Ref. Ares(2019)4372747 - 09/07/2019

"High Pressure Die Casting (HPDC) Lost-Core (LC) technology for the production of Aluminium Closed Deck blocks for next generation Euro 7 engines"

Project Acronym: CORE 4.0

H2020-FTIPilot-2015-1

Grant agreement nº 701197

PUBLIC DOCUMENT

Deliverable 1.3

"Public final report"

WP1:"Project Management, Coordination & Dissemination"

D1.1 – Public final report

Project Information

Grant Agreement Number	701197
Project Full Title	Pressure Die Casting (HPDC) Lost-Core (LC) technology for the production of Aluminium Closed Deck blocks for next generation Euro 7 engines
Project Acronym	CORE 4.0
Project Coordinator	FAGOR EDERLAN
Project Website	www.core40-project.eu

Deliverable Information

Deliverable n°	D1.3
Deliverable title	Public Final report
Type	Report
WP	WP1
WP Leader	FAGOR
Contributing Partners	TECNALIA – RAUSCHERT – FERROCTRALIC - RENAULT
Authors	Andoni Lopez de Sabando (FAGOR)
Contributors	Joannes Mendizabal (EDERTEK) Mikel Merchan (TECNALIA) Guillaume Bourdon (RSA) Alberto Menoni (RAUSCHERT) Bojan Crtralic (FERROCTRALIC)
Reviewers	Mikel Merchan (TECNALIA)
Contractual Deadline	M38
Delivery date to EC	M39

Dissemination Level

PU	Public, fully open, e.g. web	✓
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC.	

Document Log

Version	Date	Description of Change
v.1.0	31/05/2019	First draft prepared and sent to the rest of the partners for review
v 2.0	08/07/2019	Final version

Table of Contents

1 Executive Summary

This document gives an overview of the work carried out by the project Consortium during the development of the project and shows the main results obtained regarding the goals and objectives initially planned for the project.

The intended public for the document is the general public, therefore some confidential information of the project's results is not shown in this report.

2 Overview of the technical work and main results

The objective of the CORE4.0 project has been the development of aluminium closed deck engine blocks in HPDC technology using lost cores for the water jacket, intended for use in the new generation of Euro7 diesel engines.

The project tasks have been organized in 5 work packages, each of them with specific objectives, tasks and deliverables.

WP1. Project management, coordination and dissemination.

T1.1 Project management

T1.2 Project results dissemination

WP2. Product development.

T2.1 HPDC die design and simulations

T2.2 HPDC die construction

T2.3 Ceramic core die design and construction

T2.4 Development of high-resistance ceramic cores

T2.5 Production (and analysis) of 200 ceramic cores

T2.6 Casting of 200 engine blocks

T2.7 Development of the de-coring process

T2.8 Pilot scale tests

T2.9 Final inspection and delivery of the blocks

WP3. Process development for mass production and validation.

T3.1 Develop pilot core-shop for mass production

T3.2 Manufacturing of ceramic cores for process validation

T3.3 Optimization of HPDC process for industrial mass production

T3.4 Improve de-coring equipment for mass production

T3.5 Process validation

WP4. Product validation.

T4.1 Preparation of the prototypes for the testing

T4.2 Characterization of the engine blocks

T4.3 Assembly complete engine M9T

T4.4 Characterization and endurance test of the engine

WP5. Business model validation and exploitation.

T5.1 Validation of CORE 4.0 business model and exploitation plan

T5.2 Coordination of Exploitation strategies and business plans

T5.3 Market contrast and research

T5.4 IPR management and coordination of partner agreements

All work packages have been completed during the 38-month duration of the project although some validation activities of task 4.4 in WP4 are still active in the moment of this project final reporting.

2.1 Work package 2

WP2 was devoted to the product development and has been active since the beginning of the project until M19. The leader of WP2 has been FAGOR and all members of the consortium have been active to contribute in this activity.

The main objective of WP2 was to develop a closed deck aluminum engine block through the ceramic lost core technology compatible with Renault's M9T engine with the objective of reducing the total overall weight of the engine and thus reducing CO2 emissions.

The design of a cast iron diesel engine block was adapted to be produced in aluminium HPDC, resulting in a 2.0 litre diesel engine which shifted from long skirt design to a short skirt with bedplate. The total weight of the engine block, including the bedplate, was reduced to almost half of the initial cast iron engine block.

2.1.1 Development of the HPDC die

Fagor and Edertek have been responsible of the design and manufacturing of the HPDC die to produce the castings. This sophisticated die and all necessary ancillary elements such as lubrication tools and robot grippers have been designed with the use of simulation tools to make sure that the gating system, venting system and thermal control of the die had the optimum design. The die, comprising 4 sliders and a squeeze pin system in the bearings, was built with an external toolmaker and the first tests were carried out at Edertek's 2.700Tn die casting machine in November 2016. The first trials were made without using lost cores, in order to tune up the die casting die and the process parameters. These first castings served to check the dimensional tolerances of the casting, analyse the internal metal quality and test some mechanical properties.

Figure 1. HPDC die for CORE4.0 engine block

A dummy lost core was produced using additive manufacturing in ABS resin in order to check the core print system and the robot gripper with a physical core, in the absence of real lost cores due to the delay that was accumulated in the development of the ceramic cores.

2.1.2 Development of the ceramic cores

In parallel, Rauschert has been in charge of designing and building the tool for the manufacturing of ceramic cores. A pressing machine had to be modified and adapted to the requirements of the size and complexity of the water jacket, due to the fact that there was no suitable machine available in the market. The pressing force and the dimensions of the machine were increased and hydraulic and electric parts were added to a machine featuring a CNC control.

Figure 2. Pressing machine installed at Rauschert Italia

As a preliminary step, a first version of a simplified mono-cylinder ceramic core was produced, for which Rauschert had a tool used in the development of ceramic cores before the CORE4.0 project. This mono-cylinder ceramic core was tested at Tecnalia's die casting facilities, in a die casting tool designed and built by Tecnalia for this purpose.

Figure 3. Mono-cylinder cores wihout coating (left) and coated (right) inside pilot scale HPDC die

These preliminary tests were decisive in order to foresee the potential problems that could arise in the production of the more complex 4-cylinder ceramic core. One of the problems that arose in this pilot scale tests was the penetration of aluminium in the ceramic core, creating a cermet layer that could not be eliminated from the castings. Six different coatings were analysed by Tecnalia in collaboration with Rauschert in order to prevent the penetrations and laboratory tests were performed to identify the most suitable candidates. The 2 most promising coatings were tested in real HPDC conditions with the mono-cylinder tool and finally a boron nitride coating was chosen. It also was observed that the strength of the cores was not enough to withstand the injection forces of the HPDC process and so the ceramic material would have to be reinforced. Different firing temperature levels were tested for the ceramic material, and 3 point bending tests were carried out to measure the bending resistance of the cores at each firing level.

The tool for the 4 cylinder water jacket was developed and manufactured by Rauschert Heinersdorf Pressig in collaboration with Rauschert Italia, because there was no external supplier with enough skills and know-how to perform the job. In order to get all the technical information necessary to design the final 4-cylinder mold, Rauschert developed the first version of the mono–cylinder tool by building new ones focusing on the study of the geometry of the crown and of the channel. The development of the tool accumulated some delay due to the problems encountered during the experimentation with the mono-cylinder tool and also due to the high complexity of the tool. Once the tooling was built and the pressing machine had been adapted, the first pressing tests at Rauschert Italia were performed in June 2017.

Figure 4. First pressed ceramic core

The first results were not positive, resulting in tool damage in some critical areas due to the extreme forces exerted during pressing. The most critical area was in the long channel connecting the water-jacket to the water-pump. It was decided to modify the tool and supress completely the channel and avoid the tool cracking in this area. This was a decision to unblock the situation of the project, which was accumulating an important delay, and in August 2017 finally a batch of 4 cylinder cores without the channel was produced and delivered to Edertek for the casting trials. In parallel, some design modifications were agreed with Renault in the channel geometry in order to reduce stress concentrations in the tooling and the tool was modified for a future batch of final prototypes with channel.

