LIFE Project Number

<LIFE09 ENV/IT/000174 >

"Ultra Crash Treatment"

FINAL Technical Report

Project Data

Project location	Mosciano Sant'Angelo (TE), Contrada Marina, IT
Project start date:	01/10/2010
Project end date:	30/09/2013
Total Project duration (in months)	36 months
Total budget	€ 2.841.960
Total eligible budget	€ 2.461.963
EU contribution:	€ 1.230.981 (=50% of total eligible budget)
(%) of total costs	43,3
(%) of eligible costs	50

Beneficiary Data

Name Beneficiary	Metallurgica Abruzzese S.p.A.
Contact person	Mr. Giovanni Cavatorta
Postal address	Contrada Marina, IT, 64023, Mosciano Sant'Angelo (TE)
Telephone	+39-085-802331
Fax:	+39-085-200 8674
E-mail	g.cavatorta@cavatorta.it
Project Website	http://www.cavatorta.it

Executive Summary

The project began smoothly on 01/10/2010, as foreseen in the application.
The main project objectives were, essentially, as follows:

- to replace the hot-dip galvanising which the steel wire undergoes with cold-spray galvanising;
- to replace the standard blasting media with ceramic micro shot, which will optimise the galvanising procedure.

These objectives were achieved through the construction of two systems, one for ceramic micro shot blasting the wire rod and wire and the other for cold-spray galvanising, in order to test the hypotheses made at the beginning of the project, not least in relation to environmental and financial benefits achievable.
In the first months of activity, the development of the project has focused on the establishment of the relationship between the participating partners, on project management organisation and strategic planning of the project activities, and on the definition of the partnership structure through the identification of the partners' reference people for the technical aspects.
A partnership agreement has been signed between the coordinating beneficiary and the associated beneficiary.
IT tools have been set up for project accounting and to record the staff hours dedicated to the project.
At the first meeting, held on 19 October 2010, the main roles, competences, and responsibilities were assigned as follows:

- Giovanni Cavatorta, project manager;
- Sergio D'Angelo, technical manager;
- Massimo Splendiani, administrative manager;
- Nicoletta Cavatorta, dissemination manager;
- Romeo Cifeca, responsible for integrating the project into the company's communication campaigns;
- Prof. Alberto Molinari, responsible for all matters assigned to the University of Trento partner
- Paolo Dal Piaz, administrative manager of the University of Trento.

The Monitoring Team was also set up at the same meeting and it was agreed that the same people defined for the management of the project would be confirmed.
The constant and close collaboration and communication between the proponents has led to the identification of the first activities to be carried out to overcome the critical aspects related to the development of the first two technical actions of the project.
From a technical perspective, all the actions have been completed, namely:
n. 3 "*Micro shot blasting system*",
n. 4 "*New Cold-Spray galvanising system*" and
n. 5 "*Assembly of pilot line*".
As regards Action 3, carried out in the Metallurgica Abruzzese plants, an experimental phase has been set up using a shot blasting machine prototype.
Shot blasting is a system already used to roughly clean the wire rod to be drawn: this process has the twofold purpose of removing oxides that form on the surface in the storage phase and of removing millscale from the wire rod. This system is not used to clean the drawn wire as it is too aggressive: it produces deformations and micro-grooves on the surface of the wire, which then require - in the best of cases - more zinc coating than would otherwise be necessary.

With the help of third parties, the company has therefore adapted the shot blasting machine so that it can work with smaller grit particles than are normally used, in order to assess the effect of this type of treatment, which ideally is very similar to the micro shot blasting used, on drawn wire.
The university therefore carried out a series of analysis and characterisation studies on samples of processed wire supplied by Metallurgica Abruzzese, and the results showed that the use of small grit particles reduces surface deformation.
The activity then continued with a new series of micro shot blasting tests carried out at the University of Trento alongside the shot blasting tests carried out in the Metallurgica Abruzzese plants. The university tests were carried out in collaboration with an important company in this sector with which the University of Trento has worked in the past. The said tests, despite being carried out on static samples of wire and not moving wire, clearly showed a further improvement compared to blasting with microgranules and a cleanliness of the drawn wire similar to that obtained with the traditional acid pickling system.
The wire samples subjected to micro shot blasting were then subjected to galvanising tests, using both the hot dip in fluid bed and the electrolytic processes: in both cases the results are encouraging.

As regards the selection of suppliers and sub-contractors, in respect of the best value for money criteria, Metallurgica Abruzzese has identified a supplier called I.M.F. S.r.l. (Impianti Macchine Fonderia), formerly Carlo Banfi S.p.A.; I.M.F. is the leading company in the manufacture of shot blasting and micro shot blasting systems. The cost of the micro shot blasting system designed, developed, and produced by I.M.F. S.r.l. is lower than that of the other companies contacted, with the same quality and results, key elements for the assignment of the task.
A collaboration agreement has been entered into with this supplier that has also foreseen an experimental phase to be carried out in collaboration with the technical staff at Metallurgica in order to test different solutions before designing the system.
The micro shot blasting system for final wire cleaning was ordered in April and was delivered in September 2011. The system was then installed and started up in December 2011. Following on from this, operation tests were also begun, which demonstrated that the system met up to expectations and project objectives.
During the following months of the project, all necessary activities were carried out to achieve completion of joint Action 3, including the construction, installation, testing, and validation of the micro shot blasting system. The tests performed on the operational system demonstrated that the action objectives had been achieved in full.

Also during the first nine months of the project, almost parallel to the start of Action 3, Action 4 was begun (ahead of schedule), in order to allow objective assessment of the project's technical feasibility.
The University of Trento started the initial bibliographic study phase to create a database for the development of the project.
The University also contacted a zinc powder producer, as the quality of the coating is a key parameter in the coating process, especially if the cold-spray system is used.

Also during that period, Metallurgica Abruzzese began a first testing phase for the cold-spray process, using a system at an external company normally used to coat small metal articles with zinc or aluminium.
Also in this case, even though the machine is not specifically designed for this purpose and the tests are carried out on static pieces of wire rather than moving pieces, the results are very encouraging.
I.M.F. S.r.l. had also stated its availability to develop and manufacture this type of system, based on the specifications supplied by Metallurgica technicians and the processing needs to be met. Also in this case, IMF offered a better price/quality ratio than other companies, with the additional advantage of having a single supplier that can optimise both processing systems.
Cold-spray galvanising tests have been carried out, with the help of Metallurgica staff, on a small prototype specially developed by IMF under the supervision of other suppliers such as Unifer Eood, which works with moving wire and the results are very encouraging.
This has allowed the company to meet all the parameters necessary for the design of the system.

Work on the final system design had already begun at the end of 2011; the main reason why the action was brought forward was the possibility of problems arising in future stages which could jeopardise the project and its envisaged progress; some problems actually did occur and were overcome brilliantly, partly because of the greater amount of time available to the technicians.
The staff also decided to build an independent pilot line, which, firstly, allowed greater flexibility in the experimental stage, and secondly, meant that the line was not affected by the company's production requirements. The decision, however, meant greater staff commitment to the project.
When the pilot line was in the assembly stage, the technical staff were faced with a problem linked to the treatment times of the two systems developed, in that the operation of the micro shot system was three times faster than that of the cold-spray galvanising system. The technicians solved the problem by increasing the number of wires handled at once by the new galvanising system (from 2 to 6), thereby ensuring overall productivity of the two systems within the same timeframe.
Once the pilot line was assembled and the problems had been solved, the staff proceeded to carry out the various tests on the line in order to assess the environmental, technical, and financial objectives set at the beginning of the project.
The tests showed positive results, i.e. the line has a production capacity of 2.4 tonnes/day (300 kg/h), it does not produce any waste to be dispose of or emissions, and it means thinner use can be reduced. The experimentation has also demonstrated less wear of the system components, as well as considerable energy savings, both factors that result in financial savings for users of the technology.

Action 6, which concerns the dissemination phase, was carried out as planned throughout the project's duration.
The dissemination actions included:

- internet activities (website, Facebook);

- the production of printed dissemination material (brochures, notice boards, articles, etc.).
- activities to establish contact with people (networking, word of mouth, event organisation, exhibiting at trade fairs).

The dissemination activities carried out have produced extremely positive results in terms of project visibility, visibility for the European Life+ programme, and contacts received.
The website is constantly updated, offering a showcase for the project in both Italian and foreign-language versions, and has helped the staff to promote the project orally among their contacts.
Participation in trade fairs, such as the FUR SHOW held in Helsinki (Finland), has enabled us to approach a number of international companies with whom Metallurgical hopes to start networking and/or technology transfer activities soon.
The brochures and posters produced, which are on display at the company and have been distributed to customers, have played a crucial role in attracting new contacts.
Last of all, the organisation of an event at Metallurgical site to celebrate 20 years of the Life programme offered Metallurgica the ideal opportunity to provide the general public with a detailed presentation of the project, kindling curiosity and interest among the guests.
A thorough final assessment of the marketing activities undertaken allowed staff to pinpoint which actions had obtained most visibility and contacts and therefore which actions to focus on in the future; these observations played a vital role in the preparation of the After-Life Plan, which is annexed to this report (annex 16).

Metallurgica and its partner, the University of Trento, have stated that they are satisfied with the outcome of the project. All the objectives set at the beginning of the project have been achieved, in technical, financial, and environmental terms, and everything was completed on time. The staff were also able to raise awareness of the project among a large number of people, from whom it is hoped that a partner will be found for further networking or technology transfer activities.
The experience gained over the course of the project will be used when preparing the After-Life Plan and for managing future project-related activities.

Description of background, problem and objectives

The project's main goal is to replace the hot-dip galvanising which the steel wire undergoes with cold-spray galvanising. This will address all the environmental issues linked to hot-dip galvanising, through the introduction of a technology that, although using powder as raw material, works at room temperature, does not use liquid metal baths, and allows both a high level of control over the processing environment and unused powder to be recycled, while also offering significant energy savings. The project envisaged the construction of two prototypes, one for the ceramic micro shot system for wire rod and wire, and another for the cold-spray galvanising system.
The goal of the project was therefore to verify the feasibility of the proposed solution, in particular as regards the replacement of the hot-dip galvanising with the cold-spray method.

