



AST3-CT-2003-502741

**MACHERENA**

**New tools and processes for improving machining of heat resistant alloys  
used in aerospace applications**

SPECIFIC TARGETED RESEARCH PROJECT

THEMATIC PRIORITY 4: AERONAUTICS AND SPACE

**PUBLISHABLE FINAL ACTIVITY REPORT**

Period covered: from 1 January 2004 to 30 June 2007

Date of preparation: July 2007

Start date of project: 1 January 2004

Duration: 42 months

Project coordinator name: Javier Escribano

Project coordinator organisation name: Mecanizados Escribano

Revision 1

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## 1. PROJECT EXECUTION

The main goal of the project was the improvement of the machining process of aeronautic heat resistant alloys by means of more efficient tools and processes. Three materials families have been studied.

- Fe-Ni alloys. These heat resistant alloys, like **A-286**, are used in many structural components.
- Ni alloys. Two of the most relevant alloys are **INCONEL 718** and **IN100**. Due to their high heat resistance, it is mainly used in aero engine parts.
- $\gamma$ -**TiAl** intermetallic. In its gamma phase is a good candidate for high temperature applications. Due to its high cost and high difficulty in machining very few applications can be found for this material.

This improvement has come by a reduction of the cost of the part by an extension of the tool life and reduction of the machining time by new cutting technologies. This was achieved by the application of new surface treatments on tools (nano-structured coatings), new cutting technologies combined with high pressure cooling systems and re-design of machining tools according to the new surface properties (hardness, friction, material adhesion, sharpness, etc.).

This has led to the following industrial objectives:

- Tool life increase
- Reduction of production costs
- Increase of machining productivity (more advanced cutting parameters)
- Optimal coolant utilization
- Improvement of finishing quality.

**Project cost: 4,166,526 €**

**Project duration: From Jan, 1st 2004 to Jun, 30th 2007**

### **Participants:**

MECANIZADOS ESCRIBANO	Machine Shop	Spain
WZL-RWTH AACHEN	Research Centre (Machining)	Germany
PLATIT	Equipment and Coating developer	Switzerland
TECHNICAL UNIV. MUNICH	Research Centre	Germany
SHM	Coating Developer & Coating Centre	Czech Rep.
UNIMERCO	Tool Manufacturer	Denmark
ECHEVERRIA	Machine shop	France
GEYCA	Project Management	Spain
CESA	Aeronautic Components Designer and Producer	Spain
VOLVO AERO NORGE	Manufacturer of Aero engine parts	Norway

A286 and INCONEL 718 are materials that due to their high Ni content and heat resistance are very difficult to machine, and this results in a high cost of the parts manufactured with these materials. The results of this process will open for more cost-effective production processes for aerospace parts. The TiAl is a good candidate in future aerospace applications, due to its low weight and good resistance at high temperatures. However, its low machinability (10% of that of Ni alloys) makes the production costs very high for many applications. A reduction in the TiAl intermetallic machining cost will open the possibility of the design and application of new parts.

The project objectives have been addressed by the development of new tool geometries, hard and low-friction nanocomposite coatings produced by PVD methods and new machining processes (high pressure cooling). At a first stage, the machining shops and end users collaborated with the R&D Centres and the tools and coating producers in defining which machining processes and tools will be used to evaluate the new developments:

- Inconel 718 roughing, finishing and drilling
- IN100 roughing and finishing
- A286 roughing, finishing and turning

Two demonstrators were defined, as they were used at the end of the project to evaluate the performance of the new tools, coatings and machining processes. With the defined characteristics of the tools and their problems, the possibility of addressing new tool designs were evaluated, taking into account that these tools would be coated. A Taguchi testing approach was used to select the best coating geometries.

New nanocomposite coatings were developed, considering the special requirements specified by the end users and machining shops. The lines of the research were mainly three. The system AlTiSiN was optimised to cope with the demands of hardness and friction. An approach was also made to other compositions, where the Ti was substituted by other elements that have shown better friction behaviour (Zr, Cr), or where low-friction phases are added.

The developed nanocomposite coatings were tested in the laboratory facilities. The coatings were applied on both standard and newly developed tools, and the machining parameters that showed the best behaviour of the tool from the efficiency point of view were selected. The tools were also analysed to determine the failure modes, and this analysis acted as inputs for the coatings optimisation. One of the main efforts was done in avoiding the chipping failure modes on tools as this led to unreliable and little predictable machining processes.

At this point, optical microscopes, Scanning Electron Microscopes (SEM), profilometry, roughness measurement devices, wear tests and metallography facilities were used. Furthermore, advanced machining processes, like high pressure cooling machining, was tested in the coated tools to increase even more the efficiency: tool lifetime, machining speed, etc.

The third leg of the testing table will consist on the real production tests performed at the machining shops. The results of these tests gave good feedback information and helped the optimization of both coatings and machining parameters. The final results were finally evaluated in the production of real parts (demonstrators).