The first casting trials with ceramic cores without the channel were carried out in September 2017. A batch of 50 ceramic cores at 2 different sintering levels was produced and some issues arose regarding the dimensional accuracy of the cores and their strength.

Regarding dimensional accuracy, it was observed that there were deformations, believed to be produced during the sintering process, which made it difficult for the ceramic core to fit in the core prints position. Consequently, many cores were broken during the loading operation because of the stresses exerted to put them inside the die casting die. These deformations were produced because the sintering temperature applied was higher than initially expected.

Figure 5. Ceramic core without channel

The other main issue was that the area were the channel had been removed remained with very thin wall thickness and this produced a weakness area were cracks could be observed after sintering the cores. Consequently the cores could not resist the injection forces and the HPDC process parameters such as speed and pressure had to be reduced below the acceptable limits of HPDC process. The result was a batch of castings with many broken cores and rather poor casting quality due to the very low speed and pressure applied. On the positive side, 3 castings could be sent to Slovenia to be used in the experimentation of the de-coring process that was being developed by Ferro Ctralic. Another positive outcome of this first batch was to confirm that the BN coating applied in the cores was effective in preventing the aluminium penetrations inside the ceramic material.

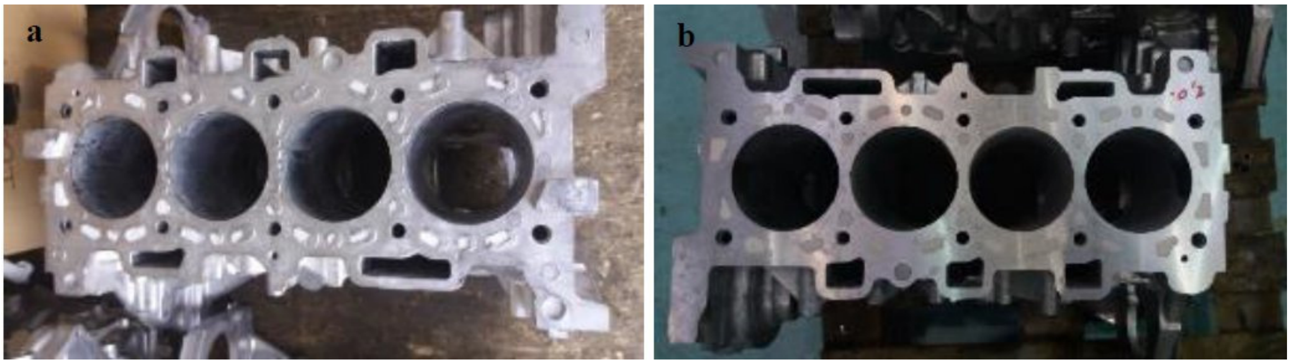

Figure 6. First batch of prototypes using 4 cylinder ceramic cores without channel.

As a conclusion of this first batch it was necessary to increase the strength of the cores, for which different additives were studied by Rauschert. Apart from adding special binders to the ceramic material, Rauschert opted for the application of a treatment with a gluing agent to impregnate the porosity of the ceramic material and make it stronger. A second batch of reinforced ceramic cores was produced in November 2017; the result was better than in the first trials, but still not showing enough strength to withstand the HPDC casting conditions. A batch of 6 castings with unbroken cores could be produced during these trials, which would also serve for the development of the de-coring process, as well as for the set-up of the machining and BSC coating operations at Renault.

As a conclusion of the activities in WP2, two lines of action were agreed in the project team. On the one hand, ceramic cores had to be improved for increased resistance, although this would affect negatively the de-coring process. On the other hand, HPDC process and tool would have to be modified and adapted to obtain the required quality with lower speed and pressure than standard HPDC parameters.

2.1.3 Development of the de-coring equipment.

Another crucial activity has been the development of a de-coring equipment capable of removing the ceramic core from the casting, leaving the water-jacket cavity completely clean of ceramic material. FerroCrtalic has been responsible to carry out these activities, focused on designing, constructing and testing of tools, equipment and procedures for de-coring. Development of innovative technology dedicated to de-coring of aluminium engine blocks crucially depended on defining workpiece specificities, which needed to be carried out in parallel with designing and setting-up the main segments of the cleaning procedure.

The equipment conceived for this project uses ultra-high pressure water jet technology with rotating lance nozzles that get inside the cavity of the water jacket. The de-coring cabin is equipped with a rotary table that allow loading the part in one side while another piece is being cleaned inside the cabin. The lance is positioned in each opening of the top face of the engine block by means of a robot, allowing access of the water jet inside the water-jacket cavity while the casting remains static in a fixed position. The chipped ceramic material is evacuated from the casting by the flow of water and partially dissolved. The water used in the operation is collected in a reservoir for sedimentation of the ceramic debris and could be further treated by filtration to be re-used. Extensive work was performed in designing and testing different nozzle tips, with specific parameters that lead to different kind of water-jet size, shape and energy, which in turn perform quite differently in destroying the ceramic material.

The development of the de-coring station was done in parallel with the development of the ceramic cores and the casting process. The first prototypes produced with mono-cylinder cores and the prototypes of 4 cylinder cores without the channel could be de-cored rather easily and in reasonable cycle times.

2.2 Work package 3

Work package 3 has been devoted to the development of the process for the mass production of aluminium closed deck engine blocks using ceramic lost cores in HPDC. The 3 main processes (ceramic core production, HPDC-LC casting and UHP de-coring) have been further developed and optimized in order to achieve a level of maturity that could allow for industrial mass production of the final product.

2.2.1 Development of pilot core-shop for mass production

Rauschert and Tecnalia focused in a first period to improve the resistance of the ceramic cores, as stated at the end of WP2. An infiltration process was developed to increase the resistance of the cores significantly, leading to a strong material that could resist the forces of the HPDC injection. Once the ceramic core was pressed and fired in the kiln, they were infiltrated with a gluing element and a second firing was carried out to dry the cores completely and achieve the required mechanical strength. On average, an improvement of 30% could be observed in the bending strength of the measured test bars.

Rauschert defined the process steps and equipment necessary for the industrial scale production of ceramic cores, based on a scenario of producing 200.000 engine blocks per year. A flow chart was defined with all the different steps of the ceramic core production, from raw material selection, preparation of the mixture, pressing of the core, sintering, infiltration, drying, quality check and packaging. The necessary equipment was defined (spray dry mixers, press, kilns, etc.), together with the calculation of required personnel for each of the steps and a layout of the core-shop was also defined.

