Additive Manufacturing (AM) has experienced a tremendous growth since its first appearance in the 1980s, both in academia and industries. Its disruptive layer-by-layer approach allows the production of unique and personalized designs at a much lower cost than conventional processes such as milling or injection molding. Furthermore, AM unlocks the generation of lightweight and shape optimized parts, while requiring less material and energy. Among the existing families of AM processes, Material Extrusion (MEX) has one of the highest potential of development in the next decade. Indeed, this process can be scaled up at a much lower cost than the others and can produce metallic or ceramic parts with the conventional injection molding feedstocks. Nevertheless, some technological locks still hamper the widespread of MEX in industry. The lack of standards, limited process predictability, repeatability and the need for post-processing before obtaining viable parts are common drawbacks. This thesis tackles these problems and aims to enable the production of ceramic parts through a hybrid approach combining MEX and milling in the same machine to compensate with one process the drawbacks of the other.

First, methods to establish the achievable tolerances of the MEX printer were developed by designing, printing and measuring innovative test artifacts called Geometrical Benchmark Test Artifact (GBTA). The proposed solution allowed the dimensional and geometrical performances of MEX printers to be assessed for short production runs. Both dimensional and geometrical performances (IT between 10 and 16 of ISO 286-1, and classes *large* of ISO 2768-2) were significantly lower than those achievable with conventional processes such as milling.

The analysis was extended to long production runs by implementing the machine performance concept (capability). Despite the comprehensive characterization it provided, conducting a machine performance analysis using the GBTA cannot be implemented in industry due to the long printing time it requires (nearly one month for obtaining the required number of parts). Therefore, a novel test artifact called the COMPAQT (Component for Machine Performances Assessment in Quick Time) was designed and enabled the characterization of the dimensional machine performance of a printer, while keeping the manufacturing time below 24 h.

As anticipated, the dimensional and geometrical performance of the tested printer remained insufficient and pushed for improving them by finish milling, using the proposed hybrid approach. This was carried out by developing an objective method to determine the cutting conditions of a tool for the milling of AM shaped materials. The developed method allowed to select, among three tools, the one that generated the most repeatable results of the desired surface texture (Arithmetic Roughness (Ra) < 1.6 µm), while avoiding a catastrophic damage mode. This was extended by a study to quantify the overall improvements brought by the hybrid approach including the debinding and sintering operations, which are required when producing ceramic parts. The geometrical deviations, compared to those obtained after the manufacturing by MEX, were decreased by a factor between 8 and 18 times. The same tendency was observed for the surface textures with Ra decreasing from approximately 50 µm to less than 1.6 µm. Moreover, the generation of sharp edges was unlocked by the milling operation.

The final part of the thesis focused on improving the reliability of the MEX process itself by developing a vision-based solution using a thermal camera and a profilometer. An innovative sample design was developed to minimize the material needed for such tests (only 2.330 cm^3 of material was needed for each tested condition). A full-factorial design was established and allowed numerical models to be obtained. This allowed the best printing parameters among those tested to be selected and opens new possibilities for the future.

The contributions of this thesis pave the way for new developments in the coming years to make hybrid machines fully viable, and have been developed within the framework of the research projects (HyProPAM and HybridAM) currently underway at the Machine Design and Production Engineering Lab.