Innovative Mechanical Design Based on Additive Manufacturing & Topology Optimization

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Additive Manufacturing (AM) is a major topic of interest for the manufacturing industries. While the common thinking is that everything can be done by AM – which is only partially true – it can be added that it cannot be done anyhow. The AM process needs to be well mastered as it introduces several new challenges which shall be taken into account already in the design phase. In parallel, reproducing by AM the same parts that are currently produced by traditional methods such as machining is usually of no interest. To ensure the highest added value (and lowest cost), the entire device – and not only the individual parts – shall be re-thought under a process oriented design perspective, including a system engineering vision. CSEM is investigating new capabilities of AM with the aim to help manufacturing industries to redesign their products according to this holistic approach.

The elaboration of products made by metallic Additive Manufacturing (AM) has been investigated at CSEM over several years, seeking at taking advantage of the new possibilities offered by AM technologies for newly designed as well as for re-engineered products with enhanced performances. The first step of this endeavor was to evaluate and to optimize all the processes involved with the aim to ensure the feasibility of complex parts, including 350 µm thick and 20 mm long flexure blades manufactured with AM, a typical geometry used at CSEM for the design of high precision mechanisms. Achieving such challenging geometries has required the identification, in-depth study and understanding of the critical AM process and post-processing parameters affecting the quality of the end product. This study was followed by specific in-house developments to master the complete AM chain, beginning with the design for AM, taking into account the new constraints of this technology, continued with the optimization of stainless steel and titanium materials fulfilling high-end mechanical performances. The post-processes such as machining, cleaning and thermal treatments have been extensively investigated. In parallel, the Topology Optimization was studied for complex structural parts to ensure the most efficient design taking into account multi-physics aspects.

Using AM technologies to reproduce a part whose design was driven by a conventional manufacturing techniques is often not advantageous, since it does not take into account the advantages offered by AM. For example, the complexity of the assembly can be reduced by designing a monolithic mechanism or by reducing the number of parts and combining the functions. The project AMAR (Additive Manufacturing of a slipring Assembly Rotor), in partnership with RUAG Space Switzerland Nyon and funded by the Swiss Space Office, is an example of a significantly improved production flow enabled by a smart combination of AM and post-processing techniques.

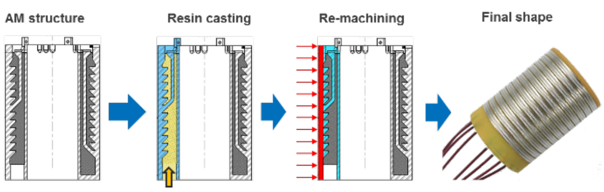

Figure 1: New process with additive manufactured parts (patent pending).

The new design developed in AMAR proposes to produce by AM a skeleton which comprises all the features, to cast it with insulating resin and to machine the final shape of the rotor. In comparison, the state-of-the-art production procedure is tedious, implying a lot of machined parts with tight tolerances to be assembled in many successive steps.

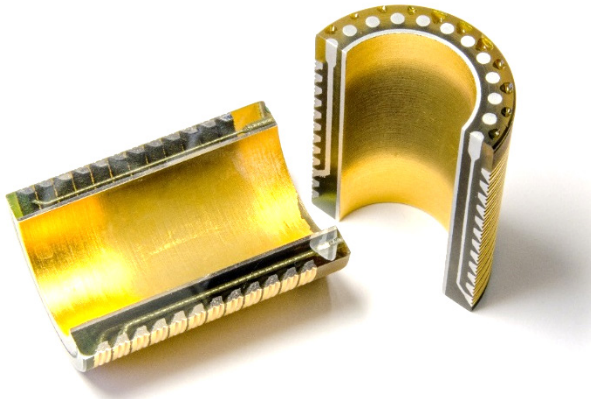

Figure 2: Pictures of the first prototype built by AM.

To ensure an optimized redesign for AM, a system engineering approach allows understanding all the parameters pertaining to the mechanism and therefore being aware of all the key requirements to be considered during the design phase. In parallel, the design constraints associated with AM are to be deeply understood as well.

To further improve the design, the use of topology optimization software is actually the most efficient method to improve various properties of the parts designed for AM at the same time: e.g., mass reduction, eigen-frequencies tuning, thermal transfer optimization, thin-wall thickness optimization, etc. The optimization can be performed using multiple criteria at the same time, including combined multi-physics analysis; e.g., mechanical, thermal, magnetic, fluidic. Topology optimization requires to precisely define the most demanding load cases and therefore to deeply understand the mechanism and the entire system. This tool is the most powerful to successfully achieve a redesign for demanding applications such as high-precision mechanisms with complex structures for space applications. The competencies developed at CSEM on the whole AM process chain are applicable to any type of industry.

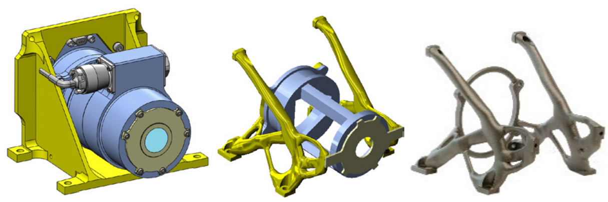

Figure 3: Example of topology optimization made at CSEM.

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