# KRAKEN

KRAKEN: the all-in-one fully integrated machine for multi-material hybrid manufacturing

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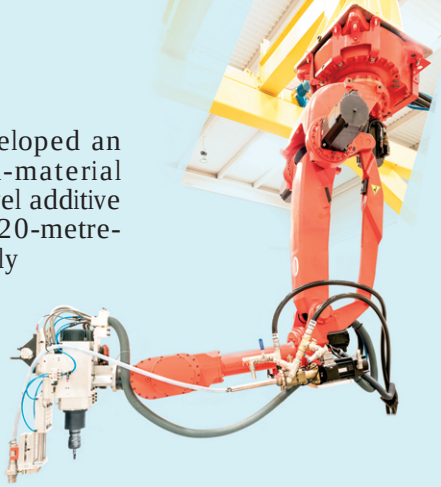
# ABOUT KRAKEN

KRAKEN is an EU funded project that has developed an automated, robotic machine for hybrid multi-material manufacturing combining both subtractive and novel additive technologies. Capable of producing parts of up to 20-metre-long, the KRAKEN machine has automatically interchangeable additive and subtractive heads, the capacity to achieve high quality and accurate results including internal and difficult-to-reach areas, and effective control over thermal stress and deformation.

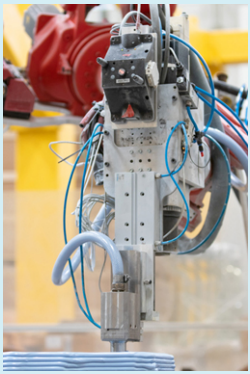


# PROJECT RESULTS

## Multi-material Additive Manufacturing

### New polyurethane paste (ALCHEMIX PU3720A/B)

A new two component machine-dispensable polyurethane paste (ALCHEMIX PU3720A/B) adapted to Additive Manufacturing has been developed within the KRAKEN project. The material is particularly suitable for the manufacture of design/styling or master models. The formulation allows the building of large prototype models within a footprint of 20m x 8m x 6m. This new paste has been designed to cure rapidly to allow a high deposition rate of 180 Kg per hour. Once cured it can be easily machined to give a very smooth surface finish.

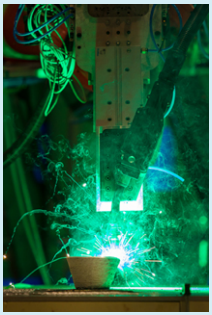


### New resin extrusion process

As part of the KRAKEN project a new dedicated resin extrusion process has been developed. The system consists of a pumping mechanism for the new polyurethane paste, a balanced mixing system, a deposition head and an automatic flow control. The system is able to reach a deposition rate of 120 kg/h, which is around 200 times faster than a conventional additive manufacturing machine. This is a scalable system, capable of being assembled in 3-axis machines and in industrial robots.

### Wire arc Additive manufacturing (WAAM)

The KRAKEN machine integrates Wire Arc Additive Manufacturing with aluminium grades that can reach metal deposition rates of up to 1.5 l/h, depending on the geometry of the part.



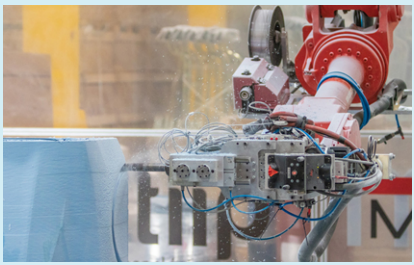
### Metallisation process

An arc spray metallisation process based on metal alloys has also been developed. This metallization process enables the use of metal Additive Manufacturing on top of a polymer part. This new process, which can reach deposition rates of 6kg/h, opens new pathways for innovation in metallisation.

## Subtractive manufacturing

The KRAKEN machine has a hybrid additive-subtractive head with automatic quick tool exchange which allows for a quick switch between additive deposition of material and subtractive operations.

The project has adapted the subtractive process based on a climb-up methodology specially designed for planar layer-by-layer and direct 3D freeform production strategies. It targets 2mm depth of cut and 10m/min speed.



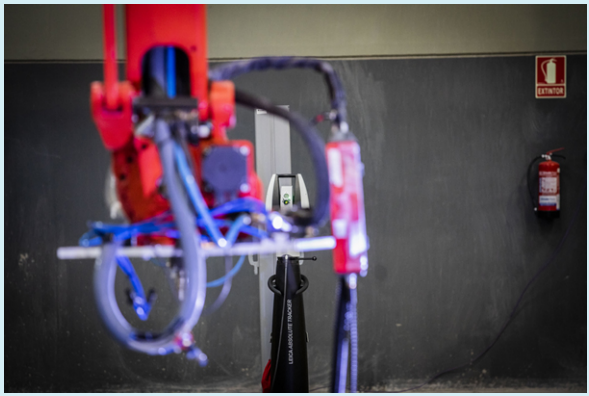
## CAM (Computer Aided Manufacturing) software for hybrid manufacturing

The existing commercial software solution, EDGECAM has been used as the base system for the CAM developments within KRAKEN. Functionality has been enhanced and new CAM algorithms for hybrid manufacturing, including planar horizontal layer additive strategies and new direct 3D freeform approaches, have been integrated. The new system has an intuitive and simple user interface and allows for the generation, automation and simulation of manufacturing tasks for hybrid manufacturing.