The main achievements of this project have been:

- Improved understanding of the nanocomposite coatings fundamentals, mainly focussed on the effect of impurities (e.g. Oxygen) in the coating properties and the importance of having 1 monolayer of interfacial Si<sub>3</sub>N<sub>4</sub>.
- Development of new nanocomposite coatings that improve machining processes:
  - o nc-AlTiSiN
  - o TiAlN

- nc-CrAlSiN
  - AlTiCO
- Machining processes are complex, and during this project the optimization had to be focussed on many aspects, and the right combination of all of them resulted in the optimum cutting procedures:
  - Tool design: tool geometry
  - Tool substrate: a compromise of a hard carbide able to machine difficult to cut materials but with a good toughness value to avoid cracks and brittle tool failure.
  - Surface preparation: This improves the tool cutting performance by optimizing edge geometry and reducing stress.
  - Coating: That increases surface hardness, reduces friction or improves thermal performance of the tools.
- This has resulted in the development of new high performance tools
  - Rough mill for Inconel and A286 alloys
  - Rough and finishing mills for IN100
  - Drill for Inconel
- Tool life of drills for Inconel has been increased over 50% by using high pressure cooling, with pressures up to 120 bar.
- Increase of tool life by changing the wear mechanism from chipping (catastrophic) to continuous wear. This makes tool life much more predictable and decreases the risk of unexpected failure (which can cause severe damage in very expensive components).

## 2. DISSEMINATION AND USE

As described in Section I, several exploitable results have been obtained as a result of this project. However, IPR issues are still under study and it is the partners' will not to publish any details until the knowledge protection is fully covered.

One of the publishable results is one roughing mill developed by UNIMERCO that includes all the developments achieved within the project. A copy of the brochure is enclosed.

**UNIMERCO**

Optimisation models | Complete tooling programmes | Customised tools | Tool maintenance | Tool management systems | Training and education

### NTS HPC MILLING TOOLS

— for high performance machining of nickel alloys, titanium and stainless steels

**High performance milling**

Optimised for:
Nickel alloys
Titanium
Stainless steels

Application areas – examples
Turbine blades
Impellers and blisks
Aerostructure components
Aeroengine components

**Upgrades include**

- Power edge - revolutionary edge preparation technique
- New nano composite coating
- Improved carbide grade
- New developed CNC ground tool geometry

**Improved benefit**

- Superior tool life
- Improved components quality
- Even higher metal removal rates than former NTS
- Minimised cost per cut

**The new NTS cutter - upgraded for superior performance**

**C7 PLUS<sup>TM</sup> Power Edge**

### TOOL SPECIFICATIONS

**NTS-HPC**

**Power Edge:** New and improved cutting edge that significantly reduces edge damage and gives optimum coating adhesion.

**Unequally divided teeth and quad-helical flute design:** Interrupt chatter frequencies, a significant factor in premature edge failure. This allows deeper and more stable cuts.

**Possibility for relieved chamfer:** To avoid rubbing in deep pockets, if required.

**Back chamfer:** To ease loading into high precision toolholders.

All tools are produced with either corner radius or corner chamfer in one CNC operation whether new or RE-NEW<sup>TM</sup> (reground). The result is better component quality with no run-inches.

Super-tough, chip-resistant carbide with C7 PLUS<sup>TM</sup> nano-composite coating maximises tool life.

All tools are manufactured on a plain shank to an H5 tolerance - UNIMERCO recommends the use of a precision ultra-high grip milling chuck.

**AEROSPACE**



## NTS HPC MILLING TOOLS

– for high performance machining of nickel alloys, titanium and stainless steels

Optimisation models | Complete tooling programmes | Customised tools | Tool maintenance | Tool management systems | Training and education

### TOOL SPECIFICATIONS



Item Number	Diameter	Length of Cut	Shank Diameter	Corner Rad	Overall Length
258752.0800	6.00	13.00	6.00	0.30	57.00
258752.0800	8.00	19.00	8.00	0.30	63.00
258752.1000	10.00	22.00	10.00	0.30	72.00
258752.1200	12.00	26.00	12.00	0.30	83.00
258752.1400	14.00	28.00	14.00	0.30	88.00
258752.1600	16.00	30.00	16.00	0.30	92.00
258752.1800	18.00	36.00	18.00	0.30	96.00
258752.2000	20.00	38.00	20.00	0.30	104.00

All tools are coated with our exclusive super-hard C7 PLUS™ nano-composite coating for maximising performance. Further details available on request.

#### Performance example

Milling of titanium component (Ti-6Al-4V)

Ap = 7 mm

#2 0.05 mm/tooth

Aa = 12 mm

Previous carbide solution, ≈ 53 min. tool life

Vc = 44m/min

NTS C7 PLUS™ Power Edge ≈ 167 min. tool life

>>> 100 % increase in tool life

**C7 PLUS™**  
Power Edge



#### Delivery and technical advice

Standard delivery equals ex stock from warehouse. Due to demand there may be occasions when this is unavailable with certain items, however we will do our utmost to ensure that we can fulfil your order in the minimum time.

Our standard terms and conditions apply throughout. A copy of these can be obtained upon request.

#### Bespoke Manufacturing Service

If you require tools that are designed to suit your particular application, UNIMERCO offers a bespoke manufacturing service with a simple feedback sheet to complete to order your customised tools. For more information on this service please contact our local sales office or contact your local area sales representative.

If you need further technical advice for cutting specific materials please do not hesitate to contact us.

#### For more information or to order...

→ find the nearest UNIMERCO service centre on [www.unimerco.com](http://www.unimerco.com) or contact your local sales representative.



Use the UNIMERCO feedback sheet when you want to place an order.

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