from it before zirconium turns into powder form. Cladding work is to be accomplished using laser cladding or selective laser sintering, which deliver material over robotic parts and provide a layer upon layer. Laser cladding is the greatest technique for concealing any form and extending the life of wear parts.

Keywords: *Design, Analysis, Hydrostatic pressure, Additive Manufacturing, Laser cladding, Properties, Zirconium*

1. Introduction

Material innovations that enable morphological unbounded shape alteration While keeping their fundamental quality and being able to switch in-and-out of rigid and adaptable states suited for reshaping in the unstructured situation, they are able to offer potentially far-reaching suggestions. While doing so, they also keep their fundamental quality. According to the findings of this study, materials can be used to construct robot parts that are sensitive and safe to cooperate with. An investigation of materials manufacturing, as well as the extraction of zirconium and hafnium, will be the focus of this investigation.[1]. Material weight, substance properties, material composition, and the ability to detect, activate, collect, and store radioactive material properties, as well as the ability to extract hafnium from zirconium and various other materials, can all be adjusted in order to achieve different degrees of mechanical inflexibility and, in some cases, self-recovery capacity.

If the material is to resist water erosion, it must be machined and framed efficiently to determine precise parameters such as specific gravity, the length and width of segment lasts, and volume and weight of material [2-4]. Zirconium's powder structure is altered by first isolating hafnium from zirconium, which has blasting properties. An automated laser cladding machine applies material to form a coating or film on automated parts while chipping away at the cladding. Any shape can be covered with laser cladding, which also increases the lifespan of wear parts. As robots take up space in the real world, diverse materials are used to give the robots shape, quality, and resilience. Auxiliary components are almost always made of metals, polymers, or composites, but other materials are occasionally used. The following sections summaries and simplify some of the relevant properties of a manufacturing strategy. There is a lot of discussion about the most basic components of modern robots: unbending materials. The final sections provide a brief overview of elastomers and adaptable tractable components, two easily recognizable material types with useful properties. This research paper examines the zirconium characteristics, zirconium extraction, strong zirconium powder development, and laser-assisted cladding procedure in detail [5-8]. With the use of lasers, it is possible to melt the metal part's surface layer and join it to a practical layering that is attached to the metallurgically-substantiated substrate. This is known as cladding. Laser cladding is used in a wide variety of industries, ranging from automotive to aerospace. Because of the hardening structure and morphology, fast cementing determines the visual appearance of cladding coatings. During laser cladding, the heated variations have an effect on the hardening process. Recent study has examined the link between warm fields and the cementing process, as well as hardening and cladding coatings/layering. Microstructure and morphology of zirconium laser cladding were studied. The warm field count in the laser cladding technique of zirconium layering has been identified, and the cooling rate of moving strong fluid interface has been read to analyses hardening morphology. Finally, check the distribution of hardness in each cladding layer [9-12].

Fig.1 Zirconium solid form

Fig.2 Zirconium powder form

Zirconium's low neutron absorption makes it suitable for nuclear devices, but hafnium's high neutron absorption makes it detrimental as a fuel cladding material for zirconium. Zirconium [13] is the tenth most abundant metal in the earth's crust and is often found with hafnium. Composite materials being developed are "multi-functional." These materials integrate load-bearing with sensing, actuation, energy harvesting/storage, electrical/thermal conductivity, and self-healing. Layers of blended fibres and two or more components make them up. [14]. Over the years, the selective laser sintering 3-D printer's design has undergone several modifications to boost accuracy and minimize operating costs. Materials are described in terms of their "character," which refers to how the structure of the material and its qualities are measured and searched. This is done in a very distinct and elaborated manner. An engineering material's scientific knowledge cannot be discovered without understanding this fundamental principle of material science.