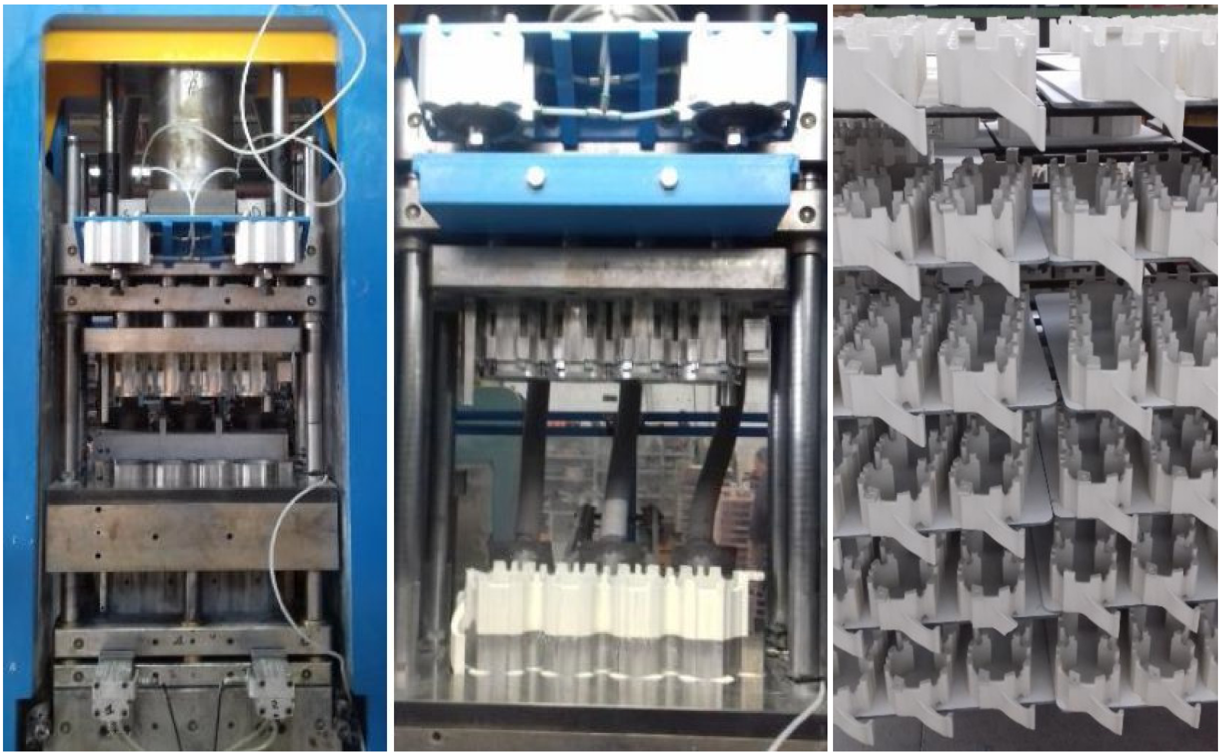

Figure 7. Pressing machine (left), pressing tool with ceramic core inside (center) and cores ready for sintering (right)

2.2.2 Optimization of HPDC process for mass production:

Different casting batches were produced in order to optimize production parameters in real operating conditions, with the aim to stablish the key parameters to and obtain realistic production ratios to validate the business case proposal.

As an initial step for WP3 and based on the conclusions of WP2, the casting team worked in producing castings with the lowest possible velocity and pressure while keeping the quality level at the required level. This development phase was initially done without ceramic cores and the castings were analysed using Xray equipment as well as optical microscope. The die design was reviewed and some modifications were done in the tooling to allow for a good filling of the die cavity at lower velocities. Once the die and casting parameters were tuned for optimum quality at the lowest filling velocities, the process optimization phase continued, using ceramic cores.

The final batch for product and process validation was manufactured in February 2018, producing over 40 good castings with ceramic cores with the channel. The cores had been improved in terms of pressing quality and reinforced with the infiltration, as well as coated to prevent penetrations. The reinforcement of the cores, together with more gentle HDPC injection conditions, lead to a successful result during this final production batch.

Figure 8- CORE 4.0 Closed deck engine block in HPDC-LC

2.2.3 Optimization of de-coring station for mass production

FerroCtralic has been responsible to optimize the de-coring equipment developed for the project, with the target to achieve the cycle time and cleanliness requirements. The optimization of de-coring process was in the focus of the WP3 activities with specific aims to process (de-core and clean) HPDC blocks containing ceramic core for further use in validation of the product and improve de-coring equipment and process to the stage enabling assessment and validation in terms of mass production process.

Different parameters have been optimized; nozzle design, water pressure and volumetric flow, nozzle rotation and advancing speed, robot de-coring strategy, etc.

In spite of all the optimizations carried out, the cycle time finally achieved for the CORE4.0 engine block was too high and not feasible for a mass production. However, the main reason for the long cycle time was mostly linked to the complex geometry of the core, especially in the water-channel area. For the rest of the core, if certain design parameters are respected, the de-coring operation would be feasible within reasonable cycle times. These design restrictions were taken into account in the definition of the ideal ceramic core design, as part of the process validation results.

Figure 9. Automated UHP de-coring machine

2.2.4 Re-design of the ideal water jacket for mass production

Although it was initially planned to produce up to 2.000 engine blocks in a continuous manner in order to validate all the process steps (Ceramic core manufacturing, HPDC-LC casting and UHP de-coring), during the development of WP2 and WP3 it became evident that the extra strength given to the core to resist the forces during the injection of aluminium, had in turn a back draw in the de-coring process. The cycle time necessary to completely clean the engine blocks was too high and it would be irrational to go ahead with the production of 2.000 units. The difficulties in de-coring were closely linked to the geometry of the ceramic core, which had a very intricate geometry, especially in the water-channel area.

It was agreed with the PO and amongst the consortium to change the objective of WP3 in this respect, and focus instead in the re-design of a water-jacket that would be feasible for all 3 steps of the process (Core making / HPDC-LC / De-coring) at the productive ratios defined, while maintaining the functional requirements for the correct cooling of the engine combustion chamber.

During the development of WP2 and WP3 enough experience was gathered to identify the critical points for each of the technologies (Pressing / sintering / casting / de-coring) in a qualitative and quantitative way, so that the consortium members could define the specifications for the new water jacket design in detail.

2.3 Work package 4

Work package 4 deals with the functional validation of the product developed in the project, the closed deck aluminium engine block for diesel applications. Renault is the leader of this work package, for which a complete engine had to be produced and assembled using current M9T engine components and also new specific parts such as the engine block and the bedplate, also manufactured in aluminium.

The castings produced using ceramic lost cores and de-cored by means of UHP water jet de-coring equipment were delivered to Renault Cleon for this purpose. Renault machined and prepared the engine blocks, applying vanguard coating technology for the cylinder bores, BSC bore spray coating. Through this process cast iron liners inside the cylinder bore are eliminated and replaced by thinner metal coating achieved through Twin Wire Arc Coating.

Inter-bore cooling channels were drilled using EDM process, in order to cool the critical inter-bore areas.

RENAULT has defined the process flow for block machining as shown below.

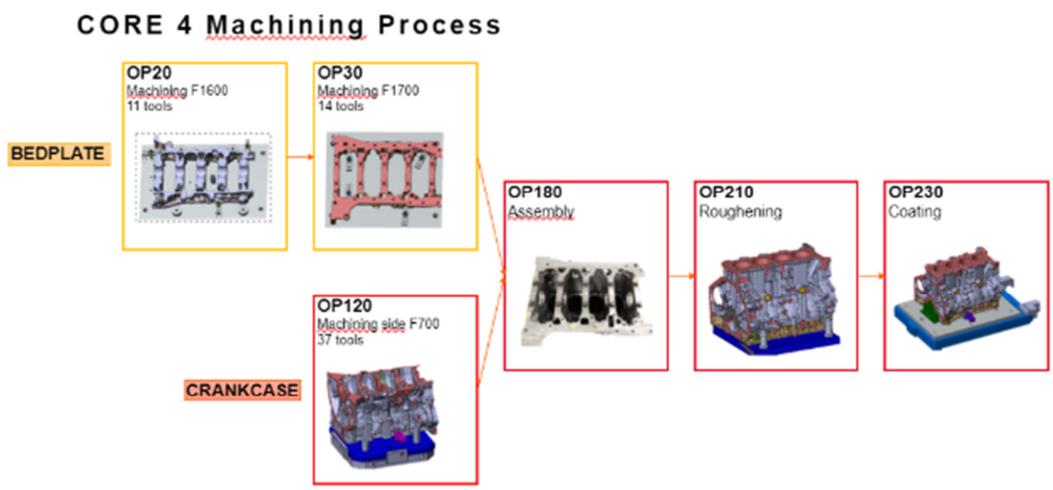

Figure 10. Engine block machining process

The coating of the cylinder bores was done using thermal spray coating technology (Figure 11).

Figure 11. Thermal spray coating process over the engine blocks

After BSC process, the engine blocks were assembled together with the bedplate to perform the final machining operation of the crankshaft supports with both parts together.

