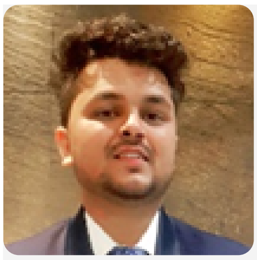

Students' Diary

Building large metallic parts with Wire arc additive manufacturing

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WAAM is one of the prominent metal additive manufacturing processes which is already been established as an alternative production process and now making an impact in different manufacturing sectors. WAAM employs an electric arc as the heat source and wire spool as feedstock combining it with robotic systems or CNC machines for motion control to a welding torch for depositing three-dimensional parts. WAAM can manufacture near-net-shape parts with modest complexity. It is particularly suitable for the fabrication of large-scale parts achievable in reasonable times with its high deposition rates (with rates ranging from 1kg/h to 4kg/h). In WAAM, employing the wire as feedstock makes it economical and convenient to handle; it also reduces the cost of parts by reducing material wastage. The application of this process is mainly found in the aerospace and marine industries.

Our work at IITH on WAAM particularly focuses on the realization of large-size components. An example of such components can be seen in the motor casing deposited. This deposition is a part of my M Tech Project under the guidance of Prof. Suryakumar S. The experimental setup used for the fabrication comprises a weld-deposition unit integrated with CNC machines. CMT variant of Gas Metal Arc Welding is used for metal deposition. Cold Metal Transfer (CMT) is one of the variants introduced by Fronius and the advantages of having CMT are excellent welding performance, good weld quality characteristics, low heat input, and virtually spatter-free mode. During welding, temperature variation has a significant impact on the material characteristics and weld bead dimensional accuracy due to residual stresses. To encounter this effect, CMT provides a controlled way of material deposition and low thermal input by using an innovative wire feed system coupled with high-speed digital control.

The deposited part is 487mm in height and diameter of 210 mm as shown in Figure. The built part fits well within the required tolerances. The deposition parameters produced a wall thickness of 5mm; against a target of 3.3mm. This deposition took 48 hours to build from the digital model.

Figure - Complete deposited Part of Motor casing

- In WAAM, the temperature distribution is transient, and non-uniform contributes to distortion and residual stresses. The emphasis should be given to the part quality (mechanical properties and residual stresses) and accuracy (surface finish and geometrical precision).
- In the manufacturing of large components, there is a decrease in the thermal gradient of the molten pool and an amount in heat loss. This is due to the reason that in WAAM, the preferential mode of heat transfer is conduction through the substrate and cooling the molten pool. The magnitude of heat flow decreases on an increasing number of layers, causing heat accumulation. Therefore, the thermal conductivity, the specific heat of the base plate, and the amount of heat applied are important for determining the cooling rates in WAAM.

Students' Diary

Exploring property space of triple periodic minimalistic surfaces (TPMS) for product design and development

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Additive manufacturing (AM) allows for the manufacturing of complex shapes, especially metamaterials. The design of metamaterials using advanced software algorithms opens the door for tailored properties in different places of the structures without changing the material and final shape of the component. Using metamaterials also decreases material consumption without negatively affecting the desired structural properties; it also brings us a step closer to the United Nations (UN) Sustainable Development Goals (SDGs) of 9, 11, 12, and 13.

Triple periodic minimalistic surfaces (TPMS) are a special kind of metamaterial, also known as Architected materials, that have potential applications in fields like Aerospace, Energy Conversion, Tissue engineering, etc. A minimal surface is a surface that is locally area-minimizing; that is, a small piece has the smallest possible area for a surface spanning the boundary of that piece. For example, Soap films/bubbles. Minimal surfaces necessarily have zero mean curvature, The minimal surface can represent the lowest energy state. The TPMS are minimal surfaces periodic in three independent directions, extending infinitely and, in the absence of self-intersections, partitioning the space into two labyrinths2. TPMS structures have an excellent mechanical properties, including energy absorption, strength, and stiffness, as well as easier control of structure properties, better load sustaining capabilities, and higher surface area densities than stochastic and prismatic cellular solids. German Mathematician H.A. Schwarz described the first example of TPMS in 1865 and named it Schwarz diamond surface2. Even in nature, many structures like butterfly wings are members of this group of structures.

One of our research work primarily deals with second-order TPMS with variable density. In this work, The hierarchy is introduced in the TPMS structure which allows us to control certain parameters depending on the applications. One such example is shown in **Figure 8.** A cube of solid material is reduced to 1st order Gyroid (TPMS) structure. On top of that, a hierarchy is introduced (2nd order Gyroid, as in **Figure 8 (b))**. This type of structure opens up new avenues for product development and design. Hierarchy allows for the addition of tailored properties in different places of the components.

The simulation and analysis of such structures are also difficult because they are essentially heterogeneous in nature. To understand the material behavior, homogenization techniques help to replace the heterogeneous material with a homogeneous material representation. **Figure 9** represents the stiffness matrix of TPMS unit cells, calculated through homogenization (colorful blobs). This helps the designers to predict the influences of the unit cell in the final designs of structural components.