In the application it had been stated that the introduction of the ceramic micro shot system for the wire rod and the cold-spray galvanising system for the company's entire production would have resulted in the following benefits:

- Annual energy savings amounting to 7.11 billion Kcal;
- Savings in waste disposal amounting to 344,000 kg;
- Savings in hazardous waste use amounting to 40,000 kg;
- Savings in emissions of fumes into the atmosphere amounting to 400,000 m^3.

The project was structured over three main phases:

1. Study, design, implementation of the ceramic micro shot system for the wire;
2. Study, design, and implementation of the cold-spray galvanising system;
3. In-line assembly of the systems described earlier and connection of the pilot system to the company's production process.

The activities, especially those related to the study and design innovations, were carried out with the help of project partner the University of Trento and various major external suppliers, such as I.M.F. s.r.l., whic provided essential support during the system construction stage.

The aim of the "Ultra Crash Treatment" was to provide the following environmental and technical benefits:

- Reduced energy consumption (-50%)
- Thinner layer of zinc coating (-30%)
- Less shot used for the micro shot blasting (3 times less);
- Shorter treatment times;
- Less wire deformation;
- Less wear of machinery parts exposed to blasting (-70%);
- Better working environment as less dust produced;
- Less zinc used (-35%);

Cold-spray galvanising also brings the following benefits:

- Energy usage for drying, cooling, and galvanising operation ranges from 300,000 Kcal/tonne to 130,000 Kcal/tonne;
- No water usage;
- No more hazardous substances;
- No more waste (ash, zinc skimmings, zinc dross);
- No more atmospheric emissions from the galvanising bath.

Expected longer term results

The environmental issue addressed by the project concerns atmospheric emissions and the production of waste caused by galvanising treatments used nowadays which, in some cases, is classified as hazardous. Sources of emissions into the air include: the re-treatment section, the surface of the molten zinc, and the combustion systems to heat the zinc bath or other treatment baths. Furthermore, during the transfer of objects from one treatment bath to another, the various liquids (acids, fluxants, etc.) can drip off the pieces. The liquid is collected and conveyed into special containers to be recycled or disposed of as chemical waste. Waste and sub-products containing zinc are the zinc skimmings and dross.

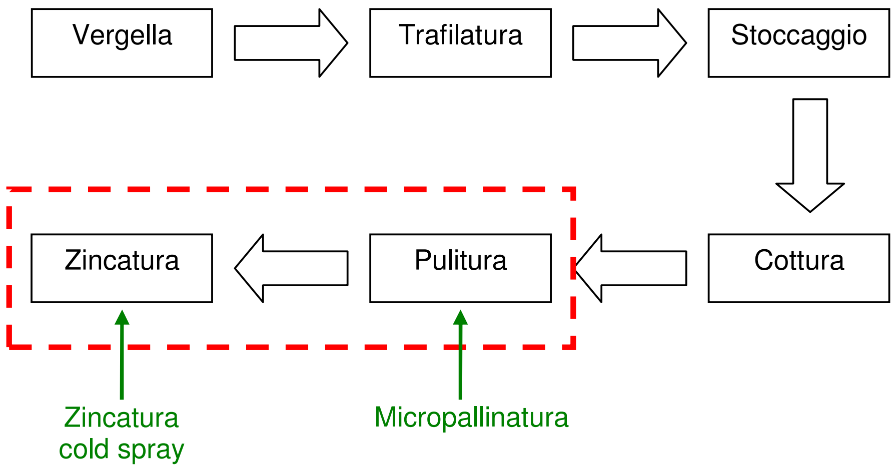
The Ultra Crash Treatment project demonstrated that the use of a cold-spray galvanising system together with a ceramic micro shot system, when properly combined, can deliver significant environmental results, e.g.:

- Compared to conventional acid bath descaling systems, the ceramic micro shot system offers up to 70% less energy usage, bringing the 320,000 Kcal/tonne required for the acid bath down to approximately 90,000 Kcal/tonne with the micro shot system;
- The new cold-spray system will bring a substantial reduction in energy usage, i.e. up to 40%, as the current drying, galvanising, and cooling stages require approximately 300,000 kcal/tonne of product, while the cold-spray method will bring consumption down to approximately 180,000 kcal/ tonne;
- No more waste (as opposed to the approximately 10 kg/tonne of ash, zinc skimmings, zinc dross produced, as well as the acid for the cleaning bath);
- No more atmospheric emissions (as opposed to 1000 m^3/tonnes of fumes from the galvanising bath containing toxic substances including: ammonia, hydrochloric acid, and zinc dust);
- No use of hazardous or toxic substances, as cleaning bath acids or thinners;
- No water usage;

What is more, a considerable improvement in the working environment has been observed, as well as improved efficiency, less deformation of the wire and a smoother finish after cleaning, and better operating times than with the old system.
The system produced so is involved in all the EU directive related to, among the others, emissions reduction, energy consumption reduction, water and waste management (waste framework directive, IPPC, IED, water framework directive, etc); moreover is easy to reproduce since once its layout has been designed it does not change when transferred from one company to another, and the changes required depending on the wire type to be handled are also minimal. The dissemination of the system will also be facilitated by the financial savings it offers, for example, this innovative system minimises component wear which means parts have to be changed less often. Savings can also be made from the lower amounts of zinc required for the galvanising process, which needs less raw materials. Not only that, zinc is also a non-renewable natural resource found in just a few regions worldwide (not in Europe), which means it is more expensive than many other materials.
In addition to the dissemination of the technology's operating principles and those of the prototype, Metallurgica Abruzzese plans to industrialise the developed system itself. The company strongly believes that the innovation inherent in this "Ultra Crash Treatment" project offers a starting point for the future development of environmentally friendly technologies for processing wire rod and wire, even if at present it is hard difficult to predict exactly how and when the industrialisation of the system will take place, partly because of the difficult economic climate.

Technical part

The Ultra Crash Treatment project aimed to tackle the environmental problem related to the zinc-coated drawn wire production process by acting on two specific phases of the production cycle: the cleaning of the annealed wire and the actual galvanising process, as shown in the production flow chart below.



The annealed and drawn wire is cleaned with a series of chemical treatments which have a strong impact on the environment. This processing phase is essential as the annealed wire oxidises in contact with the air stopping the zinc from sticking perfectly to the surface in the following processing phase.
During the cleaning process the moving wire is subjected to pickling and then degreasing in tanks of chloridic acid and surfactants; it is then subjected to ammonium chloride fluxing.
The use and management of these substances, the washing of the systems and the water treatment have always been the main problems in this sector.
The project intends to solve this problem by replacing this phase with ceramic micro shot blasting that eliminates the oxides without affecting the surface of the wire, thus eliminating the use of hazardous substances.

The clean wire is then galvanised to increase the resistance of the product and protect it from galvanic corrosion.
During the galvanising process the wire is pre-heated at 100°C and then dipped in a bath of melted zinc at a temperature of 455°C.
As the annealing, cleaning and galvanising production phases are continuous, in order not to slow down the production process the galvanising tanks must be very long as the wire must remain immersed until the steel reaches the same temperature as the zinc.
Once the galvanised wire is taken out of the tanks any excess material is removed to obtain a uniform distribution of the zinc, before cooling and winding it into coils.
This processing phase has a strong environmental impact mainly due to the high energy consumption required to melt the zinc and keep it in that state (the system cannot be switched off, it must operate continuously at full capacity even when it is not in use) and to the high production of waste.

The project intended to replace this processing phase with cold-spray galvanising which drastically reduces energy consumption and eliminates the production of waste.
The environmental benefits expected from the “Ultra Crash Treatment”, project can be summarised as follows:

- reduced energy consumption (approx. -50%)
- elimination of water consumption (-100%)
- elimination of the use of hazardous substances (-100%)
- elimination of waste production (-100%)
- elimination of emissions into the atmosphere (-100%)
- improvement of working environment

The project has been carried out in partnership with the University of Trento and involved 3 different types of actions:
The technical part of the project demonstrated the feasibility and applicability of the new micro shot blasting and cold-spray galvanising processes in the iron and steel sector, with the environmental benefits described above.

Micro shot blasting system

For the University of Trento the action started with the realization of a bibliographic study finalized to the selection and the organization of the information in the international literature to generate a data base on the effect of macro- and micro shot blasting on the surface finishing, the microstructural characteristics and the mechanical properties of steels. The shot material and the blasting/pinning energy were the main factors influencing such a characteristics which were of great interest in the application of the present project for two main reasons:

- the surface finishing influences the next step of the whole process (zinc coating);
- the microstructural characteristics and mechanical properties influence the response to the mechanical loading during application of the final product.