Figure 12. Assembly of the engine block and the bedplate

Dimensional controls and characterisations were done in the cylinder bores for all 4 cylinders of the engine blocks. The results from the BSC process and the following characterisation have been satisfactory, showing compliance with all RSA criteria for series production of similar parts regarding bore distortion, coating thickness, etc.

The crankshaft bearing were also measured to check the tightening range for cylinder head screw and bearing crankcase screw.

Renault carried out destructive characterisation tests to analyse the material properties as well as the characterisation of the layer and interface of cylinder bores coating. All these results have been satisfactory and the product characterisation has passed the validation criteria.

Rig tests have been performed to simulate the peak load exerted on the crankshaft during the ignition and explosion phase of the combustion. At the end of M38 some validation tests are still ongoing and are expected to be finished out of the time scope of the project.

3 Exploitation of Key Exploitable Results

There was a specific work package (WP5) aiming to assure that all the activities in the project had a market orientation and to continuously observe competitors and progress of technology in order to maximise the impact of the results. TECNALIA has led this WP, due to its experience in developing business plans and dealing with IPR management aspects, but FAGOR EDERLAN has been also highly involved, as main responsible of the business generated after the project to bring to the market the developed product. The rest of the partners have had also an important participation, as other results have arisen from the project and individual business plans have been prepared for them.

3.1 Exploitation and Business Plans of KERs

As a first step, the Key Exploitable Results (KERs) were identified. It was agreed that the two main results, apart from the main business of the closed-deck engine blocks manufactured with HPDC-LC processes, were the following:

	Individual Exploitation and Business Plan	
Partners	RAUSCHERT	FERROCRTALIC
KER	*Ceramic Cores for HPDC processes*	*Wand Robotic High-Pressure water solutions*

TECNALIA started to work with RAUSCHERT and FERROCRTALIC as main responsibles of these two results in the preparation of the individual exploitation and business plans. For each result the following information was collected: description of the product, exploitation route, market analysis, intellectual property and exploitation claims and risk assessment. After some months working on the analysis of this information, a preliminary version or pre-exploitation plan was prepared and sent to the EC as the deliverable D5.2 in March 2018.

Some months later, once the technical work was more advanced and the KERs could be validated, TECNALIA with the close collaboration of the consortium partners was able to define the final business plan of the analysed results. This plan was presented in the deliverable D5.3 submitted to the EC in November 2018. This document included the description of each of the mentioned technologies/products and a general overview of the market for ceramic cores and Wand Robotic High-Pressure water solutions. Besides, the report included the business models describing how Rauschert and FerroČrtalič were going to operate their respective new businesses. For such analysis, the two mentioned partners used the Lean CANVAS tool to provide information on the problem their technologies try to solve, value proposition of their respective KERs, competitive advantage against competitive solutions available in the market, main customer segments, exploitation channels, etc. Additionally, the report outlined the financial forecasts based on income and expense assumptions. Also, the partners detailed a plan containing the necessary commercial and technology actions to develop and market the innovative products developed in CORE 4.0.

Finally, a risk assessment for the exploitation of each result was presented. The most relevant risks for the exploitation of the cores were related to partnership factors. The first one was linked to the potential disagreement on ownership rules in case on transferring the technology to set up the production process of the novel ceramic cores. Additionally, the industrialization could be a risk if a relevant business partner (as FAGOR, o RENAULT) leaves the market. The highest risks for FerroČrtalič were related to technological factors. Robotic manipulators and high-pressure water pumps are one of the most complex and expensive outsourced equipment implemented in the HPWJ machine and could have influence on the feasibility and especially overall price of the product.

3.2 Business model validation

The main business of the CORE 4.0 project is the manufacturing of **closed-deck aluminium blocks produced through the innovative HPDC-LC process** using ceramic cores. The business model covers the entire production chain represented by the consortium; from ceramic core production, casting and machining of the engine blocks, including the de-coring operation and the delivery of the final product to the customer.

FAGOR EDERLAN,as main responsible of this result, has defined a business plan for an industrial scenario of producing 200.000 closed deck engine blocks per year in a 6-year long program, starting 2020 and ending in 2025. All the production ratios have been estimated based on the experience gained in the project; The Overall Equipment Effectiveness (OEE) has been estimated in order to calculate the HPDC machine saturation level during the different years of the project. The volumes required are variable in time, with a ramp during the first 3 years, and so is the OEE rate, as a result of a learning curve during the development of the project, as the product gets more mature.

Regarding the ceramic core production, the business plan considers that the cores will be manufactured in the same facilities as the HDPC casting process. For this purpose, an entire core-shop should be installed at FAGOR with the collaboration of RAUSCHERT, who would receive a payment for the technology transfer. Rauschert would remain as supplier of the base material required in this core-shop.

Detailed calculations of all the necessary manpower have been carried out, for both direct workers and indirect structural personnel of the engine block production plant. A total of 80 new jobs would be created by this business plan.

The investments for HPDC machine adaptations, heat treatment equipment, CNC machining centres and new core-shop and all ancillary equipment have been defined and distributed in the years of the project, resulting in a total investment of 20M€. It is assumed that the HPDC machines are not specific investments for this business plan, but only partially amortized in the duration of the project. Some other investments are considered specific to this project, such as the de-coring equipment (purchased to FerroCrtalic), the ceramic core-shop and the heat treatment installations.

To finalize the study, a complete financial projection plan has been calculated in order to assess the profitability of the project, playing with different scenarios and sensitivity studies. The profitability threshold of the project has been calculated, as well as the final price of the product.

A market analysis was carried out focusing in the Western European market of diesel engines, as the closed-deck architecture is suitable for these type of combustion engines. The strategy of the major OEM’s has been presented concluding that they are not willing to invest resources in the development of new diesel engines, but rather maintaining or improving the existing ones and devoting the new investment towards electrification and autonomous driving.

However, the electrification of the powertrains can open new opportunities to apply the HPDC-LC technology for a series of components that need to have integrated fluid galleries that can be manufactured by using lost cores, improving their performance and reducing costs. A comprehensive analysis of alternative applications to this technology in the automotive market has been carried out.

3.3 IPR agreements

The knowledge and products and processes developed within the project must be protected for the (commercial) benefit of all participating project members. Therefore, the ownership’s distribution of the intellectual property rights (IPRs) of the project results had to be accurately defined to achieve a maximum advantage of their exploitation plans once all partners reached an agreement.

First of all, a work was done among all the partners to identify the most relevant results of the project in terms of exploitation. The selected results are commercial results which can be exploited as a stand-alone product, process or service, and have business potential. The final list of exploitable outcomes of the project was shared and agreed at the project meeting held in Slovenia on April 2018. The list of most relevant results is shown in Table 1.

Table 1. List of the main exploitable results of the project and partners involved

Exploitable Result		Type	Partner(s) involved
ER1	Closed deck aluminium engine block manufactured by HPDCLC	Product	FAGOR
ER2	Ceramic cores to be used in the HPDC-LC process	Technology/Process	RAUSCHERT, TECNALIA, FAGOR
ER3	Ceramic cores for closed deck aluminium engine block manufactured by HPDCLC	Product	RAUSCHERT, FAGOR
ER4	De-coring technology	Technology/Process	FERROCRTALIC
ER5	De-coring machines for HPDCLC casted products	Product	FERROCRTALIC
ER6	Aluminium cast components produced by HPDC-LC	Technology/Process	FAGOR, TECNALIA
ER7	Knowledge on design of the water jacket	Product/Process	FAGOR, RENAULT
ER8	Diesel engine blocks with combustion pressure over 170bars	Product	RENAULT

A template was elaborated and sent to gather the IPR claims of all partners for each result and with the information provided the deliverable on IPR and exploitation agreements was prepared. This document included the background know-how, the foreground IPRs and the exploitation rights for each result.