1.1 Powder based Additive Manufacturing

It's appropriate to use the word "additive manufacturing" to describe the processes that create 3D objects by adding layers of material, whether it's plastic or metal or concrete. 3-D modelling software (also known as Computer Aided Design or CAD), machine apparatus and layering of material are commonly used in additive technologies. Data from CAD drawings are fed into a 3D printing machine via a process known as "additive manufacturing." Layers of fluid, sheet material, powder or other materials are laid down or added sequentially in a layer to fabricate a three-dimensional object from the CAD file. For example, 3D printing, rapid prototyping (RP), direct digital manufacturing (DDM), layer-based production, and additive fabrication are all included in AM. Each additive manufacturing process has its place. the three-dimensional cad model is converted to STL file format, which is a three-sided mesh of the body, and then cut into two-dimensional profile layers using the CAD software [15-17].

The main AM technologies are:-
- Selective laser sintering (SLS).
- Stereolithography (SLA).
- Fused deposition modeling (FDM).
- Direct metal laser sintering (DMLS).

The most important components that ought to be considered in picking a fitting AM innovation for a specific intention are precision, time, and cost of creation. The parameter of exactness alludes to the thickness of the layers and the arrangement of union, and since AM strategies are without instrument manufacture techniques, time of creation can exceed expanded manufacture costs per thing.

1.2 Selective laser sintering

A 3D printing technique known as selective laser sintering (SLS) is one of the most up-to-date methods for transforming computer designs into 3-dimensional physical models. In terms of light weight manufacturing, SLS is one of the best technologies available, but there are a number of alternative options as well [18]. Deckard and Beaman originally envisioned it. Cutting of 3D structure and checking examples of each layer are processed naturally, and then the creation of the finished part using SLS technique, which has two stages: the creation of a 3D plan and transfer of CAD information to a specific laser sintering machine to perform the manufacture with wit. Each AM framework has a unique technique for tying the layers together. SLS innovation's coupling system may be broken down into three main categories. For materials that are difficult to sinter, fluid stage sintering is commonly used. Adding an additional component to the powder during the sintering process before the framework stage is possible with the aid of a fluid sintering stage. For the production of 3D pieces from clay materials, a small number of polymers are used to consolidate the clay and then break down and completely disappear. Metals and burned materials are more likely to undergo full liquefaction than polymers. Currently, full thickness is achieved in one stage by softening the particles completely with a laser bar, thus avoiding lengthy post-handling procedures[19-20]. Molecule size estimations in the 10–150 m range are popular at the moment. It is possible to adjust the laser power and output speed to get the ideal laser vitality thickness, which is determined by the sintering strategy (in the fluid stage) or powders (in the full softening system). The laser inspection speed can be slowed down to obtain denser pieces. Due to a longer duration between the laser bar and the powder, the amount of vitality sent to the powder bed increases. By increasing the laser filter speed, less liveliness was transferred to the materials, resulting in increased porosity and less sintering as a result of the process. Improving liquid flow and penetration into a dense structure by increasing the strength delivered to the bed of powder. This improves powder softening and allows for faster liquid flow and penetration into the spaces between the particles.

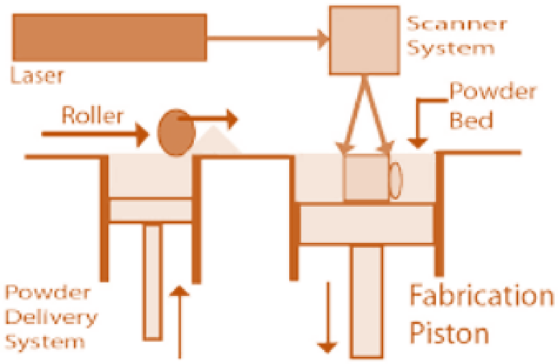

Fig 3 SLS (SELECTIVE LASER SINTERING)

2. Properties of Zirconium

From these physical and chemical qualities, (Zr) zirconium is a strong, malleable, and ductile metal. Its heat and corrosion resistance are adequate. It is a highly divided metal that may spontaneously fire at a high temperature in the air. Alkalis and acids should not be able to dissolve it quickly. Zirconia and zirconia oxide are the most commonly utilized forms. Low thermal conductivity and high melting point characterize zirconium oxide (Zr).

2.1 Behavior during Fabrication and Heating

2.1.1 Machinability

Due to the fact that Zr (zirconium) powder and chips can catch fire, machining Zr (zirconium) material must be done so with extreme caution. while, you'll need an incredible structure for cooling, an overpowering amount of feed rates, and really conscious rates.