In the meantime, Metallurgica Abruzzese has acquired a shot blasting system which has been duly modified - with the help of an external company - to operate on drawn wire with metal abrasives in the shape of micro spheres or small cylinders. (Figure 1)

Fig. 1: Conventional shot blasting, adapted for the experimental phase

The first tests carried out with metal grit showed that this process removed the oxides from the annealed wire but also damaged the surface thus reducing the resistance of the wire or generating negative repercussions on the following galvanising phase. (Figure 2)

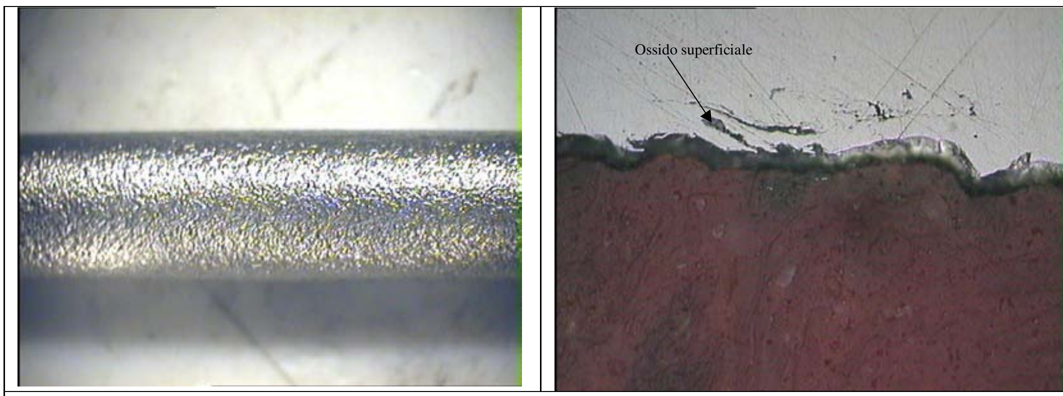
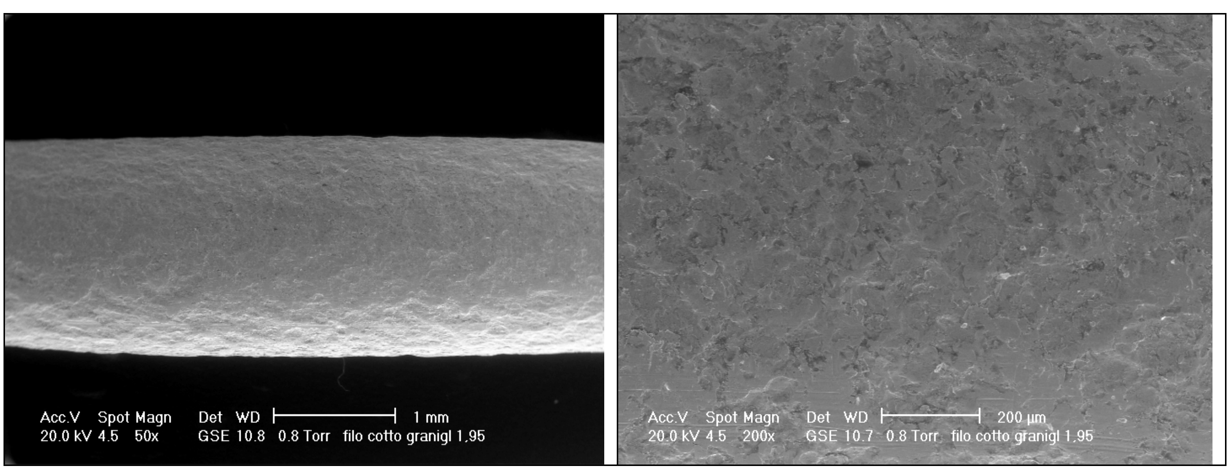


Fig. 2: Tests realized in Metallurgica Abruzzese

The University of Trento then went on to study the wire rods and wires after conventional shot blasting.
The analysis of wire rods and wires after conventional shot blasting were carried out to characterize the surface quality in terms of residual contamination and deformation.
Figure 3 shows, as an example, the case of an annealed wire. At low magnification the surface quality seem quite good but the observation at high magnification shows traces of oxide which has not been removed by the treatment, as well as an extensive deformation.
A surface as that shown in Figure 3 is not suitable for the zinc coating.



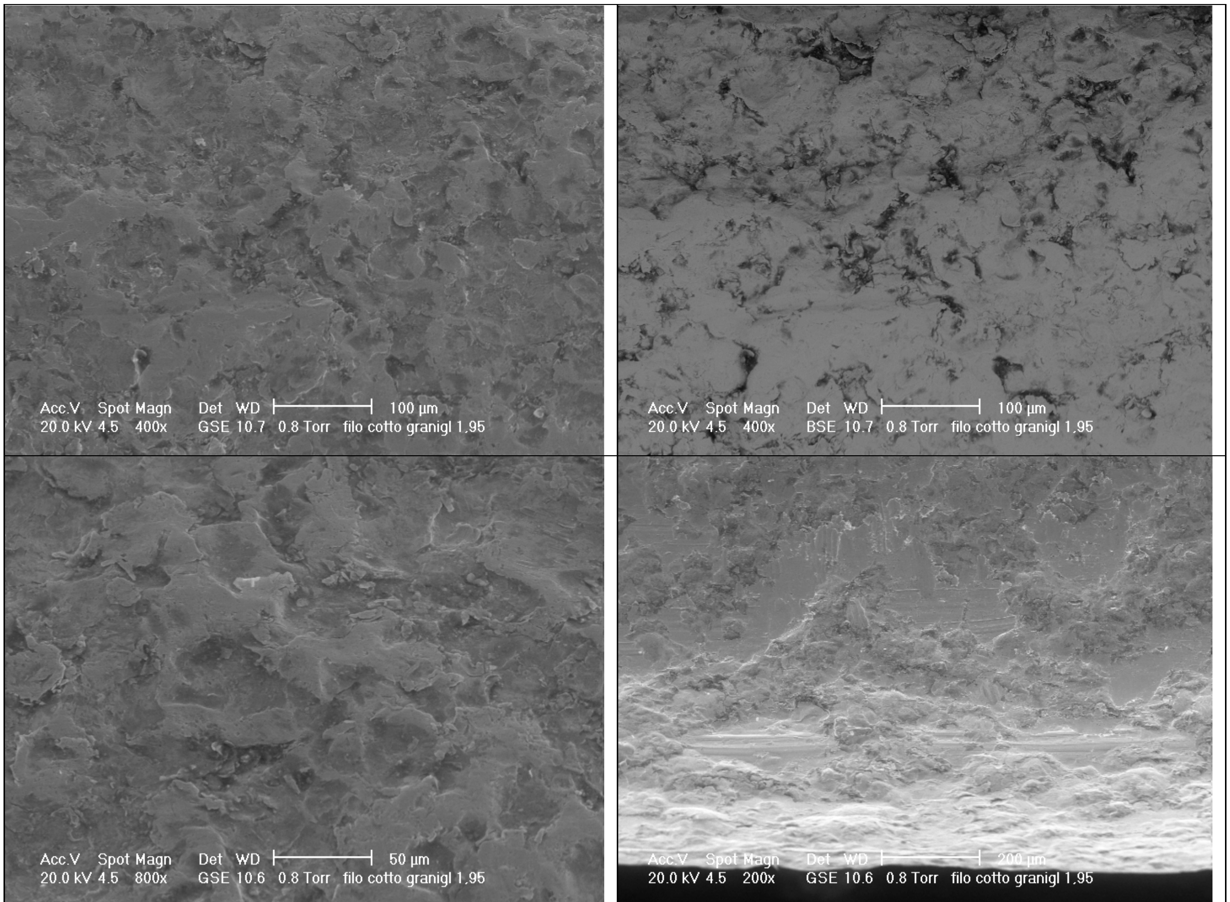


Fig. 3: surface finishing of an annealed wire after conventional shot blasting

Figure 4 shows, as another example, the case of a crude wire. It is harder than the annealed one shown in figure 3 due to the work hardening. In this case the surface finishing is better, with a more homogeneous deformation, but the traces of oxides are still evident.

This means that the conventional shot blasting does not fit the final requirements in terms of surface quality.

The limitation of the conventional shot blasting is the excessive energy transferred to the wire, which causes deformation. Deformation tends to indent the surface, and the surface contaminations are forced in the surface rather that removed.

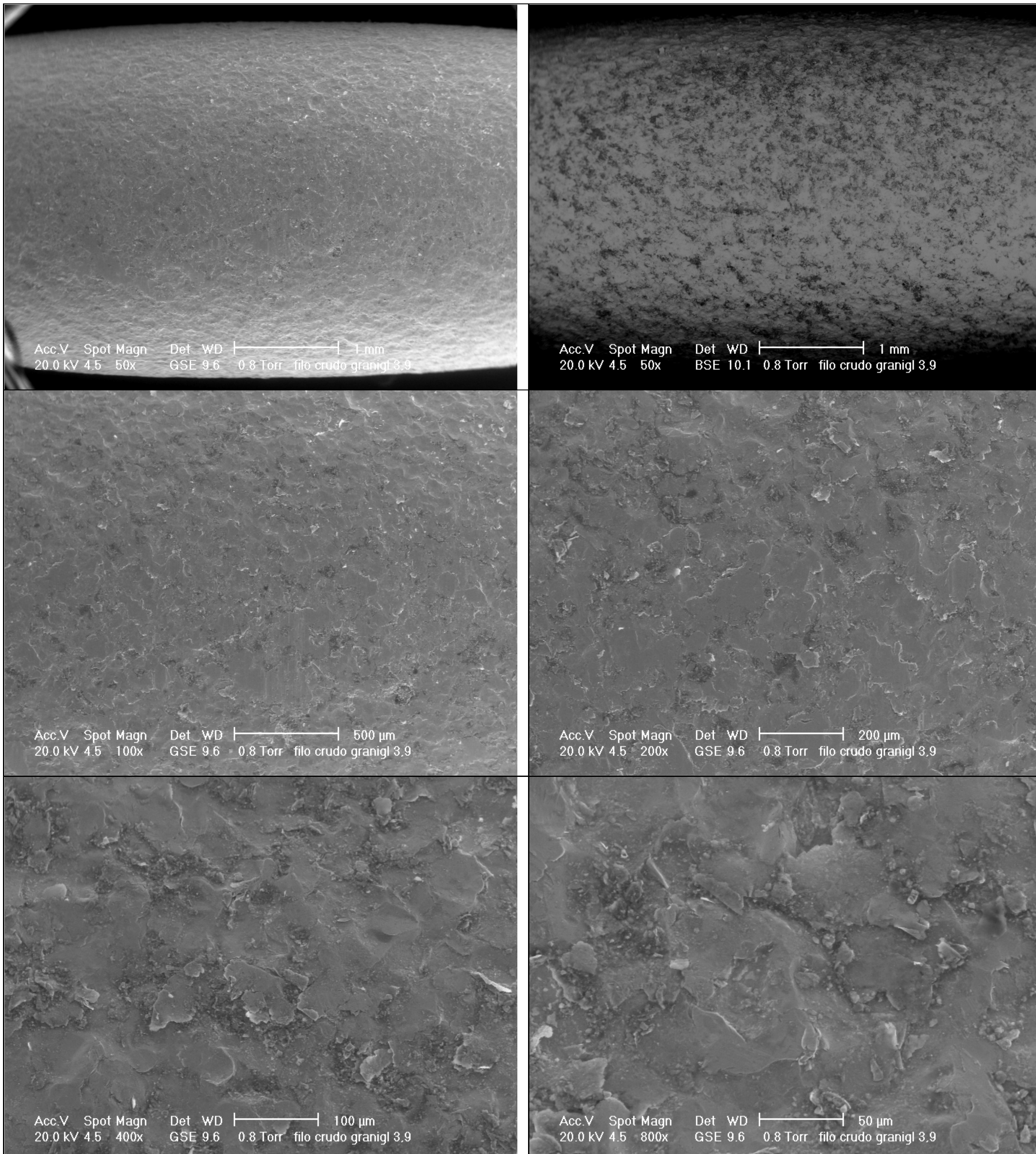


Fig. 4: surface finishing of a crude wire after conventional shot blasting

Micro s**hot blasting** is expected to perform better, because of the reduced deformation.