Summarizing, FAGOR EDERLAN claimed the entire IPR of the main result of the project (ER1) as the knowledge of manufacturing HPDC castings with lost cores has been implementing since 2007. RENAULT claimed the IPR on the design of the engine block (shape and wall thickness) (ER8). Concerning the water jacket for the HPDC-LC application (ER7), as the knowledge has been generated during the project, both FAGOR and RENAULT have claimed rights over this result, so an specific exploitation agreement should be prepared in case this result is exploited commercially.

The results concerning the de-coring technology, both the process itself (ER4) and the product (the robotic machine to de-core the block with high-pressure water) (ER5) will be property of FERROCRTALIC as any other partner claimed for any right over these results. Even if FerroCrtalic does not intent to patent the de-coring technology, they will work in its commercialization.

Finally, there are two more results related to the ceramic core production. In the case of the product (ER3) RAUSCHERT claimed the background and the foreground of the results and also the exploitation rights. Besides, FAGOR EDERLAN claimed to have contributed with their knowledge in the development of the cores and that they would like to use this knowledge for in house ceramic cores production. In the case of the process of core production (ER4), RAUSCHERT, TECNALIA and FAGOR claimed to have provided background and foreground knowledge to this result. Rauschert claimed the exploitation rights, specifically to manufacture and sell the ceramic cores, to use the knowledge to make something else, for further research, licensing, other services and other uses. Besides, Tecnalia and Fagor would like to use the knowledge acquired in the project; Tecnalia, for future research activities or projects, and Fagor, for in house ceramic core production and research purposes.

4 Dissemination and communication

The dissemination and communication activities have been part of work package 1 and have been led by TECNALIA. First of all, a preliminary dissemination plan was prepared with the main target of spreading the public results coming out from the project to all the scientific and industrial community interested. In this plan, the objectives of the dissemination and communication activities were set, the target audience was identified, and the dissemination and communication tools and channels were determined aiming to reach the selected audience.

4.1 Public website and logotype

The first action was the preparation and launch of the public website available at the address http://core40-project.eu as it is the main communication tool. It was launched in September 2016. ALL THE PARTNERS collaborated in the preparation of the website by supplying the information asked by TECNALIA, mainly the short and long description of their companies and the logotype with good quality.

The website is divided in two parts: the public part, accessible to everyone interested in having information about the project, and the private part. This private part is divided in two sections: the private area of the website, accessible only to the partners of the project and where final deliverables of the project are stored, and the private intranet, a working area accessible only to a limited numbers of users of the partners involved in the project.

The information regarding the website, the private intranet and the main guidelines of the dissemination plan was included in deliverable D1.2 sent to the EC in October 2016.

As part of the visual identity of the project, a logotype was created using a blurred image of an engine block and writing the letters of the acronym of the project over the image. The logo was distributed among the partners for their approval. This logotype has been included in all the templates and all the dissemination materials prepared along the duration of the project.

4.2 Update of the dissemination plan

The dissemination plan has been constantly updated along the project and the updated version has been presented in each Consortium Meeting. To give all the partners the possibility of contributing to his plan, an excel file was generated and shared through the private intranet. This file included the dissemination calendar (Figure 13) that was also updated along the duration of the project and the different extensions that were requested and approved by the EC.

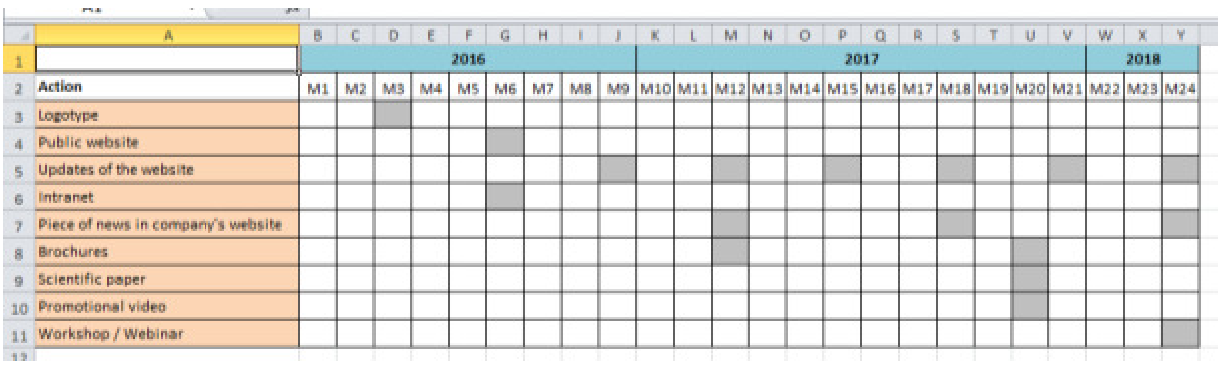

Figure 13. Screenshot of the original dissemination calendar

4.3 Communication material

Communication materials are very important to disseminate the developments and results of the project. Different materials have been prepared during the project, including two leaflets, a poster and a promotional video.

The first leaflet was prepared in month 12, including the problem to be solved with the technology developed in the project and the value proposition benefits in its front page and the project road map with the main contacts of the partners in its last page (Figure 14). The business model was also explained in the two interior pages.

A second leaflet was prepared in month 24., including the main information of the project (title, duration, partners involved), a summary of the technical work carried out and milestones achieved and an explanation of the three main developments performed up to the month 24, i.e. the 4-cylinder ceramic core, the closed-deck aluminium engine block, and the de-coring machine (Figure 15).

