2014 November 12th

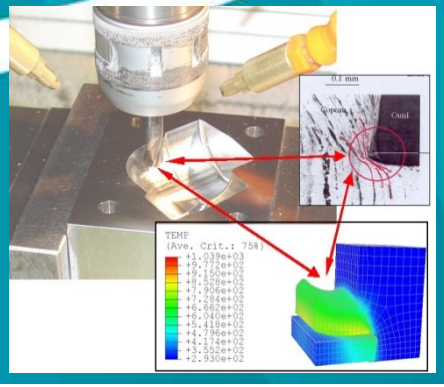
MONDRAGON UNIBERTSITATEA

GOI ESKOLA POLITEKNIKOA

ESCUELA POLITÉCNICA SUPERIOR

High Performance Machining Research Group

Mondragon University- Faculty of Engineering- Manufacturing Department



Pedro J. Arrazola (pjarrazola@mondragon.edu)

20500- Arrasate/ Mondragon - Spain

http://www.eps.mondragon.edu

http://www.mondragon.edu/en/phs/research/research-lines/high-performance-machining-processes

Location

Faculty of Engineering of Mondragon University

2,1 Million inhabitants (303 inh./Km2)
GDP= 21% from Industry (25%)
Unemployment rate: 15,21%

CANTABRIA-SANTANDER

Biarritz

FRANCE

Eustat
EUSKAL ESTATISTIKA ERAKUNDEA
INSTITUTO VASCO DE ESTADÍSTICA

http://www.eustat.es/

NAVARRA-PAMPLONA

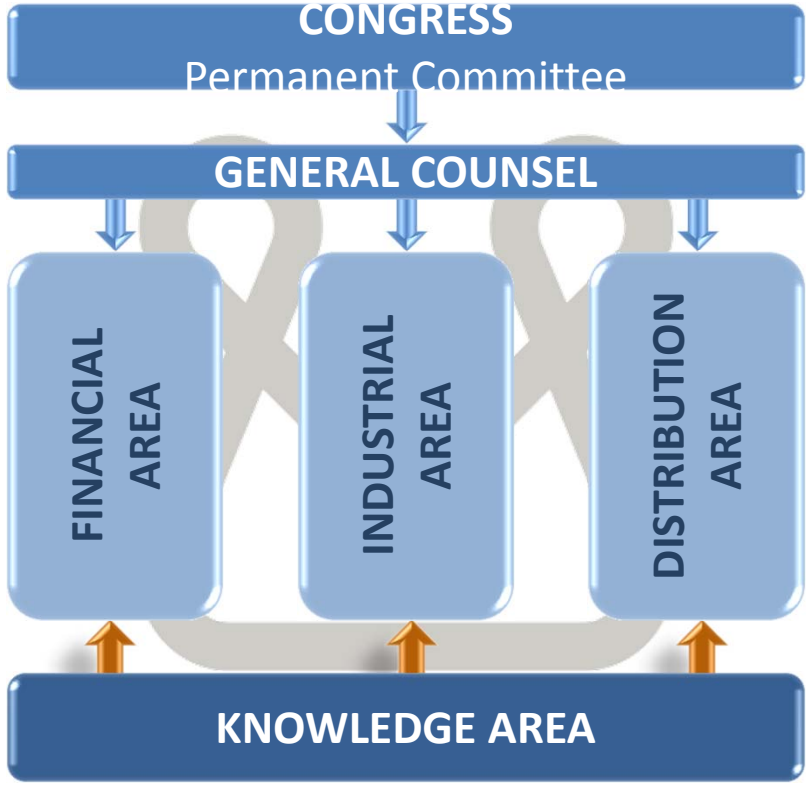
LA RIOJA-LOGROÑO

Mondragon University / Mondragon Group

- Founded by José Maria Arizmendiarrieta in 1956
- Total Turnover (Industrial and Distribution): 12.574 M€ (2013)
- Workforce at year-end : 74,060 (2013)
- Over 257 companies