The University of Trento therefore started, together with a company with which it has been collaborating for many years, a first experimental phase of micro shot blasting to define the most appropriate working parameters for the micro shot blasting system. Figure 5 shows an example of the surface of a wire rod after micro shot blasting in a preliminary tests. The surface is still deformed, even if much more homogeneously than after macro shot blasting. The absence of residuals of the surface contamination is a very promising result.

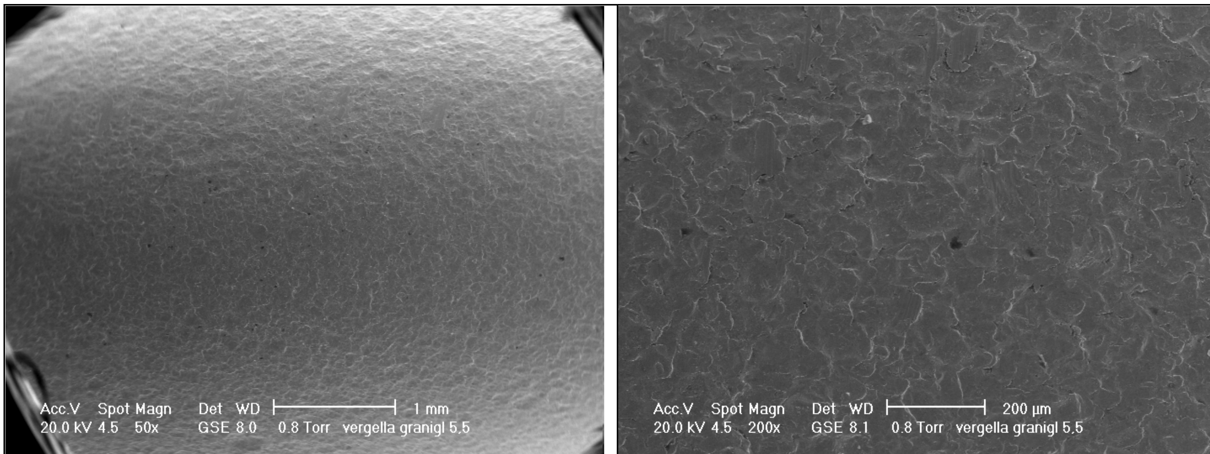


Fig. 5: surface finishing of a wire rod after micro shot blasting

On the basis of the preliminary tests the following parameters for the micro shot blasting apparatus were defined: shot S110; three turbines; 30-80 m/s centrifugal velocity.

On the basis of the results of the tests carried out at the Metallurgica Abruzzese plant and of the processing parameters identified during the experimental phase carried out by the University of Trento, an agreement has been entered into with I.M.F. S.r.l. (Impianti Macchine Fonderia). I.M.F. is leader in this sector and operates world wide; the group also includes Carlo Banfi S.p.A., a company specialised in the design, production and development of "made to measure" shot blasting, shot peening, and metal surface finishing systems.
I.M.F. S.r.l. has been chosen as it is the company which offers the best value for money, taking into account the following aspects:

- the purely economic aspect of the offer;
- the supplier's experience in the sector and the certainty of obtaining the required results;
- the possibility of carrying out testing also at the supplier's premises before the final development of the system;
- the production of a "made to measure" system created according to the company's specific needs;
- the "after sales" service which foresees a series of testing and fine tuning activities until the results foreseen are obtained.

A series of tests were carried out by the company's technicians and workers, which was followed by a design phase with the help of some subcontractors; on the basis of this, the system has been ordered, delivered, and started up in December 2011 (Figures 6).

- The system has the following fundamental characteristics:
- no. 3 turbines positioned at 360° – turbine Ø mm 360 –turbine speed 2950 rpm, which can shoot 110-120 kg of grit per minute each. The turbines are powered by 3 motors, 7.5 kW each;
- grit to be used: spherical S110;
- possibility of processing unwound wire of a diameter from 1 to 5 mm;

- production speed 200 m/min on 2 mm wire;
- system size: length approx. 3.8 m, width approx. 3 m, height approx. 4.5 m.

The data above is in conformity with the operational parameters defined by the University of Trento in the experimental phase.

The micro shot blasting system is made up of a machine with three high performance turbines positioned at 360°. Each turbine is powered by a 7.5 kW motor. The pieces pass in the tunnel and are guided to the exit. The grit (ceramic micro spheres) previously placed in the upper hopper of the elevator, is automatically sent to the turbines. The turbines give the grit the necessary kinetic energy and shoot it against the moving piece. The grit is then taken to the reception mouth of the bucket elevator which lifts it into the upper hopper of the selector for an accurate separation of waste, dust and spent grit. Reusable grit automatically passes into the silos and then into the pipes that feed the turbines. Each grit passage opening to the turbines can be manually and independently adjusted and calibrated. The grit shot by the turbines is always cleaned and selected so it is of the right size. The cleaning cycle is therefore totally automatic. The opening and closing of the supply of grit to the turbines is automatically controlled by an electro-pneumatic unit powered by compressed air at a pressure of 5 kg/cm2. The dust is removed from the pickling tunnel through air vents using a suction system that generates a current inside the tunnel which takes the fine dust to the vent of the main suction duct.

In addition a dry cartridge filter is used to remove the air sucked from the system to guarantee the optimal working condition of the system.

Fig. 6: Micro shot blasting system

At the same time, the action continued with a series of studies and tests conducted by the University of Trento, in particular regarding the best way of cleaning the wire in preparation for the next cold spray galvanising.

More specifically, we focused on the comparative analysis between the micro shot blasting process and the micro shot peening process. The comparison was

performed on the basis of the changes introduced in the wire, both on the surface and the subsurface layers, and the envisaged effects on galvanising.
Both processes promote the following effects:

- change of surface roughness due to micro abrasion and/or plastic deformation of the protrusions;
- improved adhesion of the coating due to surface cleaning and removal of the surface oxide, as well as the increased roughness;
- increased mechanical strength due to the hardening caused by plastic deformation and due to the accumulation of residual compressive stress in the surface layers.

These effects are accentuated in micro shot peening and therefore, in consideration of the particular adhesion mechanism of the zinc layer produced with the cold spray method, the micro shot blasting process was considered more suitable.
A comparative analysis was also carried out between the use of steel and ceramic shot (Annex 3 "Presentation of study about ceramic vs. steel shot peening"), to set up the first experimental trials. From literature and from the experience obtained from studies and experimental trials, it emerged that use of ceramics accentuates the increase in surface hardness and the accumulation of residual stresses. Therefore, since the desired effect is essentially the surface cleaning and removal of the oxide, and excessive mechanical resistance on the surface can adversely affect adhesion of the zinc, it was decided to proceed with initial tested, using steel shot which, among other things, reduces wear on the equipment compared to ceramic shot.

The first tests carried out when starting the system, while confirming the validity of the wire cleaning via micro shot blasting, nevertheless showed a greater presence of surface oxides than the newly set minimum objectives.

Based on these observations, a careful experimental phase was begun at the Metallurgica Abruzzese works.
Using the DOE (Design of Experiment) approach, the experimentation was set up based on three main parameters:

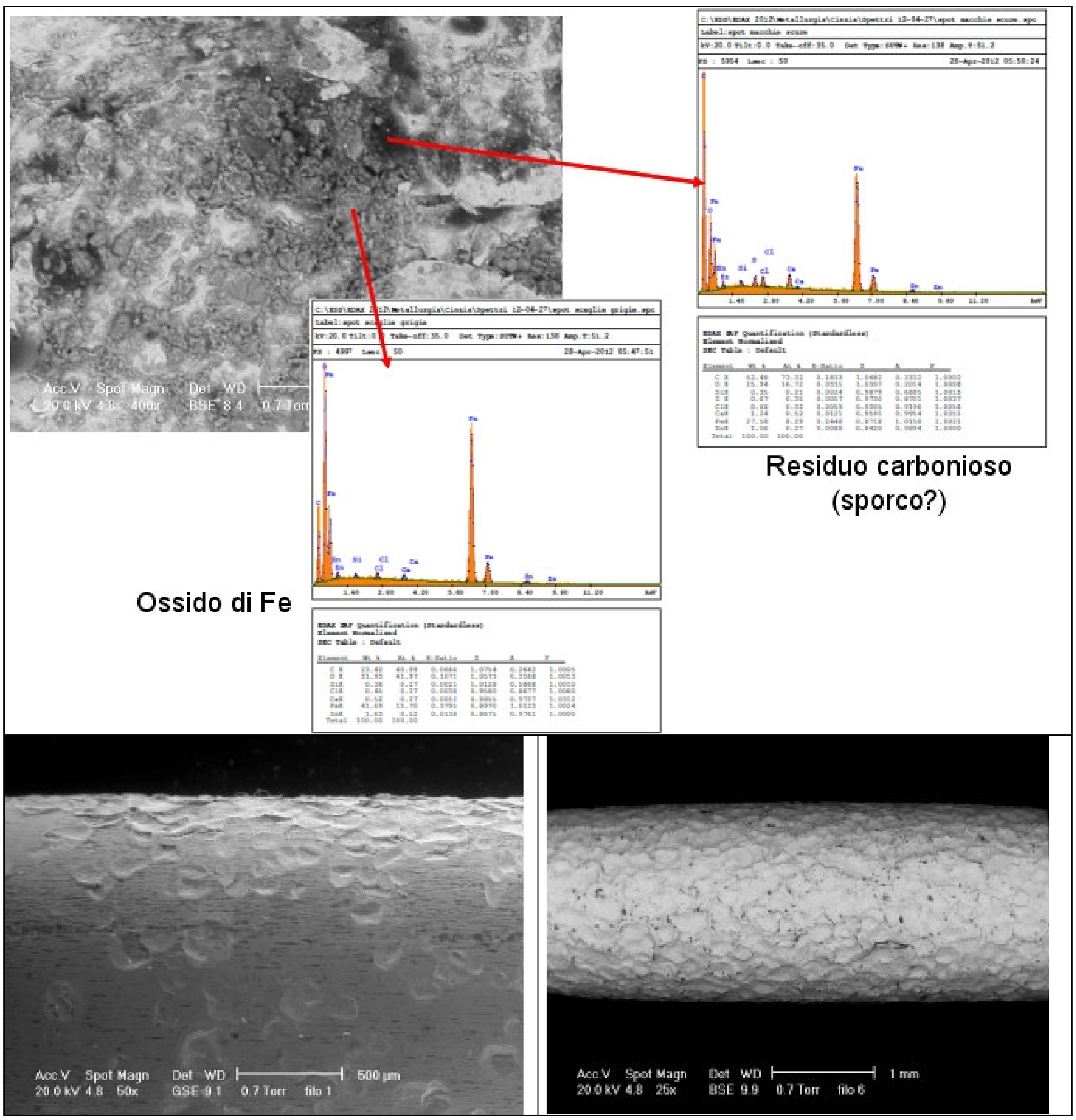
- Q = quantity of shot which affects the wire per time unit;
- V = shot impact velocity (changing the turbine transmission);
- T = time of stay experienced by the wire in the shot-blasting system (varying the wire travel speed).

These parameters are varied over two levels (-1 and +1), according to the following table:

Test	Q	V	T
1	-1	-1	-1
2	-1	-1	+1
3	-1	+1	-1
4	-1	+1	+1
5	+1	-1	-1
6	+1	-1	+1
7	+1	+1	-1
8	+1	+1	+1

To obtain statistically valid data, each test cycle must use the same type of shot and the wire to be cleaned must have the same diameter.
The tests carried out so far have envisaged the use of steel shot with diameters of 0.6, 0.8 and 1.0 mm.
While initial tests showed encouraging but still not good results, the latest experiments have delivered excellent results, with almost no traces of oxide in the last samples of blasted wire analysed (Figures 7).

The tests have therefore demonstrated that the envisaged objectives have been achieved perfectly and have confirmed the system’s expected productivity (300 kg/h) and the level of cleaning required of the wire rod (> 99%).



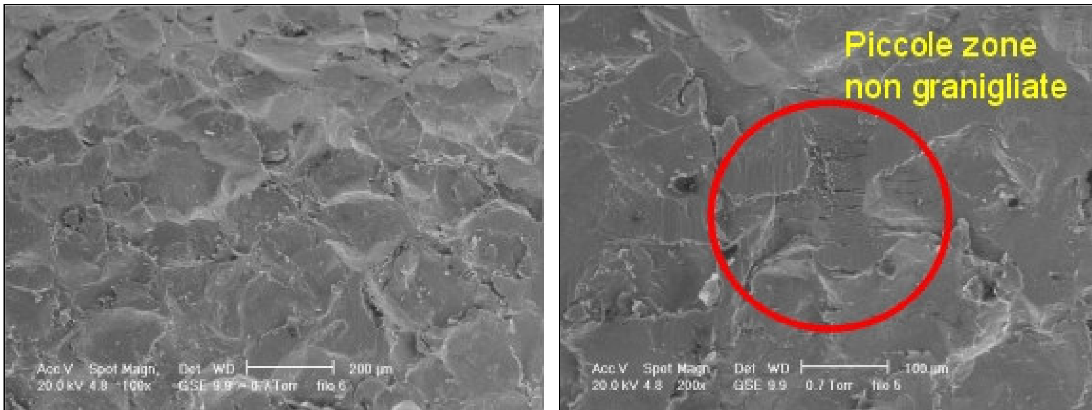


Figure 7: EDSX microanalysis of deposits on the wire and analysis with an Environmental Scanning Electronic Microscope (ESEM)

Tests have been performed also on the final pilot line; such experimentation have confirmed the expected results both on a mechanical and aesthetical point of view.

New Cold-Spray galvanising system

The action was started ahead of schedule. Also in this case the activity was started by the University of Trento with a bibliographic study of international literature to create a database on the effects of wire galvanising and on the characteristics and mechanical properties of the wire.
In this case the literature on zinc cold-spray coatings is very scarce, which means that the data base covers the process rather than the final application.
Contacts were also taken with a zinc powder manufacturer, since the quality of the zinc powder is a key parameter for the success of the cold-spray process.

At the same time Metallurgica Abruzzese carried out, in-house, some galvanising tests of wires with different characteristics and diameter; the tests were made using both the hot dip in fluid bed and the electrolytic processes. The analysis of the samples obtained was carried out as the characteristics of the wire, galvanised using these traditional methods, represent the minimum qualitative characteristics that the wire galvanised with the cold-spay system must have. (Figure 1)

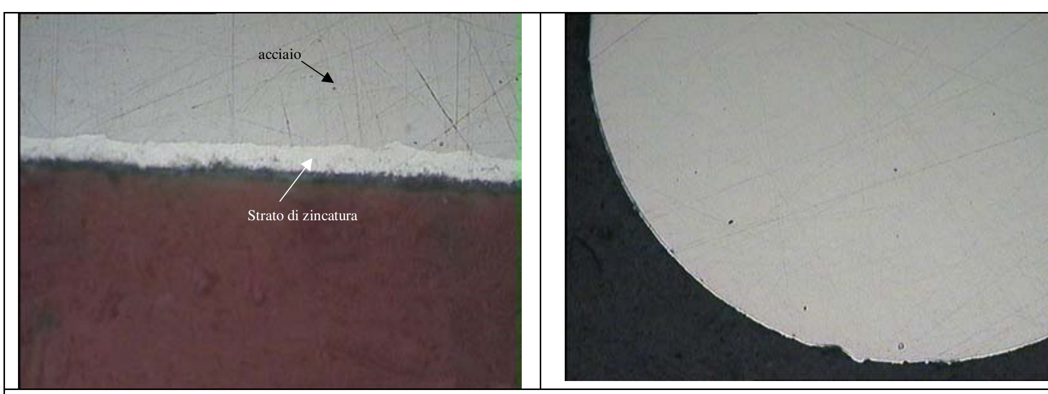


Fig. 1: Tests performed by Metallurgica Abruzzese

Metallurgica Abruzzese then carried out, at an external company, some cold-spray galvanising tests.
The tests were carried out on pieces of wire as the system used is designed for the galvanisation of small metal articles and not for moving products.
Despite these restrictions the first tests provided encouraging results: the zinc spheres become deformed when in contact with the wire providing an effective coating.
Obviously the coating obtained was not uniform and lasting as work still has to be done on the position and number of nozzles and on the spraying speed of the zinc micro spheres.

After a series of contacts with possible suppliers it was decided to choose I.M.F. again: this choice not only provides an optimal quality/price ration but also the unquestionable advantage of having one single supplier that guarantees the development of the two systems which have to work in line, and that can therefore adapt the different working and operational parameters according to the system needs.
Also in this case, in order to guarantee an optimal plastic deformation of the zinc we have opted for the use of turbines instead of pneumatic guns as they guarantee a greater output speed of the zinc spheres.
A first phase of tests carried out, with the help of IMF and other suppliers, has shown that positioning one turbine at 120° with respect to the other should allow optimal wire coverage. Additional tests were carried out on this basis, with the assistance of the University of Trento, which led to the identification of the exact positioning.
We then proceeded with the final design of the cold-spray galvanising system and the procedures for its implementation have begun.
The plant, built to process two wires simultaneously, so as to allow the installation in line with the micro shot blasting system, was delivered in June 2012, but the first tests did not give the desired results.
More specifically, the coating was unsatisfactory, with various areas in which the zinc had not adhered.
This was essentially due to the speed of the wire feed, necessary to ensure the expected productivity of 300 kg / h and in order not to slowdown (and hence the loss of productivity) the previous step of cleaning the wire with the micro shot blasting system.
A series of tests showed that, to ensure a wire galvanised in compliance with the minimum requirements, the feed rate of the wire had to be reduced by 1/3.
This would have reduced the productivity of the entire pilot line to 100 kg / h, which was definitely not acceptable as it would not have allowed us to demonstrate the possible industrial use of the new technology.
We therefore contacted once again the manufacturer of the system, I.M.F., and we completely redesigned the machine, to find a solution to the problems outlined above, to comply with the objectives of productivity foreseen by the project and to achieve the quality of galvanized wire necessary for the use of the final product.

We therefore examined the possible solutions, i.e.:

- Increase the wire feed speed to ensure the productivity foreseen;
- Maintain the product feed speed and increase the quantity of product processed.