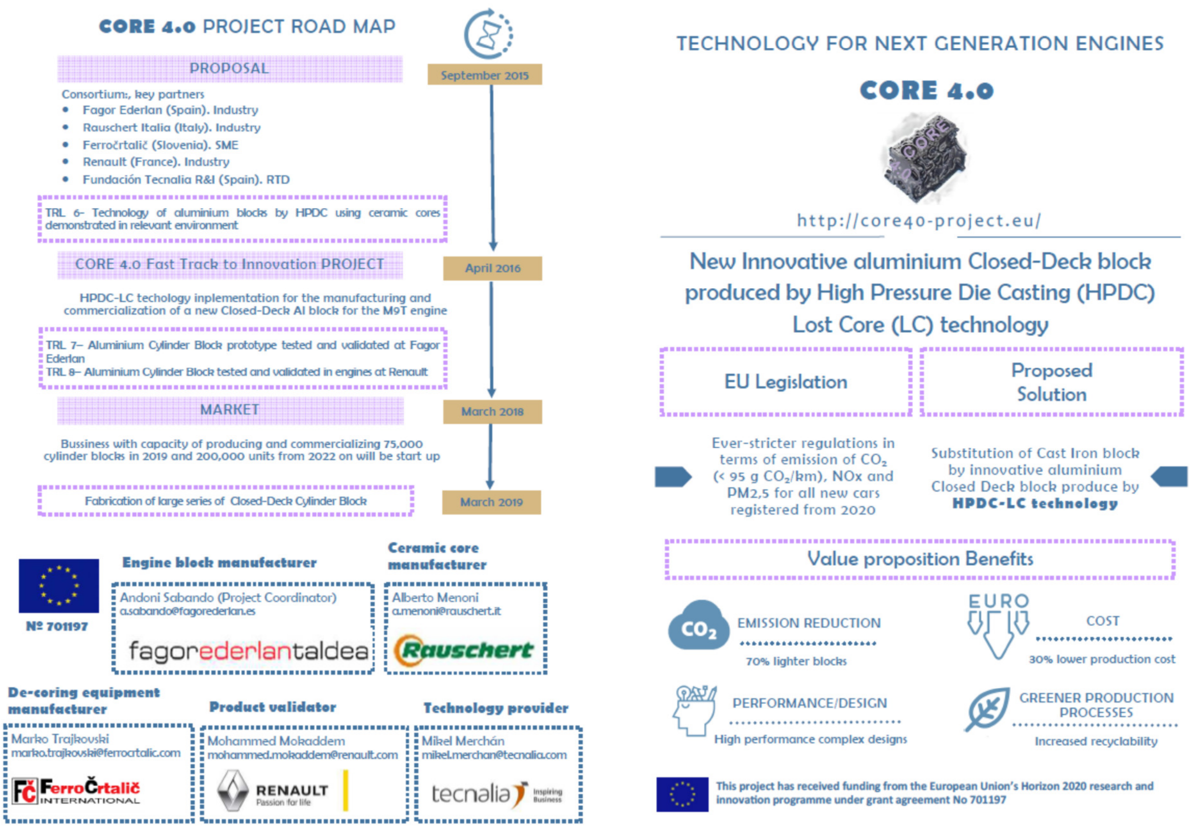

Figure 14. Front page and last page of the CORE 4.0 project leaflet

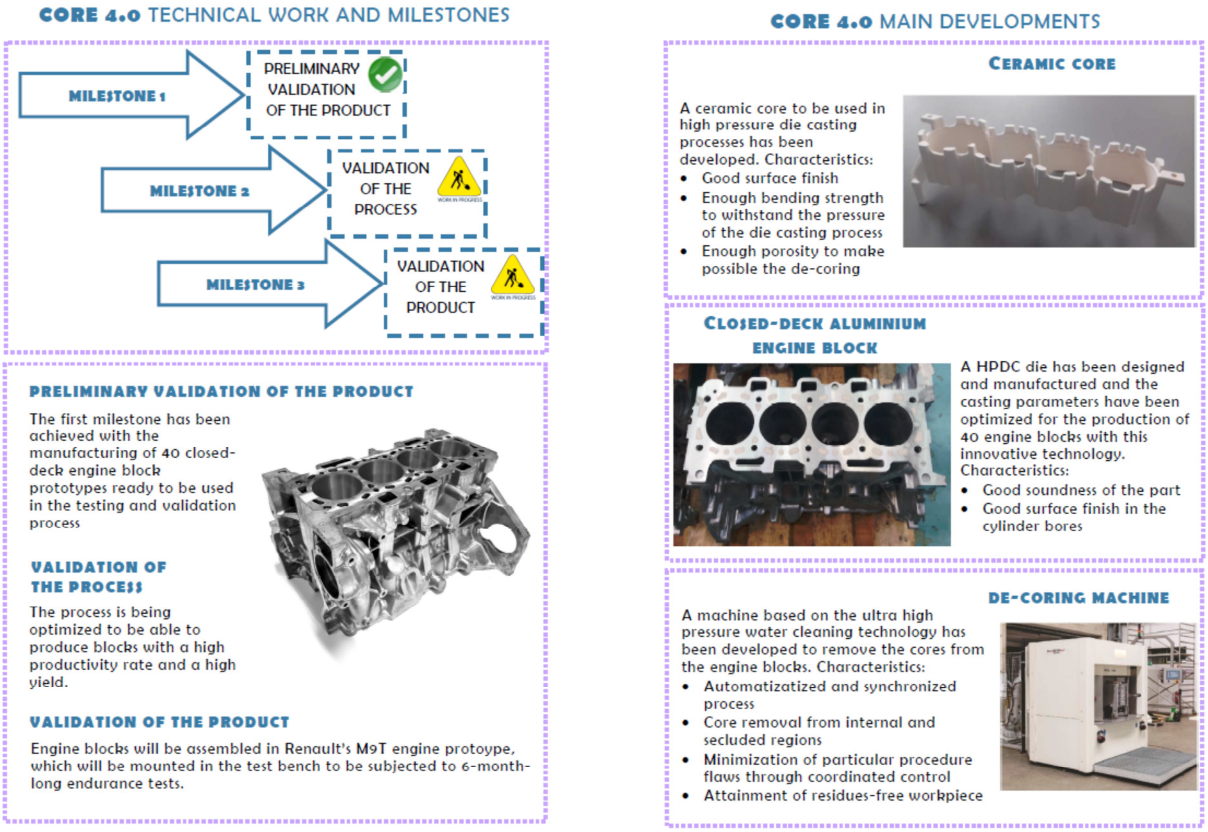

Figure 15. Middle pages of the second CORE 4.0 project leaflet

A second leaflet was prepared in month 24., including the main information of the project (title, duration, partners involved), a summary of the technical work carried out and milestones achieved and an explanation of the three main developments performed up to the month 24, i.e. the 4-cylinder ceramic core, the closed-deck aluminium engine block, and the de-coring machine.

TECNALIA prepared also a document with relevant information of the project to be printed as poster format to be used in the different fairs that were attended and would be attended in the future.

Finally, a 3-minute long promotional video was prepared including interviews to representatives of the five companies involved in the project following a script previously prepared and agreed by all. Some resources were also recorded in Tecnalia, Edertek and Rauschert to be used in the video. The video was launched at the end of September, distributed to all the partners, uploaded in the webpage of the project and published in the Tecnalia's Youtube channel. It was also shown in some of the fairs attended by the partners (see section 4.4).

4.4 Dissemination events

Consortium partners have been very active and have attended different fairs to present the developments of the project.

FERROČTALIČ was the first to attend a fair in April 2017. They were present with a booth in the most important industrial fair in Europe, The Hannover fair where they showed the de-coring machine prototype developed within the project (Figure 16). A leaflet and a banner were prepared to present the machine in their stand in the fair. Around 150 leaflets of the project were printed and distributed among the visitants of their exhibition booth.

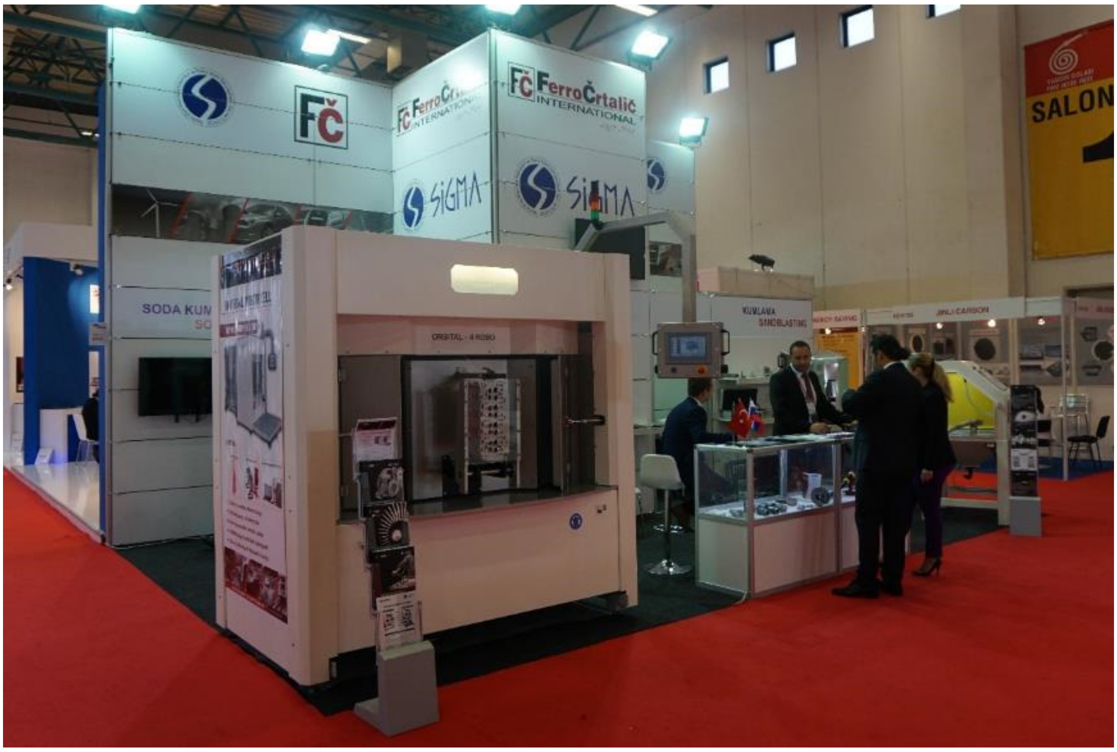

Figure 16. Booth of FERROČTALIČ in the Hannover fair

RAUSCHERT attended the International Fair CERAMITEC held in Hannover (Germany) in April 2018, where they had their own stand and could show a sample of the 4-cylinder ceramic core was shown.

