HYROMAN – Hybrid robotic additive manufacturing platform for agile production of large multi-metal components

INTRODUCTION
A European consortium comprising of 10 partners has recently filed an innovative manufacturing platform that combines additive¹, subtractive² and transformative³ manufacturing technologies on a single platform to build the next generation of multi-metal products.

HYROMAN was submitted to the European Commission Horizon 2020 program, namely to the FOF-07-2017 call (Integration of unconventional technologies for multi-material processing into manufacturing systems), which is a part of the H2020 Research and Innovation Actions program.

WHAT IS HYROMAN?
HYROMAN is a research driven innovation activity that intends to build a disruptively innovative manufacturing system (called HYROMAN platform – Figure 1) that enables agile and cost-effective production of radically new multi-metallic components (e.g. functionally graded material). This creative production platform was designed based on the novel approaches and state-of-the-art technologies to provide defect free, cost-effective and rapid processing of multi-metal components.

WHAT IS THE HYROMAN PLATFORM?
The HYROMAN platform is an advanced robotic system – built as a demonstrator in the HYROMAN project - that comprises a modern deposition tool (additive) for near-net shaping of a given component, equipped with an in-situ machining station (subtractive) together with an in-situ surface treatment (transformative) cell to minimize the production time, shop-floor space and required capex.

WHY IS THE HYROMAN PLATFORM INNOVATIVE?
Remarkable changes during the past few years in the manufacturing sector through adaption of the technologies instigated by Industry 4.0, such as additive manufacturing, digitalization, collaborative automation, etc., shows that cutting edge yet cost-effective solutions are ultimately required to expand competitive European industry.

Consolidation of all relevant net-shaping processes will be an upswing step towards one-stop-shop manufacturing of the complex multi-material components. Consequently, since the HYROMAN platform uses low-cost net-shaping technologies to substitute the conventional processes, it is expected that such an engineered method will bring a significant reduction in cost, energy consumption and production waste through introduction of optimized and interactive processes. This can be considered as a breakthrough in the field of manufacturing and metal processing.

The HYROMAN project will lead to advancements in the manufacturing technology, including robotics, beyond the state-of-the-art through the following radical innovations in a systematic and holistic manner:

1) HYROMAN will deliver an operational platform that integrates opposite concepts, among others, additive/subtractive processes, to obtain a powerful tool for modern advanced manufacturing of complex parts. This is quite a challenge, in terms of cell design, programming environment and operational environment, since HYROMAN wants to fully release the potential of the integration of the two above opposite concepts to any design and production engineer;

2) HYROMAN is truly a multidisciplinary project that will provide grounds for pushing the boundaries of technology within different areas of expertise by facilitating the process integration;

3) The HYROMAN platform will further improve the versatility and flexibility of the design and production of

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1 Additive manufacturing refers to all the technologies that join the materials layer by layer using the CAD data to make an object.
2 Subtractive manufacturing refers to all the technological methods that successively cut material away from a solid block or structure of material.
3 Transformative manufacturing in this context refers to a set of complementary technologies that alter the quality, properties and microstructure of materials each of which considered as a finishing step in the entire value-chain.
complex parts, simply because the additive, subtractive and transformative processes are fully combined. HYROMAN platform is among the first in class to enable multi-material processing and finishing.

4) The challenge for flexible and agile manufacturing relies on simple and natural human-machine interfaces. We want to be able to simply tell them, or show them, what we want them to do. This means, at HYROMAN level, the possibility to program complex platforms using tools that any engineer is able to use: CAD packages, for example. This solution is an interesting approach since CAD packages are available at SMEs and users are usually prepared to use it. Code generation can be available (preferably), but it could also be based on services, or RPC/XIRP calls;

5) High-Level-Programming (HLP) technologies are explored to hide from the users the complexity of how things are done, allowing them to focus fully on the operational task he needs to handle. As part of a HLP, the automatic path planning (i.e. tools) that take the geometrical data to generate a toolpath is also explored and implemented. This will shorten the time between the design of the components and the component production and will allow highly customized metallic and multi-metallic part production.

In other words, the programming environment of the HYROMAN platform was designed to allow users to interactively explore the combination of additive, subtractive and transformative manufacturing in the processes of designing and producing a new part, by integrating existing software tools (i.e., CAD packages) with advanced human-machine interfaces and software constructs. This effective interweaving of several operations will give an unprecedented flexibility to the new manufacturing setups.

WHAT ARE THE HYROMAN PLATFORM OBJECTIVES?
The main objective of this project is to design, develop and demonstrate a fully automatic robotic platform that can be used to produce multi-metallic (FGM) parts, by integrating the following three different manufacturing processes:

1) Deposition manufacturing technology (additive process);
2) Robotic milling (subtractive process);
3) And a set of modular (optional) surface treatment methods to modify the surface microstructure (transformative process);

This platform is a complex system while keeping the lead-time, waste and costs way below the ones offered by conventional production routines.