# Real-time control and monitoring

## Real-time control

The high accuracy of the KRAKEN machine is achieved through a closed-loop control of robot motion and end-effector position and orientation (6DoF) in real-time based on absolute laser tracking. The position of the head is monitored and controlled with a frequency of 1000 Hz with an accuracy of 0.1 millimetres over 20-metre parts. The machine also relies on an automatic calibration system based on absolute laser tracking.

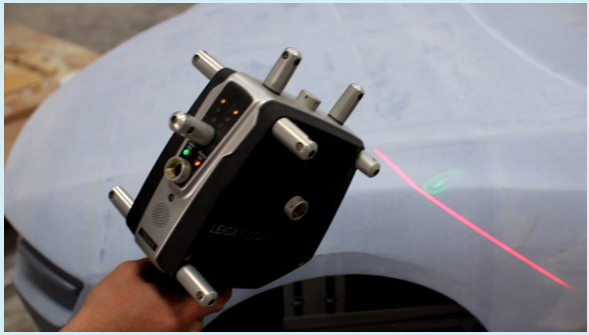


## Quality Monitoring systems

The KRAKEN machine includes a laser tracker-based scanner allowing for in-process geometry validation of semi-finished and finished parts.

In addition, a vision-based monitoring system helps to analyse the surface quality during the resin extrusion process. This system comprises both hardware and software including high-definition cameras that complement a stereoscopic machine vision system, as well as image acquisition, processing and control software able to detect defects in the resin deposition process.

These quality monitoring systems allow for early failure detection and correction, leading to significant reductions in operator and machine time, material waste and total effort spent to print different components and products.



## E-learning platform

The project has also developed an e-Learning platform with comprehensive information on hybrid and additive manufacturing processes and the KRAKEN machine. This online platform is a resource for further developing and disseminating design, engineering and manufacturing knowledge and expertise in hybrid manufacturing. It is an important tool aiming at overcoming existing barriers in modern industrial production.

The platform can be accessed for free at the following website:
krakenproject.eu/elearning

# DEMONSTRATION CASES

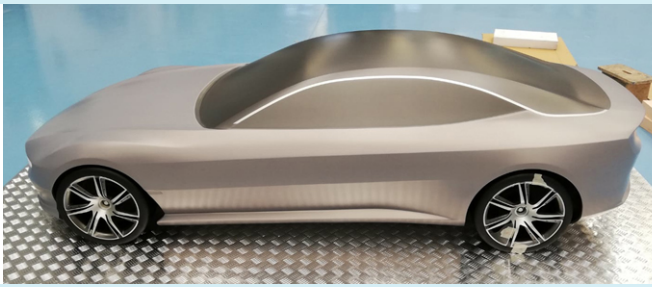
The KRAKEN system has been validated through a series of demonstration cases. Sectors that can potentially benefit from the adoption of this technology and the project results include aerospace, automotive, power generation and energy, industrial equipment and tooling, shipbuilding, construction and the creative industries.

### Hybrid lining panels for tunnels

Hybrid lining panels for road tunnels have been manufactured with the KRAKEN machine for ACCIONA Construction. KRAKEN multi-material capability has allowed to embed, into a monolithic part, auxiliary elements such as electrical wiring for the emergency lighting and metal profiles for panels assembly, which can help speed up the installation process. Its flexibility and simpler setup compared to current technology provide an alternative for the manufacture of short series and parts with complex geometries.

Mock-up of a Pininfarina car design

The KRAKEN technology was used to reproduce the exterior style of the Cambiano, a recent Pininfarina showcar. The model has been manufactured in 1:2 scale by the KRAKEN machine and then finished by Pininfarina with other exterior features. Equipped with a structural frame, the hollow demonstration case should be a promising alternative to the manufacture of style models in the near future.



Aluminium metallic back and front frames for a car

CRF validated the KRAKEN technology by manufacturing the back and front metallic frames of an Alfa Romeo 4C. The KRAKEN technology provided a new solution integrating large material quantities deposition and hybridization between polymeric and metallic parts, currently not achievable with other AM technologies. Within KRAKEN, CRF demonstrated the good performances of both polymeric and metallic materials that are suitable for automotive applications even for large area components. This will allow to reduce drastically investment costs with a positive business case even for medium volumes.

# BENEFITS OF THE KRAKEN MACHINE

The KRAKEN machine offers the following advantages in relation to other technologies:

- 90% less floor space thanks to the use of a ceiling installation and the reduction of necessary workplaces.
- 40% faster thanks to the high deposition rates of the resin extrusion process and WAAM and the integration of the milling and finishing in a single machine.
- The KRAKEN machine is an affordable solution with a lower price than current equipment and solutions for the production of final parts for the production of large customized functional parts.
- 25% more productive thanks to the accuracy achieved through real-time path programming and control and real-time monitoring and geometry inspection.


KRAKEN

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