HUMANITY AT WORK MONDRAGON

http://www.mondragon-corporation.com/



Moulds and dyes

Machine-Tools:
Grinders, Milling, Turning machines,

Elevators

Automotive components

Mondragon University / Mondragon Group

- Founded by José Maria Arizmendiarrieta in 1956
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HUMANITY AT WORK MONDRAGON

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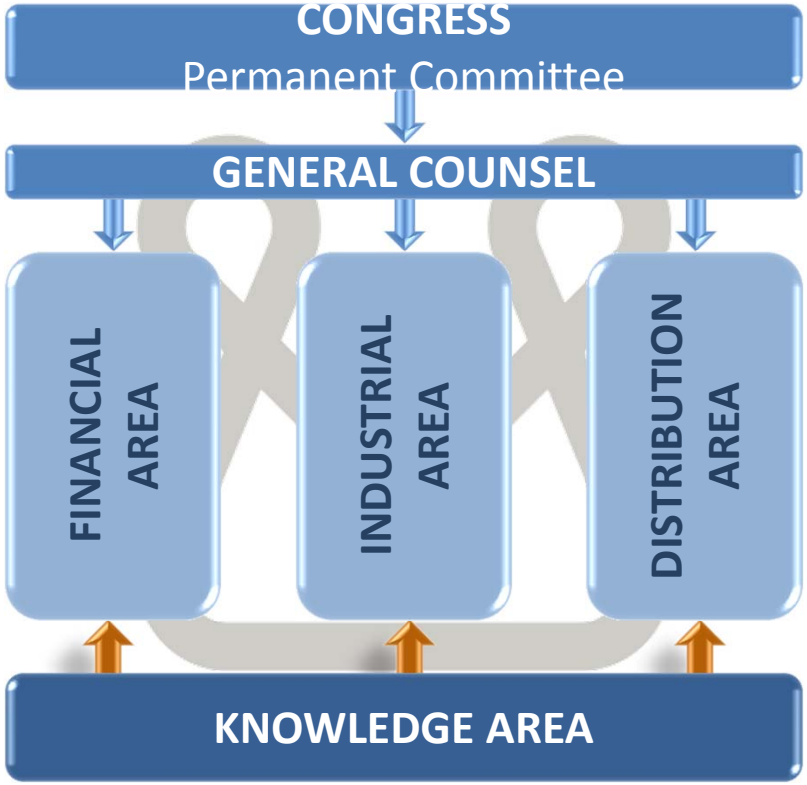


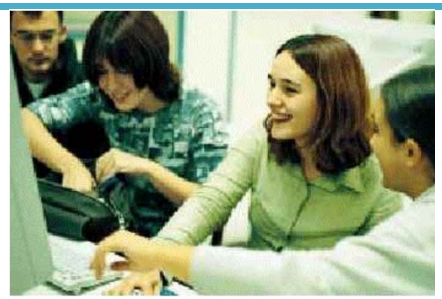
CAJA LABORAL
LAGUN ARO SEGUROS
FAGOR
ULMA
EROSKI
GRUPO ORONA
URSSA Construcciones Metálicas / Steel Construction
DANOBAT

Mondragon University

MONDRAGON UNIBERTSITATEA

MONDRAGON UNIVERSITY

MONDRAGON UNIBERTSITATEA, S.COOP.



- ***THE UNIVERSITY OF KNOWLEDGE TRANSFER***
- *Private, non-profit making university (1997).*
- *Open to any member of society and to any type of company.*
- *Four Faculties (3,750 full-time students)*

MONDRAGON GOI ESKOLA POLITEKNIKOA, JOSE Mª ARIZMENDIARRIETA, S. COOP. Ltda.