WHAT ARE THE HYROMAN PLATFORM EXPECTED IMPACTS?
The HYROMAN platform is designed to have a dramatic impact in the following:

• Reduction of at least 20% in the production time, through the integration and optimization of operations and the reduction of idling time between manufacturing steps.
• Reduction of at least 25% in the production cost, through process integration, which reduces operations, and improved manufacturing quality for straightforward designs and 50% for intricate designs.
• Improving resource efficiency by at least 50%, just by a) reducing the use of raw materials; b) reducing the energy consumption; 3) reducing the waste, and 4) eliminating the need to transport parts from one processing station to another.
• Developing a manufacturing setup to meet the increasing demand for production flexibility by implementing high-level programming (HLP).
• Developing and integrating a quality control mechanism in the platform, which uses real-time robotic vision and multi-sensorial systems to obtain high-quality processing.
• Bridging the technological knowledge gap in this type of hybrid manufacturing operations, namely in terms of a) interoperability; b) CAD interfacing systems; and c) materials technology.
• Further strengthen the global position of the European manufacturing industry, and associated value chain, through the intensive
implementation of innovative and unconventional technologies.

• Developing and exploring the disruptive innovation as a reasonably low capital investment solution suitable for SMEs.

WHY IS ADDITIVE MANUFACTURING (AM) SO IMPORTANT?

1) AM-driven smart factories offer an exciting prospective solution to limiting the carbon footprint across all of the industrial sectors, without compromising competitiveness. In industrial activities such as manufacturing, the additive technologies provide the ability to produce a complex version of the end-product parts, which may allow for as much as 96% reduction in raw material usage compared to traditional subtractive methods.4

2) Since 95-98% of materials fabricated additively5 have been found to be recyclable, we can argue that there is a correlating relationship between economic and environmental performance of manufacturing systems. Although lacking empirical justification, hypothetical scenarios with regards to AM sustainability impact on logistics, distribution and supply chains suggests that a shift from a centralized to a de-centralized and regional manufacturing model, carry implications such as shorter spatial frame of value-addition directly impacting the carbon-footprint through decreased transportation activities.

3) From a pure sustainability perspective, establishment of smart factories dedicated to manufacturing of metal- and alloy-intensive equipment to the industry should clearly benefit from a transition from traditional fabrication of highly complex, discrete parts, requiring multiple iterations and material blends nearly impossible to achieve with traditional methods. Moreover, adding to it the economic perspective, it is evident that the future road for manufacturing competitiveness is directed through the sustainability roundabout. As political initiatives such as industrial emission fees and transport regulations is becoming a part of the game, the benefits of AM are extending beyond those of volume vs. scope, customization and complexity happening on the factory floor, to those in which has the potential to shake up the operational infrastructural in manufacturing, where environmental sustainability performance is an integrated part of the strategic pursuit of cost efficiency.

4) Additive Manufacturing, unlike conventional approaches, is more likely to accentuate cooperation of wider spectrum in the labor market. The manufacturing routine shortcut that brings the product closer to the idea by eradicating the intermediate manufacturing steps, introduces an enthusiasts atmosphere for almost everybody to participate in the design-promoted rally.

5) Additive manufacturing is growing by means of the “paradigm shift” that this technology provides. It is the fusion of several design elements including new concept, ambition, intellectual perception and expertise. Appropriate implementation of this technology will result in radically improved products. AM keeps aloof from manufacturing driven design and opens up to unlimited possibilities.

6) Estimates (Wohlers Report6) of the additive manufacturing market is beyond 20 billion dollars by 2020. Siemens predicts that 3D-printing will become 50% cheaper and up to 400% faster in the next five years7.

7) Combination of additive manufacturing with subtractive manufacturing in the same platform, as proposed by the HYROMAN project, has potential to lead to an unprecedented flexibility to the new manufacturing setups. This will have major impact in the productivity and competitiveness of actual manufacturing plants.

WHAT IS THE COMPOSITION AND GEOGRAPHIC DISTRIBUTION OF THE HYROMAN CONSORTIUM?

The HYROMAN consortium is composed by 10 partners (Figure 2) which are leaders in the research, design and production of manufacturing system that include traditional and additive manufacturing technologies.

WHAT ARE THE FINANCIAL AND OPERATIONAL DETAILS OF THE HYROMAN PROJECT?

| Total Budget: | 5,000,000.00 € |
| Total Personnel: | 589 Person-Months |
| Total Investment: | 1,286,000.00 € |
| Project Duration: | 36 Months |
| Deliverable: | Manufacturing Platform Demo |
| Starting TRL: | TRL-4 |
| Closing TRL: | TRL-6 |

Figure 2. HYROMAN consortium in a glance.

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6 Collins F. "Wohlers report 2014 uncovers annual growth of 34.9% for 3D Printing and Additive Manufacturing industry" . 2014.