PROGETTO LIFE13 ENV/IT/000593

“Titanium life in titanium hands: advanced use and reuse”

LIFE for life's material

The LIFE programme:

The LIFE programme is the EU's funding instrument for the environment. The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental policy and legislation by co-financing pilot or demonstration projects with European added value.

LIFE began in 1992 and to date there have been three complete phases of the programme (LIFE I: 1992-1995, LIFE II: 1996-1999 and LIFE III: 2000-2006). During this period, LIFE has co-financed some 3104 projects across the EU, contributing approximately €2.8 billion to the protection of the environment.

The current phase of the programme, LIFE+, runs from 2007-2013 and has a budget of €2.143 billion that covers both the operational expenditure of DG Environment and the co-financing of projects.

During the period 2007-2013, the European Commission will launch one call for LIFE+ project proposals per year. Proposals must be eligible under one of the programme's three components: LIFE+ Nature and Biodiversity, LIFE+ Environment Policy and Governance, and LIFE+ Information and Communication.

LIFE+ Nature & Biodiversity

The Nature & Biodiversity component continues and extends the former LIFE Nature programme. It will co-finance best practice or demonstration projects that contribute to the implementation of the Birds and Habitats Directives and the Nature 2000 network. In addition, it will co-finance innovative or demonstration projects that contribute to the implementation of the objectives of Commission Communication (COM (2006) 216 final) on "Halting the loss of biodiversity by 2010 – and beyond". At least 50percent of the LIFE+ budget for project co-financing must be dedicated to LIFE+ Nature and Biodiversity projects.

LIFE+ Environment Policy & Governance

The Environment Policy & Governance component continues and extends the former LIFE Environment programme. It will co-finance innovative or pilot projects that contribute to the implementation of European environmental policy and the development of innovative policy ideas, technologies, methods and instruments. It will also help monitor pressures (including the long-term monitoring of forests and environmental interactions) on our environment.

LIFE+ Information & Communication

This component will co-finance projects relating to communication and awareness raising campaigns on environmental, nature protection or biodiversity conservation issues, as well as projects related to forest fire prevention (awareness raising, special training).

LIFE+ is open to public or private bodies, actors or institutions registered in the European Union. Project proposals can either be submitted by a single beneficiary or by a partnership which includes a coordinating beneficiary and one or several associated beneficiaries. They can be either national or transnational, but the actions must exclusively take place within the territory of the 27 Member States of the European Union.

http://ec.europa.eu/environment/life/funding/lifeplus

ENVIRONMENTAL PROBLEM TARGETED

The use of recycled metals at industrial level is becoming increasingly important both to meet the demands of the public about the environmental conservation and protection and as an attempt to reduce costs, possibly shortening the supply chain.

Metal recycling has an important role, providing environmental benefits in terms of energy saving, reducing waste volumes and the reduction in emissions deriving from the energy savings.

In the case of titanium, recycling is even more important as the metallurgical extraction process that leads to the titanium sponge involves high labor, energy and capital intensity. Furthermore, additional steps of crushing and repeated melting of the sponge are required to remove inclusions and achieve the required level of uniformity. The multiple stages of primary metallurgical processes mean that titanium has a high embodied energy although, quantitatively, is the fourth most abundant metal, constituting about 0.62% of theearth's crust.

It is obvious to note that the primary metallurgy of titanium involves another environmental problem, namely the generation of chloride waste (Zheng and Okabe, 2008). In particular, during the $TiCl_4$ reduction, intermediate compound, is produced a considerable amount of magnesium chloride. To partially solve this environmental problem, this material is placed immediately in a recycling cell. This cell firstly separates the magnesium metal and then collect the chlorine gas. Both of these components are reused for the industrial production of titanium. Despite these productive problems, nowadays, the world market for titanium, in all its forms, is increasing.

Titanium and its alloys are used in various fields, but the reference markets are aerospace and aeronautics that, alone, absorb over the 80% of global production, using mainly Ti Grade 5 (Ti_6Al_4V), very fine material. If we consider the industrial sectors, the use of titanium in 2011 reached its historical record, reaching over 30% growth over the previous year. Among the industrial applications, chemical, power and desalination plants are representing the largest market share, followed by medical and automotive sectors.

So, recycling of titanium is of fundamental importance, both environmentally and economically. But while the recycling of titanium scraps and bigger pieces can be somehow managed by acid pickling and recasting in appropriate conditions (Veronesi, 2013), this usually does not apply to chips produced during machining operations for material removal. The problem resides in the specific metallurgy of titanium, which tends to show excessive interstitial absorption of oxygen, nitrogen and carbon in the chips, with irreversible changes of the properties of the alloy (increasing of the resistance but decreasing of toughness). Furthermore, due to the low thermal conductivity of titanium, conventional machining requires the use of large amounts of metalworking fluids that further contaminate the chips. For these reasons, the recycling of titanium chips today is not environmentally and economically advantageous: would require the use of mixtures of hydrofluoric and nitric acid with losses of up to 10% and the production of special waste (sludge).