The first solution was ruled out, since it would have required the construction of a plant triple the size of the current one, with a series of logistic and construction complications and an increase in energy consumption for its operation which was absolutely unacceptable.
We therefore chose the second solution, tripling the number of wires processed, passing from 2 to 6 (Figure 2).

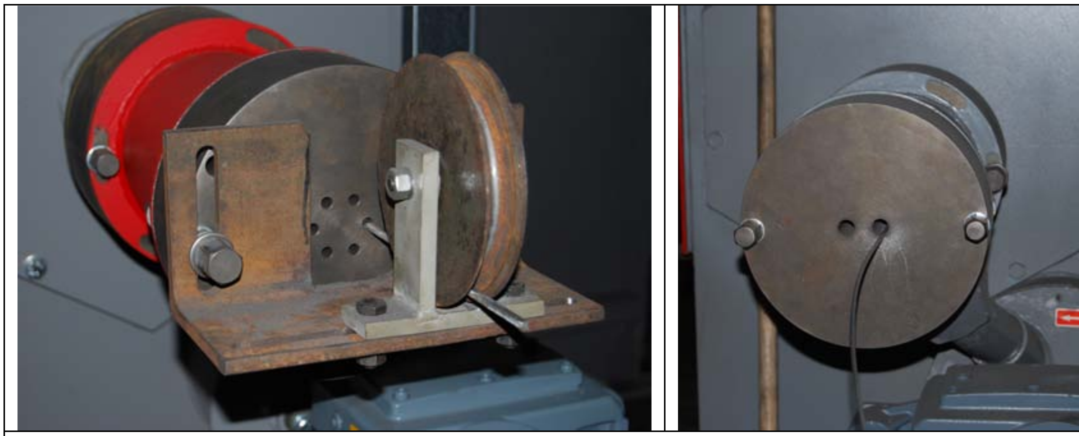


Fig. 2: left: new solution with 6-wire system; right: old 2-wire system

We therefore redesigned and constructed the new system which was delivered and installed at Metallurgica Abruzzese in January 2013 (Figure 3).

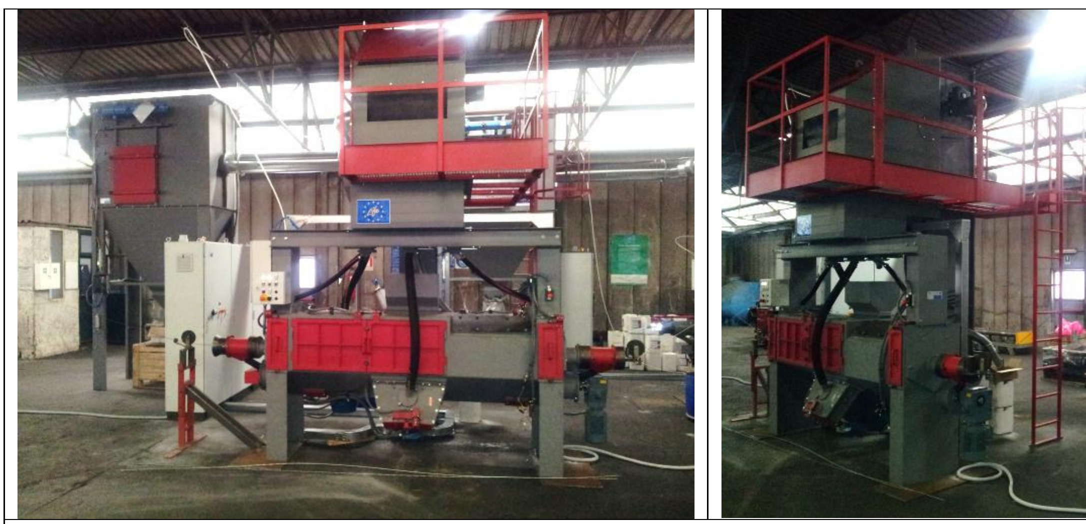


Fig. 3: Cold-spray galvanizing system

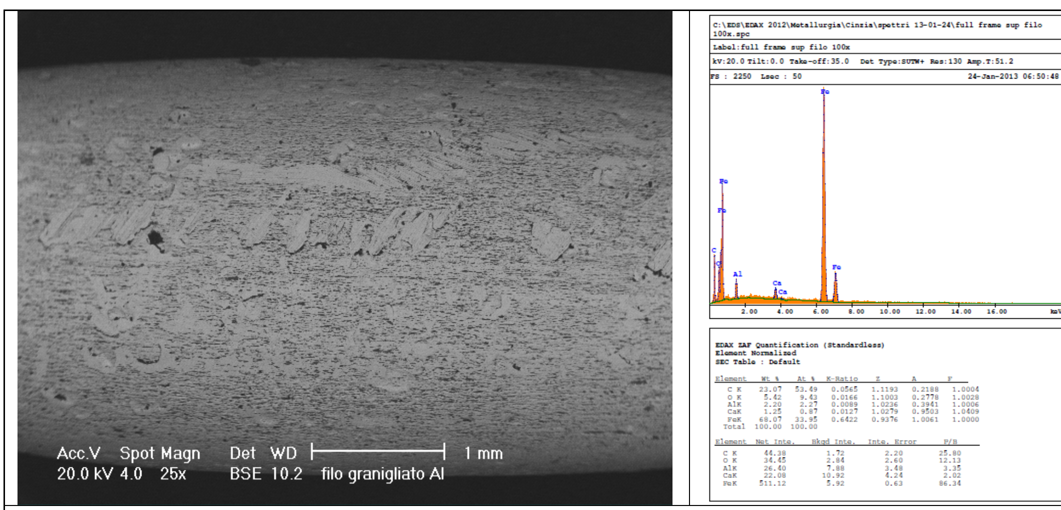
The tests carried out showed significantly better results, but still not optimal ones: to ensure the achievement of the required quality standards, we replaced the turbines, increasing the power and capacity, and we replaced the system electronic control and management part.

The new cold-spray galvanizing system was started and tested at the end of April 2013; tests carried out in May have produced galvanized wire, in compliance with the quality standards set and with the productivity values established.
Therefore, this action can be considered successfully completed.

In addition, as further added value to the project, we also carried out tests on aluminium coating instead of zinc.
These tests were carried out for a number of reasons:

- Aluminium is preferable to zinc for certain uses, because aluminised wire has a considerably higher corrosion resistance compared to simply galvanized wire, especially in a saline environment.
- Aluminizing is a process with an high environmental impact, therefore it is not used in the steel industry.
- The use of zinc-aluminium eutectic alloys is spreading, but this is not possible with cold galvanizing, because in this case the two metals do not form an alloy.
- To ensure the quality results required, it is preferable to use primary zinc, with a well-defined minimum degree of purity; the zinc recycling process is not very widespread and produces a poor quality raw material, therefore only partially usable; the recovery cycle of aluminium is an established practice, and recycled aluminium has properties equivalent to the original one, and energy consumption for its production is much lower than that for the production of primary aluminium.
- Zinc is considered a rare metal and its extraction is concentrated in a few countries (mainly China, Australia and North America); aluminium is plentiful in nature, and it is produced in all continents and about 1 / 4 of the entire world production of aluminium comes from the recycling industry.

The results obtained however, have proved unsatisfactory (Figure 3).



Element	Wt %	At %	K-Ratio	Z	A	F
C K	23.07	53.49	0.0565	1.1193	0.2188	1.0004
O K	5.42	9.43	0.0166	1.1003	0.2778	1.0028
AlK	2.20	2.27	0.0089	1.0236	0.3941	1.0006
CaK	1.25	0.87	0.0127	1.0279	0.9503	1.0409
FeK	68.07	33.95	0.6422	0.9376	1.0061	1.0000
Total	100.00	100.00				

Element	Net Inte.	Bkgd Inte.	Inte. Error	P/B
C K	44.38	1.72	2.20	25.80
O K	34.45	2.84	2.60	12.13
AlK	26.40	7.88	3.48	3.35
CaK	22.08	10.92	4.24	2.02
FeK	511.12	5.92	0.63	86.34

Fig. 3: Aluminium coating test results

This is caused by a number of factors:

1) The density of aluminium is considerably lower than the density of zinc (7.13 g/cm3 vs. 2.7 g/cm3); therefore, if the volume is the same, the kinetic energy of aluminium is 2.6 times lower than that of zinc (E = 1/2 m * v2); when in contact with the iron substrate of the wire to be coated, the deformation of the aluminium will be lower, as well as the ability to interact with the substrate or with other particles already deposited, thus deforming and compacting them. The layers of

Aluminium therefore result less dense and with porosity or discontinuities; in order to avoid this drawback, in other sectors co-spraying of ceramic particles is often adopted, to increase the kinetic rate; the ceramic particles however are incorporated in the coating and therefore this method cannot be used for the project.

2) Aluminium rapidly forms a hard and brittle surface oxide (alumina), which reduces the adhesion and cohesion of the coating layer; with Zinc this occurs less, also because the greater kinetic energy favours the breakage of the oxide film.
3) Aluminium and its alloys harden very quickly, i.e. the mechanical properties increase if they are deformed (hardened materials deform less and break more easily). Zinc alloys, however, recrystalise at room temperature, becoming less hard and less brittle, thus allowing the wire to be subjected to subsequent processing (for example, mechanical bending and welding for the construction of mesh).

In light of the above, while considering extremely interesting the possibility of replacing, at least for certain products, zinc with aluminium for the protective coating of the metal wire, we have interrupted the experiments in this sense because this objective was not among those foreseen by this project, and because the technology does not seem suitable to obtain the desired result.

We confirm however, that the action was - albeit late - positively completed, having achieved the objectives set.

Assembling of pilot line

The first activities for the assembly of the pilot line were started in autumn 2011, including identifying the most appropriate area of the works in which to accommodate the line.