Additive manufacturing technologies enable the manufacturing of TPMS structures which otherwise would not have been possible. But it is still a challenging domain, especially for metals, which calls for further research and explorations.

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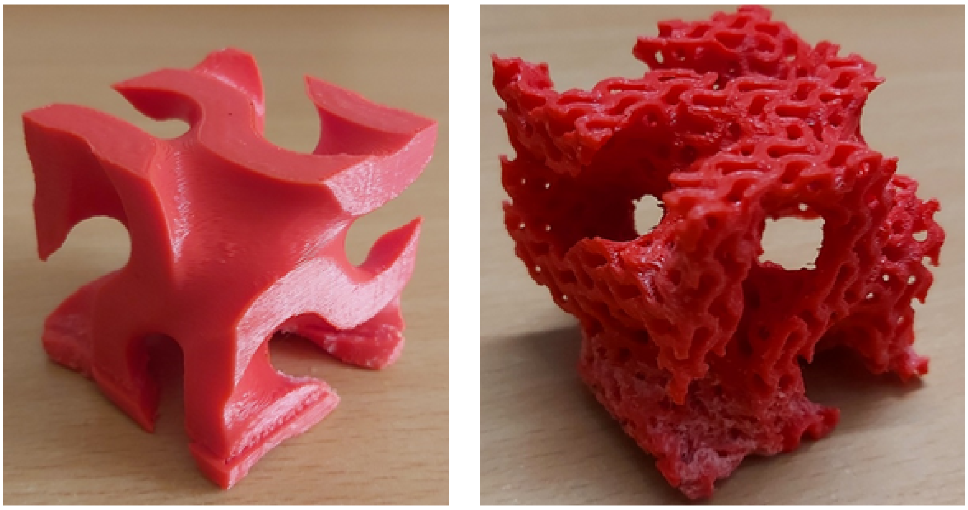

(a) (b)

Figure 8: Hierarchy in TPMS. a) 1st order Gyroid, b) 2nd order Gyroid

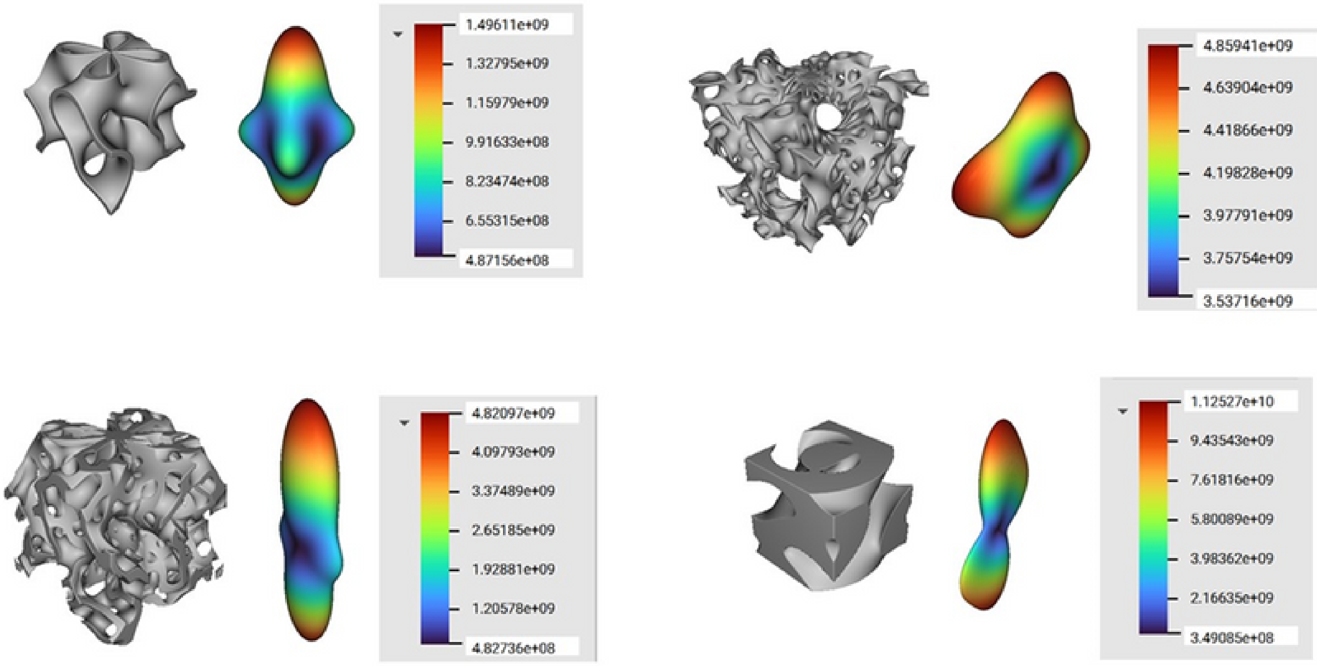

Figure 9: Property space of TPMS (Values in MPa).