WORK PROGRAMME

To achieve the ambitious goals listed above, will be necessary the development of the following actions:

- implementation of the coolant system with liquid nitrogen;
- modification of the machine tool to operate with coolant liquid nitrogen;
- changes to the system for conveying and collecting the chips;
- turning, milling and drilling tests with total recovery of chips, their chemical and particle size analysis and acquisition of optimal processing parameters, compared to standard cooling lubrication systems;
- preparation of preliminary pressing system chip (briquetting) functional to the next step of sintering;
- adaptation of the SPS system for the rapid sintering to the theoretical density of the pressed chips: obtaining a master curve of sintering;
- study and optimization of sintering conditions with the varying of the temperature and of the pressing pressure;
- characterization of the obtained sintered (Ti recycled) and assessment of their machinability and characterization of chips obtained;
- realization of finishing operations on sintered (drilling, deburring, grinding) and recovery of scraps and their reintroduction into the pressing stage of the chips from bar virgin;
- energy and mass balance of the new recycling process of the Ti chips; assessment of the eventual cost and environmental effectiveness, considering the benefits of lower consumption of tools, increased productivity, lower energy consumption, lower number of non-compliance;
- simplified LCA of components in Ti from recycled chips compared to similar components made from virgin Ti.

PROJECT OBJECTIVES

The project's objectives are essentially environmental and technical-economic:

- complete elimination of the use of lubricating oils and coolants or their emulsions in machining of the titanium grade 5;
- increase the useful life of cutting tools (WC-Co coated with a triple layer ceramic), up to 40% more than the current values in the case of turning, or 260% in the case of milling. This results in less waste production and a lower level of contamination of the chips worked;
- full recycling of the titanium scraps, no longer contaminated with organic coolant without any pre-treatment for sintering;
- recycling process in which the only energy input occurs in the sintering step by FATS techniques; with an energy saving estimated in 40-60% compared to remelting in an induction furnace under vacuum. It is estimated that sintered parts obtained through recycling with sintering possess have an embodied energy lower by 45% than similar pieces obtained by fusion; similar estimations could be applied for the CO2 footprint;
- no need to clean the scraps (no use of soaps, detergents and pickling acids), neither the machined components: liquid nitrogen simply evaporates and returns to the air without any pollution;
- recycling by sintering of scraps obtained from cryogenic processing in nitrogen liquid allows, for the first time, to form a closed cycle which does not produce scraps, because the eventual chips are recyclable within the same production cycle;
- creation of lighter components due to sintering with minimum densification, for high temperature applications in the automotive field and racing in general, with the consequent possibility to increase operating temperatures (increasing of the efficiency), reduce consumption (lightweight components) and increase useful life of the component (high resistance to thermal oxidation, lower centrifugal forces in action).
- realization of innovative high-performance components, in addition of the company's standard production: in particular the higher oxygen content in the sintered products will lead to higher breaking loads, partially at the expense of toughness, while the production of porous structures will increase drastically the specific resistance of the components made;

TECHNICAL PROGRESS

The project began smoothly on 01/06/2014, as foreseen, with the organization of both the technical and the administrative/financial and dissemination activities to be carried out.

The first technical activities undertaken were based on the choice of the preparation of the raw material (chips resulting from processing with automatic titanium machines): grinding of the chip prior to sintering or use of the raw material in the condition in which it is fed out from the work centres.

We then proceeded to decide on the work centre that would initially be fitted out with the new system on the coordinating beneficiary's premises, and likewise to analyse and consider changes which would need to be made by external suppliers in order to allow installation of the new cooling/lubrication system and the scaling of the nitrogen generation and/or distribution plant based on the size and capacity of the work centre itself.

Research was also carried out in order to obtain information about the costs of a portable XRF analyser and for the chip vacuum-packing system, the thinking being that we could use a food-packing plant, in order to test the system and the effectiveness of the solution without wasting resources.

In order to make up on lost time, the activities concerning titanium waste sintering systems were launched early. The chips originate from conventional machining and therefore are "dirty". As a result, they were delivered to partner K4Sint, which then cleaned them with acids, ground them, and then pulverised them with a high-power mill. Part of this was used in-house to perform experiments with the SPS method and with an extruder. Another part, meanwhile, was passed on to the University of Modena in order to begin testing the microwave sintering method.

The technical activities then continued with the Caleffi staff producing a simplified plan of the changes to be made to the machine tool to be used to build the cryoscopic processing system. The purpose of this system is to deliver the liquid nitrogen to the cutting tool but not to the surrounding area. Supply is drawn from a low pressure stand-alone tank placed next to the modified milling machine. A double-walled and vacuum insulated custom made supply hose delivers the liquid Nitrogen to the custom made nozzle. Control of the liquid nitrogen flow is regulated by both nozzles and by throttling of the main valve at top of the supply tank. The first nozzle bracket was cobbled up to mock up locations, and then perfected for the final version.