More particularly, the overall size of the micro shot blasting (peening) and cold-spray galvanising systems was considered and, for reasons of space, it was decided to build a new line in the works dedicated to the production of electrowelded mesh. This is possible because the new wire cleaning and the cold galvanising can be seen as a separated processing phase from the conventional cycle, which requires the annealing, acid pickling, and hot dip galvanising cycles to be consequential.

The stand-alone positioning of the pilot line also allowed all the necessary experimentation activities to be carried out without being influenced by the company's normal production cycle (and vice versa). The wire, in fact, can be prepared (annealed) before and stored in the new system, until it is actually used on the pilot line in the experimental phase.

After that, we proceeded to prepare the layout design for the entire line, earlier than envisaged in the application, and the first adjustments have been made to the general systems that have been used to start up the line.

The reasons which led Metallurgica Abruzzese to bring forward the design activities for this action are linked to the desire to avoid delays to the project as a whole if delays are experienced in the cold-spray galvanising system implementation, testing, or experimental phases.

This choice proved to be correct because the problems that actually occurred in the previous Action 4 could have had a detrimental effect on this present Action. This however did not occur and the action is being completed regularly.
As stated, the first tests had shown that it was impossible to install in line, with a continuous cycle operation, the two systems of micro shot blasting and cold-spray galvanizing, due to the different production speed of the systems.
In particular, the micro shot blasting system ends the work cycle of a reel of drawn wire in a time equal to 1/3 of the time required to coat the wire with the cold-spray galvanizing system.
This problem was overcome by increasing the number of wires in galvanizing system (from 2 to 6), so as to ensure the same overall productivity of the two systems in the same operating time.
The pilot line, of course, works in a "semi-continuous" cycle, i.e. the micro shot blasting systems performs three production cycles in the time in which the cold-spray galvanizing system finishes one, but this makes it possible to always operate at full capacity, guaranteeing the expected results of 300 kg / h (Figure 4).

Fig. 4: Final Pilot Line

In the last months of the project, Metallurgica Abruzzese committed itself to the implementation of tests on the plant. The optimal processing parameters have been defined and the achievable results quantified. The coordinator has proceed also to collect data related to the consumption of the system and its production. This was implemented thanks to the help of the University of Trento which has collected and analysed the data exploiting the software DoE (design of experiment)

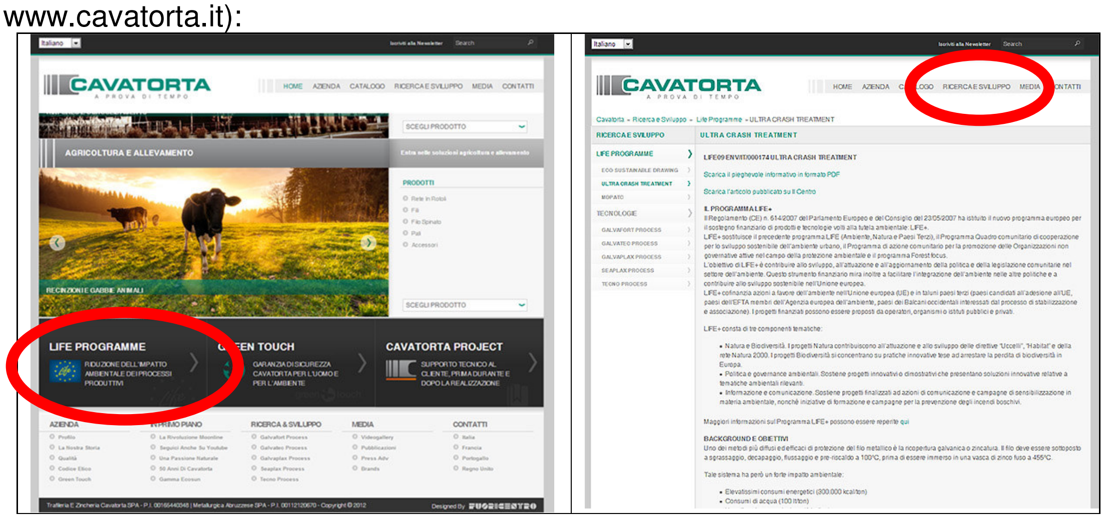
As it was previously described, the different processing speeds of the two systems made it impossible to install the two systems for continuous processing, otherwise productivity of the pilot line would have been drastically reduced and consequently the project objectives would not have been achieved.
The solutions found to overcome this problem were to triple the processing speed of the cold-spray galvanizing system, tripling the system size and the number of components; this would have resulted in a huge increase in costs, logistic problems related to the positioning of the system, an increase in the risk of technical problems, as regards machine operation, and a huge increase in energy consumption, and the maintain of the processing speed of the galvanizing system, increasing productivity

by tripling the number of wires processed; and this has made it possible to limit the size of the machine without problems as regards its positioning, to reduce the technical construction and management risks and not to increase energy consumption.

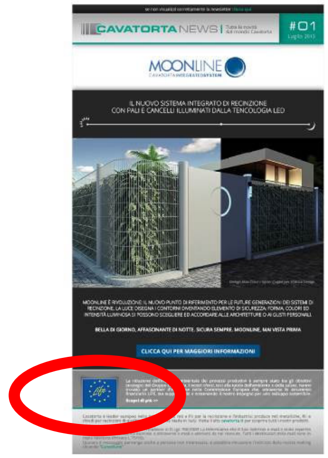
Dissemination actions

Numerous measures were taken to guarantee maximum visibility of the project results and to raise awareness of the environmental problem.
The dissemination strategy defined has achieved the main purpose set, i.e. of ensuring maximum impact within the European Community and bringing visibility to the project both inside and outside the iron and steel industry, involving public institutions as well as private-sector end users.
The activities implemented were also inspired by and organised according to a dissemination plan, which was constantly updated throughout the project based on the progress made and the commitments for the following period.
The main activities included:

- creating and posting a section in the website dedicated to the LIFE project. The section dedicated to the Ultra Crash Treatment project has been updated and is easily accessible from the group's website www.cavatorta.it, either using the link in the footer of the site, or from the "Research and Development" section (Figure www.cavatorta.it):



- a newsletter mailing plan was also set up, as a direct communication means for the dissemination of the "Ultra Crash Treatment" project, and two newsletters have been sent out, in September 2013 and December 2013. This system has replaced the house organ titled "Pagine" , which the Cavatorta Group no longer publishes. We will keep this activity going once the project has ended.



- three different kinds of notice board have been produced: one 150x150 cm notice board, located in the reception area at Metallurgica Abruzzese S.p.A., on the premises where the company has both its office and production facilities; two 80x100 cm notice boards, including one located in the Metallurgica Abruzzese S.p.A. meeting room and the other (in Italian and English) used for dissemination activities, such as fairs and events; two 80x100 cm notice boards, located inside and outside the Metallurgy and Microstructures laboratory at the University of Trento's Department of Materials Engineering;

	
Sample of notice board in Metallurgica Abruzzese	Sample of notice board in Università degli Studi di Trento

- the tool chosen to circulate the flow of information, i.e. Internet, offers the highest dissemination levels available today, using online journals and industry portals. More specifically, an editorial product has been posted within the Edilportale site (www.edilportale.it), which is the most important portal in the Italian building industry, with over 300,000 members, and is used daily by professionals in the trade. The same publication was sent via newsletter to all the portal's contacts.

- the "Ultra Crash Treatment" project was also disseminated through a major article in the Italian-language magazine "Tecnologie del Filo" (Wire Technologies), the official house organ of the ACIMAF (Association of Italian Manufacturers of Machinery for Wire), which outlined the project in detail and the results achived (Annex 7). Two editorials were published over the course of the project, in "IL CENTRO", an Italian-language newspaper published by the L' Espresso group, in both the printed and the online version, in 2011 and 2013. This has allowed us to highlight Cavatorta Group's commitment to curbing the environmental impact of the processes linked to the industry within which Metallurgica Abruzzese S.p.A. operates, with particular attention to the LIFE projects underway.

IL CENTRO — Economia — XIX

GRUPPO CAVATORTA

Reti ecocompatibili targate Ue

Il progetto sviluppato nella Metallurgica abruzzese di Mosciano

Il processo Ultra Crash Treatment è stato sviluppato in sinergia con l'ateneo di Trento

Il gruppo ha ottenuto il riconoscimento della commissione europea denominato Life+

Lavoro, il 38% nei green jobs

Abruzzo, una impresa su 4 investe sull'ambiente

RICERCA E SVILUPPO

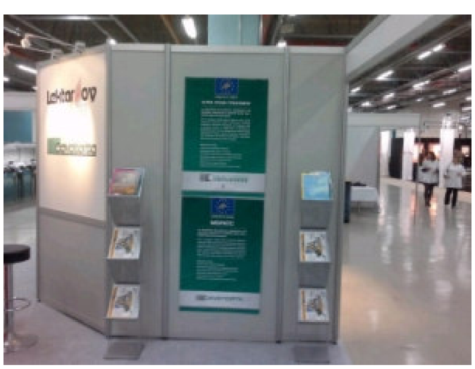
Traguardo europeo per la Metallurgica abruzzese