2.1.2 Forming

Zirconium, or Zr, has a ductile structure, which makes it very easy to manipulate. However, the galling impact is being avoided by using the appropriate lubrication.

Table 1. Properties

Physical properties	
Melting-point	1850°C
Density	5.41 g / cm³
Mechanical properties	
Tensile strength	325 MPa
Poisons ratio	0.35
Elongation at breakdown	32%
Modulus of elasticity	93.4 GPA
Yield strength	230 MPa
Thermal Properties	
Thermal Conductivity	15.8 W/mK
Thermal Expansion Coefficient (20-100°C / 70-210°F)	6.10m/m°C

2.1.3 Welding

The welding process known as tungsten gas arc welding is the one that works best when it comes to fusing zirconium. When zirconium is fused, it is imperative that the process be handled with the utmost care; otherwise, the result may be a weld that is fragile and brittle.

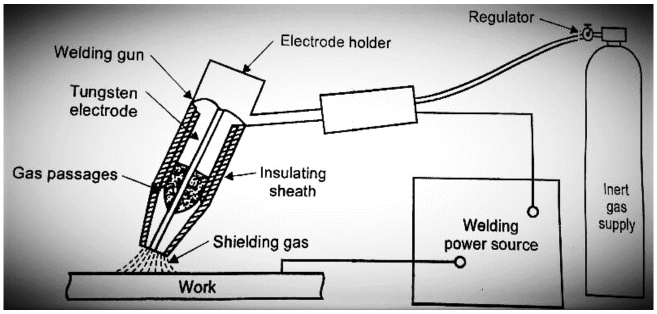

Fig.3 TGAW Tungsten gas arc welding

2.2 Zirconium hafnium separation and extraction-

Cladding and auxiliary materials in warm neutron power reactors favour zirconium combinations due to their low warm retention cross-area and high mechanical and erosion-resistant properties. Zinc and hafnium are inseparable in the natural world. Hf has a large thermal absorption cross-section, despite its chemical similarities to a lot of other materials. The zirconium used in nuclear reactors must consequently be devoid of hafnium. Production of hafnium-free zirconium has given rise to a number of new techniques. Both hafnium extraction and metal production have been used in each of these processes.

- Pyrometallurgical routes
- Hydrometallurgical routes

The overall stability of hafnium mixtures is similar to that of zirconium complexes, which are more stable. Several methods for separating hafnium from zirconium were devised based on these concepts, with the Newnham process being the most notable. [5]

3. Experimental Procedure

An underwater robot's chassis, consisting of an aluminium alloy alloy, is laser classed or layered with zirconium rhodium in this experiment. It was decided to use a 300 mm 150 mm 15 mm chassis for zirconium laser-cladding treatment because of its dimensions. The chassis plate was pulverized using multiple grades of 300-grid SiC abrasive sheets before being cleaned with ethanol and acetone and then laser clad. The Ni35 alloy powder feeding material's microscopic particles range in size from 48 to 130 mm. The powder was dried in a drying oven for 24 hours in order to remove the moisture.

Table. 2 Configurations for the specimen and the powder for layering / cladding

Element	Zr	C	B	Mn	Fe	P	S	Ni	Cr
Steel 45	0.40	0.40	0.25	0.20	Bal.	<0.03	<0.03	0.25	<0.25

A 450-watt CO_2 laser, a 3-axis CNC machine, and a coaxial powder feeder with a handling head make up the test setup. Metal powder is mixed with the liquid pool of the metal powder by the powder conveying through spouts in the middle and then dissolved and immediately hardened by means of this method known as laser cladding. Layer that can be dropped by the laser-substrate movement or by the movement of the work surface. Coaxially, a stream of argon protective gas was blown at a rate of 100 mm/min to protect the liquid pool from oxidation. The powder feeder also used argon as a gas conveyance medium. One hundred-millimeter-long layers are cladded on the substrate using various preparation parameters, such as laser powers of 400, 450, and 350 W., in order to examine how handling constraints, affect hardness and microstructure.