Figure 17. Stand of RAUSCHERT in the CERAMITEC fair and 4-cylinder ceramic core

TECNALIA attended the 22nd International Fair of Technologies for foundry METAL held in Kielce (Poland) in September 2018 with a 9m² stand showing the closed-deck aluminium engine block and the 4-cylinder ceramic cores (Figure 18). Apart from that, a screen was placed in one of the walls and the promotional video was shown. 50 leaflets were distributed to the visitors that were interested in the developments of the project.

Figure 18. Stand of TECNALIA in the METAL fair showing the developments of CORE 4.0 project

Some days before this fair, TECNALIA was also present in the 73th World Foundry Congress held in Krakow (Poland), where Mikel Merchán presented an oral talk related to the work made on the coatings and infiltration to strengthen ceramic lost cores.

Figure 19. Presentation of the oral talk at the 73WFC

In October 2018, FAGOR EDERLAN participated in the IZB industrial fair in Wolfsburg (Germany) with a booth to show the closed-deck engine block (Figure 20).

Figure 20. Stand of FAGOR EDERLAN in the IZB fair

Just one week later, RAUSCHERT attended the ALUMINIUM International Trade Fair in Düsseldorf (Germany) with its own booth (Figure 21) to show the 4-cylinder ceramic core and the poster. They distributed more than 70 leaflets to the visitors interested in the developments of the project.

Figure 21. Stand of RAUSCHERT in the Aluminium fair

In June 2019, it is expected that TECNALIA will attend the International Fair of Manufacturing Processes and Equipments to be held in Bilbao (Spain). And FERROČTALIČ and RAUSCHERT have confirmed their presence with one booth each in the International Foundry Trade Fair (GIFA) to be held in Düsseldorf (Germany) the last week of June.

4.5 Publications

Publications are one of the ways to reach specific target groups. During this project, different publications have been released (scientific papers, publications in industrial magazines and publications in newspapers for the general audience).

Concerning the scientific paper, the team from TECNALIA published a paper related to the work done during the pilot scale trials to find optimum coating to avoid the aluminium penetration and an infiltration agent to increase the strength of the ceramic cores. This paper was sent to the “International Journal of Metalcasting” who decided to publish it after the peer-review process. It was published online in January 2019 and the printed issue including this paper will be released probably in June.

A one-page news was published following an interview to Mikel Merchán in the first number of 2019 of the “Empresa XXI” magazine, one of the most important magazines dedicated to the basque industry. In February, “El Diario Vasco”, the main and most read newspaper in the region, published in their online version a reduced version of a piece of news published in Tecnalia’s website. And recently, another newspaper of the Basque Country contacted with TECNALIA showing their interest in preparing a publication related to the project. This newspaper, “Gara”, prepared an article that was published in their printed edition the 30th of May.

Fagor Ederlan y Tecnalia suman sinergias para la fabricación de bloques de aluminio ligeros

Renault es el usuario final de la tecnología desarrollada a través del proyecto Core 4.0

▸Fagor Ederlan ha dado junto a Tecnalia el salto a la fabricación de bloques motor en aluminio a partir del proyecto europeo Core 4.0. De forma conjunta, han desarrollado la tecnología HPDC-LC, cuyo usuario final es Renault para la fabricación y comercialización de motores más ligeros que cumplan con la próxima regulación Euro 7.

AINARA LOZANO. Derio

Frente a la tendencia del sector del automóvil por el desarrollo de motores más ligeros y eficientes, Fagor Ederlan optó hace unos años por dar un paso más allá y fabricar bloques motor en aluminio, hasta ahora producidos en hierro, con vistas a su industrialización. Un reto que ha asumido junto a Tecnalia en el marco del proyecto europeo Core 4.0, del programa Horizon 2020, que tiene como usuario final y validador a Renault, aunque en el consorcio también participan las empresas Rauschert y FerroCrtalic. El objetivo del proyecto y el consorcio se ha extendido doce mese más, hasta primavera de 2019 concretamente, para que el fabricante francés pueda completar las pruebas de validación del producto desarrollado en su banco de ensayos.

Para la fabricación en aluminio del bloque de motor, la cooperativa y el centro tecnológico han desarrollado la tecnología High Pressure Die Casting Lost-Core (HPDC-LC), un proceso de fundición de alta presión con una alta productividad y con una calidad de pieza alta.

Gracias a su configuración, estos bloques se pueden integrar en motores con presiones de combustión alta, además de permitir una reducción de peso de 37,7 kg, lo que representa el 3 por ciento del peso total medio de un vehículo y una reducción de más de 500 kg de emisiones de CO2 en la vida del turismo.

Como explica el responsable técnico del proyecto de Tecnalia, Mikel Merchán, la tecnología HPDC “se lleva utilizando hace mucho tiempo en la fundición de aluminio y magnesio, ya que es un proceso flexible, que proporciona una productividad muy alta y con calidades de superficie buenas. Pero hay ciertas piezas que no se pueden producir con este proceso por sus complejas geometrías, lo que nos ha llevado a desarrollar la tecnología HPDC-LC”.

El fabricante francés está validando el producto

Para la fabricación de los bloques, se ha desarrollado unos machos cerámicos, sujetos a unos recubrimientos refractarios para su buen comportamiento durante el proceso de inyección. Sin embargo, según admite Merchán, el proceso de limpieza de esos machos, efectuado a través de un equipo creado por la empresa eslovena FerroCrtalic, es muy lento, lo que dificulta su industrialización al no resultar factible para una producción en serie. En ese contexto, el proyecto se encuentra en estos momentos con dos líneas de trabajo. Por una parte, Renault está validando los bloques ya fabricados en París, cuyos resultados estarán listos entre abril y mayo del presente ejercicio. Al mismo tiempo, el ensamblador galo y Fagor Ederlan trabajan en el rediseño de la camisa de refrigeración del bloque con la idea de hacer más sencilla su geometría para en un momento posterior validar conceptualmente el proceso y poder así completar su industrialización.

Una vez finalice el proyecto, Tecnalia continuará con la línea de trabajo planteada en Core 4.0 al tener la tecnología un gran potencial tanto en automoción como en otros sectores industriales.

Mikel Merchán junto al bloque de motor de aluminio fabricado con tecnología HPDC-LC.

Proyecto Core 4.0

Convocatoria: El proyecto se enmarca en el programa Horizon 2020, en la convocatoria Fast Track to Innovation Pilot.

Consorcio: Coordinado por Fagor Ederlan, participan también Tecnalia, Renault, Rauschert y FerroCrtalic.

Plazo: Del 1 de abril de 2016 al 31 de mayo de 2019.

Presupuesto: 4,09 millones de euros.

Objetivo: Implementar la tecnología HPDC-OLC para la fabricación y comercialización de un nuevo bloque de aluminio de plataforma cerrada para el motor diesel M9T, una de las que serán las siguientes generaciones Euro 7 motores de Renault.

Tecnalia y Fagor Ederlan trabajan en la fabricación de motores de automoción más ligeros

Los motores de Tecnalia y Fagor son para Renault. / AFP

La iniciativa se enmarca en el programa europeo Core 4.0

FERNANDO SEGURA

Lunes, 18 febrero 2019, 12:12

Tecnalia y **Fagor Ederlan** trabajan conjuntamente en la fabricación de **bloques-motor en aluminio** desarrollando la tecnología HPDC- LC. Su **usuario final es Renault** y se emplea en la producción y comercialización de **motores más ligeros** que cumplan con la regulación Euro 7.