Giovanni Cavatorta, responsabile del progetto

MOSCIANO SANT'ANGELO

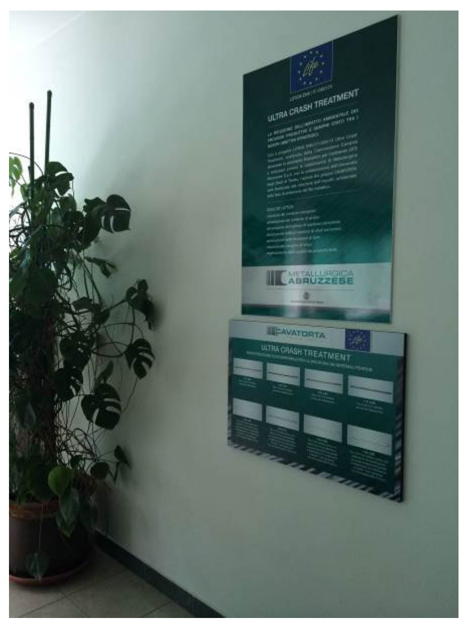
Si chiama Ultra Crash treatment, il nuovo processo messo a punto dalla Metallurgica abruzzese del gruppo Cavatorta dopo tre anni di lavoro all'interno del programma europeo Life+ per il sostegno finanziario di prodotti e tecnologie volti alla tutela dell'ambiente all'interno del territorio dell'Unione Europea. Ultra Crash Treatment aveva l'obiettivo di dimostrare la fattibilità tecnica ed economica di un nuovo processo ecocompatibile per la zincatura dei materiali ferrosi. L'obiettivo del nuovo processo è infatti la sostituzione delle attuali fasi di "decapaggio" in acido e di successiva zincatura a caldo con un innovativo processo di micropallinatura (con utilizzo di microsfere di ceramica o di acciaio) e di ricopertura mediante spruzzatura a freddo di polveri di zinco. Partner del progetto è il Dipartimento di Ingegneria dei Materiali e delle Tecnologie Industriali dell'Università degli Studi di Trento, che ha assistito l'azienda nelle fasi preliminari e nella caratterizzazione dei prodotti. I risultati ottenuti con il nuovo processo sono i seguenti: una sensibile diminuzione dei consumi energetici, sia nella fase di pulizia del filo, sia in quella di zincatura; l'eliminazione totale dei rifiuti e delle emissioni di fumi in atmosfera, derivanti dalla fase di zincatura a caldo; una sensibile diminuzione del consumo di zinco.

- participation in trade fairs. In October 2011, we took part in Helsinki's FUR SHOW (Finland), with a Cavatorta Group stand which featured a section on LIFE projects and displayed the Metallurgica Abruzzese "Ultra Crash Treatment" posters (as well as the "MDPATC" project by 'Trafileria e Zincheria Cavatorta'). English-language leaflets were also handed out. The company also took part in the BIG 5 SHOW (International Building & Construction Show) in Dubai, although not with its own stand. English-language leaflets were also distributed at the exhibition, which was considered strategic due to the great visibility offered (over 50,000 admissions), the considerable attendance of European actors, and because plenty of emphasis is placed on the environmental aspect of products and processes (thanks to the 130 free seminars and the Green Build Congress)



- The project can also be found in the "Think Eco Live Green" Facebook page, which has been created in association with other beneficiaries, through networking activities, and brings together various projects carried out in recent years in different sectors but with similar goals.

- Several samples of the product were produced and then displayed and distributed at meetings and to all those interested, even if they were simply visiting the company. Special display units were also produced and then distributed and used at trade fairs and events.



- Bilingual leaflets and flyers were produced and then distributed at trade fairs and events either organised or attended. A pdf version of the leaflets is available for download on the website. There were also 5000 product catalogues produced for the French market, which featured a final page dedicated to Cavatorta Group LIFE projects underway.

- An audio-visual aid was also produced, accompanied by an explanatory booklet, which showed the new process developed by the "Ultra Crash Treatment" project and the relative environmental benefits. This can also be viewed in the website and on YouTube (https://www.youtube.com/watch?v=A-W-INAxGDw&list=UULH0RmVfx6vQ_IL3rBf8lnA). A copy of the video was distributed during fairs and events and can also be viewed via the "Think Eco Live Green" Facebook page. The section below contains some excerpts:

- The LIFE logo and the project number have been added to the new company letterheads. This paper is used for all business correspondence. A file version of the letterheads had been created first, after which the Life+ logo was integrated into the paper version when it was altered following the restyling of the company logos for the 50th anniversary of Cavatorta; the letterheads are now available in both printed and digital format.

- Two events during the project were determining for the dissemination of the project results. It was decided to bring the first event forward so that it would coincide with the 20th anniversary of the LIFE programme. So, working in association with Trafileria e Zincheria Cavatorta S.p.A, we organised an event to mark the LIFE anniversary, which was held on 5th June 2012 at Metallurgica Abruzzese S.p.A. During the event, both the LIFE projects implemented by the group were presented, as well as the 20 years of EU support through the LIFE action for environmental sustainability. The meeting was attended by local authority representatives (three local mayors and a provincial councillor), as well as representatives from the business world (industrialists from our and other fields), and from various associations (including the Confindustria association). The event included the presentation of the principles that inspired the creation of the LIFE instrument, the history of LIFE and the characteristics of the 2012 call for proposals, as well as a brief presentation of ongoing projects by Cavatorta Group. This was followed by an extremely interesting debate, which offered the opportunity for a comparison between European opportunities, businesses' needs, and the situation of local public authorities. The meeting ended with a visit to the company's factory, to show the technical progress of the "Ultra Crash Treatment" project.

LIFE's 20th Anniversary event

A second event (final event) has been held on 28 March 2014, at the conclusion of the project. During the event information on the results achieved in economic and environmental terms have been disclosed and product samples have been given to those interested. The turnout was fairly good and mainly involved representatives of the industry and universities as well as representatives of the public administration. During the final event the cooperation of those present for networking and transfer of technology was publicly requested; some companies have shown interest in this activity, therefore we believe that in future we will establish important contacts for the development of these actions.

Evaluation of Project Implementation

The project was based on three mainstays:

- Administrative management;
- Technical management;
- Dissemination.

The administrative management ran smoothly, without any particular hitches; ongoing communication between the partners and among staff members ensured no time was wasted and blind alleys were avoided, and this meant that all the main project results were achieved. The only obstacle was encountered during the preparation of the final documentation, when problems related to the administrative department slowed down production of the report. Apart from this negative note, the project was carried out on schedule, with the desired results achieved.

The project's technical management also ran smoothly; the technical activities (consisting mainly in the design and implementation of the micro shot blasting system and the cold-spray galvanising system, followed by the final assembly of the two systems), were carried out on schedule with the key results achieved. No substantial changes occurred with respect to the events foreseen at the time of application; correctly established buffer periods ensured that the technical staff could complete the project on schedule. The innovative nature of the systems to be implemented undoubtedly represented a challenge for the technical staff but they all managed to solve the problems well with the help of external advisors.

The dissemination activities were completed as scheduled; the main expected outputs were produced on time, while the others were produced after the project had ended. The main reason for this delay was the fact that the management preferred to wait until it had a clear overview of the situation - based on the results obtainable with the pilot system - before disseminating the information externally. A second dissemination event was organised after the end of the project with a view to ensuring effective dissemination of the results

All the results achieved in this project are immediately visible and appreciable.
The project produced several benefits, some of which were financial, others environmental, including:
As regards the ceramic micro shot blasting system, the main benefits it brings in relation to conventional sand blasting are:

- less power consumption (up to 70%)
- more efficient oxide removal system and smoother finish
- much thinner zinc coating (40% less of zinc)
- up to ten times shorter treatment times
- less wire deformation
- the lower dust production allows a significant improvement of the working environment

As regards the galvanizing system, it solves many of the key environmental aspects of the hot dip galvanizing and has economic advantages. In particular:

- less power consumption (up to 40%)
- no water consume (100 litri/ton)
- no use of hazardous substances (1 kg / ton of thinners)
- no waste production (about 10 kg / ton of ash, zinc skimmings and zinc mattes)
- no emissions into the atmosphere (1000 m3/ton fumes from the galvanizing bath containing toxic substances as ammonia, hydrochloric acid and zinc dust)
- decrease in the consumption of zinc, with obvious economic effects as the cost of zinc is the main cost of galvanizing.

In the medium-to-long term, the company will assess the possibility of industrialising the system built and make these results real. The possibility to widespread the technology developed has been evaluated and the company is available to disseminate it to all interested in the hope of great environmental benefits for all Europe and possible technical collaboration and networking.

Environmental benefits

Metallurgica Abruzzese and the University of Trento have completed the “Ultra Crash Treatment” project within schedule, achieving the objectives set. The project was executed in line with what was foreseen in the application and the small variations that occurred did not affect the achievement of the expected results.

From a technical point of view the main environmental results obtained that can be measured in the long term are:

- significant reduction of energy consumption: about 70% less as regards wire cleaning and about 40% as regards the galvanising phase, with a reduction of over 200.000 Kcal/tonne in the first phase and over 110.000 Kcal/tonne in the second one. Considering that the company’s production is of about 40,000 tonnes per year, the possibility of extending, in the long term, the demonstrated process to the entire yearly production of the company would lead to savings of over 12,000 million Kcal. Considering that only at national level more than 4 million tonnes of wire are produced and more than 25 million are produced in Europe, the possible benefits in the long term are considerable.
- Thinner layer of zinc coating: about 36% less, which leads to a reduction in the consumption of zinc of about 40% with consequent environmental and economic benefits;
- 100% reduction of water for the cooling process (about 100 litres per tonne of wire): a saving of 4 million litres by the company if the technology is applied to the entire production. The possibility of substantial savings in the European context is a fact if the technology is disseminated, since the saving of water does not depend on the current situation of the plants or on the technology used; the implementation of the new technology in any case leads to 100% saving of water;
- No use of hazardous substances: about 40,000 kg per year of zinc chloride and ammonium in the company and more than 20 million kg estimated at European level;
- No production of waste, such as ash and zinc foam or solid zinc waste (slag), and subsequent disposal: approximately 350,000 kg of waste produced per year by the company would be saved if the proposed technology is industrialised; this value can be reach over 200 million kg at European level;
- Substantial reduction of emissions into the atmosphere, with total elimination of emissions from zinc baths: savings of approximately 400,000 m3 of smoke emissions containing ammonia, acids, zinc dust and zinc alloys.

Furthermore, additional benefits include:

- Shorter treatment times;
- Less wire deformation and consequently an improvement of performance in the galvanising phase;
- Less wear of machinery parts exposed to blasting;

The improvement of the working environment due to the production of smaller quantities of toxic dust must not be underestimated, since the benefits in this context are considerable and very much hoped-for.