Table 3 Parameters Laser speed and feed for powder

Number	1	2	3	4	5
Laser speed	100	150	200	220	250
Rate of feed of powder	0.65	0.75	0.85	1.00	2.00

Table. 8 Desired parameters for laser cladding machine

Power(W)	Speed (mm/min)	Feed rate	Laser spot size in (mm)
450	$\frac{100}{60}$	~14	2
400	$\frac{100}{60}$	~14	1.5
350	$\frac{100}{60}$	~14	1

4. Results

When compared to testing conducted on zirconium in its solidary form, the evaluation of the properties possessed by nano-form zirconium, which has been evaluated and found to contain various characterisation properties, tends to offer results that are divergent. When covering rover parts with Zr powder, it has been shown that this delivers considerable increases in mechanical rigidity, structural load bearing capacity, electrical insulation, natural self-healing capabilities, and corrosion protection.

4.1 Design Factors that Should be considered

Solid modelling software – solidsworks – was used to build the underwater robot's chassis before its proportions were chosen in accordance with the requirements. The coordinate system used for these measurements is the CGS. The features of the design are depicted in the figure below.

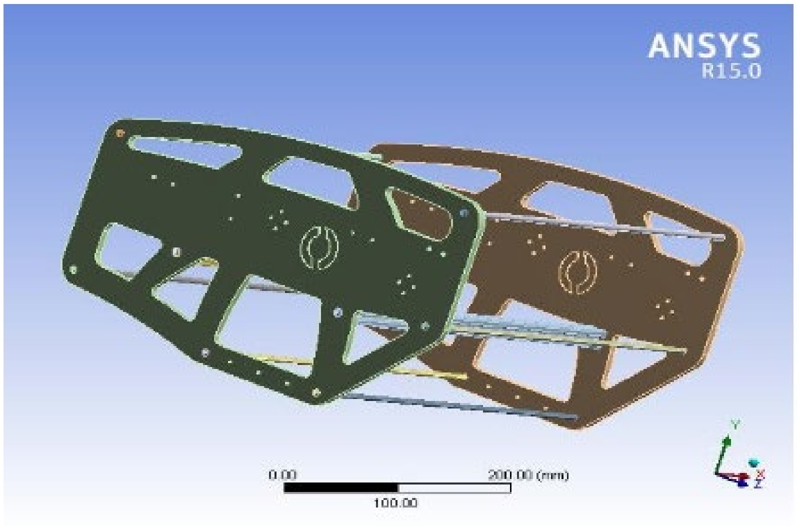

Fig.4 Chassis Design

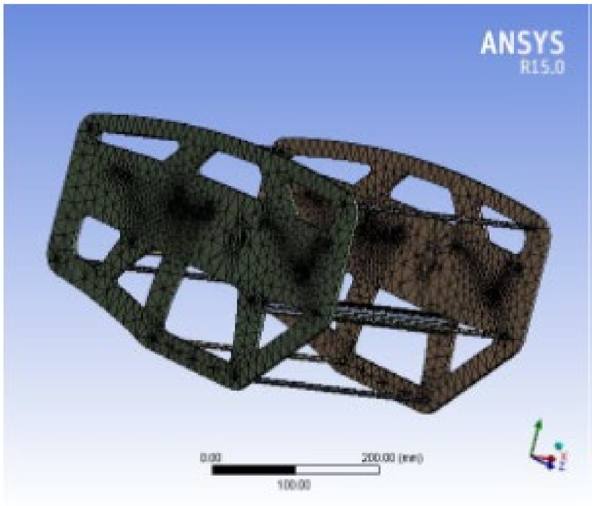

Fig.5 Meshed view

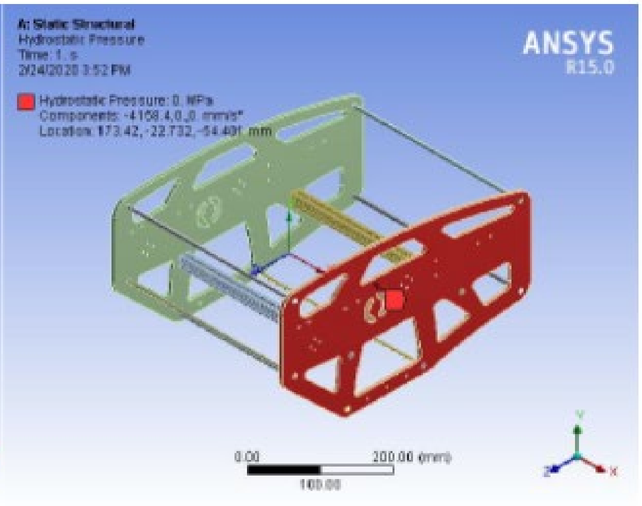

Fig. 6 Static Structural Hydrostatic Pressure

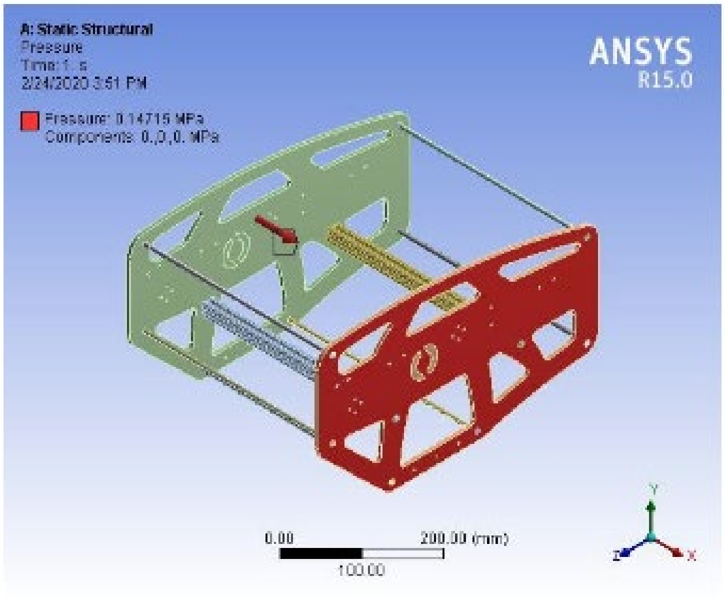

Fig.7 Static Structural Pressure

Table. 4 details of hydrostatic pressure and free surface location

Object name	Hydrostatic pressure	Pressure
State	Fully defined	
Scope		
Scoping method	Geometry selection	
Geometry	2 faces	
	Definition	
Type	Hydrostatic pressure	Pressure
Coordinate system	Global coordinate system	