Fagor Ederlan fabrica bloques-motor en aluminio, **hasta ahora producidos en hierro**, con vistas a su industrialización. Un reto que ha asumido junto a Tecnalia en el marco del **proyecto europeo Core 4.0 del programa Horizon 2020**. El usuario final y validador es Renault, aunque en el consorcio también participan las empresas Rauschert y FerroCrtalic.

Gracias a su configuración, estos bloques se pueden integrar en motores con presiones de combustión alta, además de permitir una **reducción de peso de 37,7 kilos**, lo que representa el 3 % del peso total medio de un vehículo, y **una reducción de más de 500 kilos de emisiones de C02 en la vida del turismo**.

Fagor Ederlan y Tecnalia reducen el peso de los motores para minimizar las emisiones

El proyecto CORE 4.0 permite fabricar bloques de aluminio más ligeros que posibilitarían una reducción de más de 500 kgs de emisiones de CO2

J.S. | DONOSTIA

Los fabricantes de automóviles están volcados actualmente en el desarrollo de motores más ligeros y eficientes con el objetivo de minimizar el impacto de sus emisiones en el medio ambiente, al tiempo que se ajustan a la legislación europea en torno a emisiones de CO2 y NOx, cada vez más estricta y cuya próxima regulación (Euro7) se espera entre en vigor en 2020.

Para ello, Fagor Ederlan y Tecnalia trabajan en el desarrollo de una tecnología que tiene a Renault como usuario final y validador del proceso, que permitirá reducir el peso de los bloques motor, el componente unitario más pesado de un automóvil. En concreto, se ha estimado una reducción de 37,7 kilogramos, el 3% del peso total promedio de un vehículo, al sustituir los actuales bloques de hierro por los de aluminio, lo que se podría traducir en una reducción de más de 500 kilogramos de emisiones de CO2 a lo largo de la vida del vehículo.

A través de este proyecto, denominado CORE 4.0, se ha desarrollado la tecnología High Pressure Die Casting Lost-Core (HPDC-LC), que permite fabricar bloques de aluminio ligeros mediante un proceso de fundición de alta presión con una alta productividad y con una calidad de pieza alta. Debido a su configuración, estos bloques se pueden integrar en motores con presiones de combustión altas.

La tecnología HPDC se emplea desde hace tiempo en la fundición de aluminio y magnesio. Es un proceso flexible, que proporciona una alta productividad, con grandes calidades de superficie.

Una tecnología con futuro

Según datos facilitados por Tecnalia, el mercado global disponible en 2020 para el bloque motor de aluminio fabricado por inyección de alta presión se estima en 6,5 millones de unidades anuales. La capacidad de fabricación estimada alcanzaría las 800.000 unidades anuales en 2025, superados los seis años necesarios para consolidar el negocio y amortizar las inversiones. Esto supondría una cuota de mercado de un 12% y unos ingresos de alrededor de 105 millones de euros anuales.

Además, la tecnología desarrollada podría aplicarse para la fabricación de otros componentes, tales como motores para generadores eléctricos, aerogeneradores o maquinaria agrícola.

La tecnología desarrollada en el proyecto CORE 4.0, en el que junto a Fagor, Renault y Tecnalia, participan las empresas Rauschert y FerroCrtalic, servirá a cada uno de sus socios para introducirse en nuevos mercados y diferenciarse en sus respectivos sectores.

FUNDICIÓN DE ALTA PRESIÓN

La tecnología High Pressure Die Casting Lost-Core (HPDC-LC) permite fabricar bloques de aluminio ligeros mediante un proceso de fundición de alta presión con una alta productividad y con una calidad de pieza alta.

Figure 22. Pieces of news published (from left to right) in “Empresa XXI”, “El Diario Vasco” and “Gara”

Another piece of news was published in “Il Sole 24 ore”, the most important economic Italian newspaper. The news related to the work performed by RAUSCHERT was published in the edition of the 22nd of May 2019 (Figure 23).

Il Sole 24 ORE

26 Mercoledì 22 Maggio 2019 Il Sole 24 Ore

INFORMAZIONE PROMOZIONALE

Speciale CERAMICA - Realtà eccellenti

SIMEC: 30 anni di esperienza e innovazione

Tecnologie di spicco per il trattamento e la finitura delle grandi lastre

Nuovo design ceramico all'Isia di Faenza

Innovazione, ricerca e stampa 3D nei corsi universitari triennio e biennio

Rauschert: 120 anni di storia di eccellenza

Una sfida per il futuro fra tradizione, progresso e grande innovazione

Figure 23. Pieces of news published in “Il Sole 24 ore”

As a conclusion, the communication and dissemination plan prepared at the beginning of the project has been fulfilled performing nearly all the actions included in this plan and even carrying out some other that were not expected at the beginning. The partners have been highly involved in the different dissemination actions that have been performed and the results of the project have been satisfactorily disseminated to different audiences.

5 Socio-economic impact

The objectives initially planned for the project envisaged a scenario of a future Euro7 diesel engine for Renault with the engine block being manufactured in HPDC-LC technology. It was foreseen that the production of such an engine would start by the year 2020 with estimated volumes of 200,000 units per year. The business plans and exploitation of results were calculated under the basis of this expected scenario and showed profitable business cases for all members, with the creation of over 80 jobs.

However, the events that followed the diesel scandal and the evolution in emission regulations have produced a turn in all the forecasted market trends for diesel engines. Renault has stopped the development of the new E7 diesel engine, focusing instead in hybrid powertrain solutions, predominantly using petrol engines. The future of diesel engines at Renault is not clear and it seems very unlikely that a new development could take place. In the current context of diesel engines globally, the demand for closed deck engine blocks will decrease or even disappear, because petrol engines can perform correctly with open deck configuration engines, for which the lost core technology is not needed.

In any case, the development of the lost core technology for HPDC has brought some positive outcomes to the partners of the consortium.

Rauschert hast developed a technology that may open a new field of application of its products in the casting industry, with cutting-edge dry pressing technology able to produce extremely complex geometries. Rauschert as a company has improved their reputation on the market by showing up such a remarkable and complex piece, that nobody has been able to do before. On the other side they are confident that the obtained positive results motivate to strengthen the relationship within the consortium beyond the CORE project and search for future collaborations.

FerroCtralic has gained experience in the application of the ultra-high-pressure water jets for de-coring and cleaning of aluminium castings that may also be used for other castings. This opens the opportunity for sales in the casting industry for automotive or other applications, such as de-coring and de-burring cabins for aluminium and cast iron

Fagor Ederlan has demonstrated the feasibility of lost core technology for HPDC, which opens a new field for the development of hollow castings for automotive applications. A market prospect has been carried out within the scope of activities in WP5 and potentially interesting applications have been identified for the hybrid and electric vehicles of the future, opening new business opportunities for Fagor Ederlan.

Edertek, as technology centre of Fagor Ederlan, has gained experience and reputation in the field of lost core for HPDC, and the experience and know-how gathered in the project will be an important asset for future development projects.

Tecnalia has contributed to the development of the innovative HPDC-LC process finding technological solutions to some of the constraints of this technology. This development opens the possibility of substituting heavy components with complex geometries in sectors such as automotive or aerospace by lighter aluminium components manufactured with a cost-efficient and robust process. And this has a positive impact in the emissions reductions and the environmental sustainability.

6 Conclusions of the action

The project consortium has been able to achieve the main goals of the project regarding the technical challenges initially planned. The technology for the production of hollow castings in HPDC using ceramic cores has been validated in real production environment, with the development of 3 core competences: ceramic core production, HPDC casting with lost cores, and UHP de-coring technology.

Despite the technical success of the project, the business plan could not be realized as initially planned. The market trends in the automotive sector have given a turn against the diesel engines during the period of the project, and the final application has not reached the market. Nevertheless, the technology and know-how developed in the project can be applied in alternative products, some of them related to the electric and hybrid vehicles. The members of the consortium will focus on the identification and development of such opportunities that will lead to successful market applications in the near future.