Suppressed	No	
Fluid density	950 kg/mm^3	
Define by		Normal to
Magnitude		0.13258MPa (ramped)
Hydrostatic acceleration		
Define by	Vector	
Magnitude	4036.1mm/s^2 (ramped)	
Direction	defined	
Free surface location		
X coordinate	170.20mm	
Y coordinate	-20.652mm	
Z coordinate	-48.325mm	
Location	Defined	

Table. 5 Properties of Aluminum Alloy

Density	2.77e-006 kg mm^-3
Coefficient of Thermal Expansion	2.3e-005 C^-1
Specific Heat	8.75e+005 mJ kg^-1 C^-1

4.2 Analysis of chassis

Ansys 15.0 has been used to analyse the design that was previously discussed. Its meshing throughout the analysis phase was fine. The hydrostatic pressure and pressure were applied at the chassis' side boundaries, and the software's results, as well as meshing and pressure data, are discussed below.

5. Conclusion

A new class or generation of Nanomaterials called "robotic materials" are capable of actuation, communication, load bearing, and identification of which materials are appropriate for specific parts of robots. However, several aspects of the research have been left unfinished. The primary goal of the project is to extract zirconium from hafnium, as well as selected material for the suitable component, and to do some research on nanomaterials. The design of the chassis was created using the solid works software, which is a solid modelling software, while taking into consideration the appropriate characteristics in light of the actual environment situations. After that, the model is analysed using Ansys, and the conditions (pressure) are applied to the model. These conditions and the outcomes of applying them have been detailed in the portion of this paper devoted to the analysis and design considerations.

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