Mondragon-Ordizia

Faculty of Engineering (MGEP)

ETEO, S.COOP

Oñati-Irun

Faculty of Economics

HUHEZI, S.COOP

Eskoriatza

Faculty of Humanities

Basque Culinary Center

Donostia/ San Sebastian

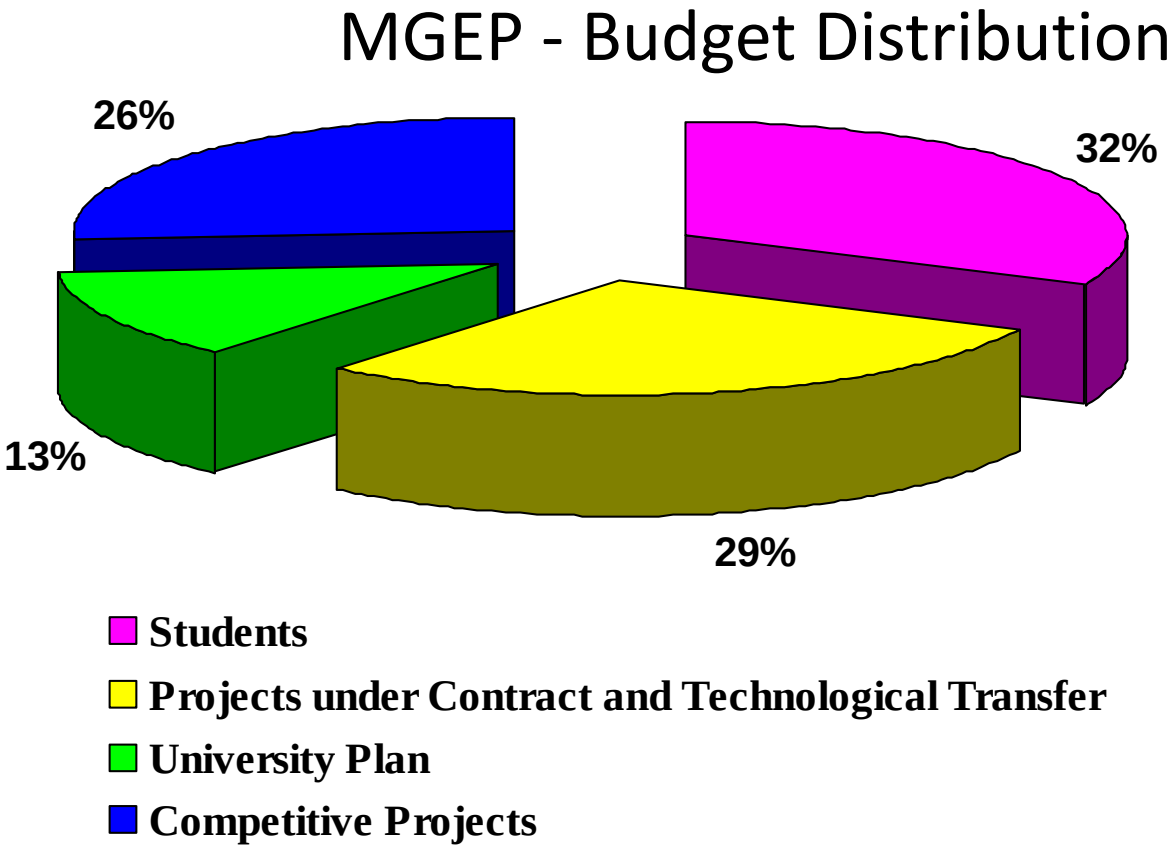
Faculty of Gastronomic Sciences

MGEP

- *2013/2014 Budget: 27 M€*
- *250 workers (members and contracted people)*
- *About 1.500 full-time students, 101 PhD students*
- *Training courses to 3.500 workers every year*

http://www.mondragon.edu/es

- Budget 2012-2013 (27,4 M€)



Mondragon University / Faculty of Engineering
R&T activity in numbers (12/13)

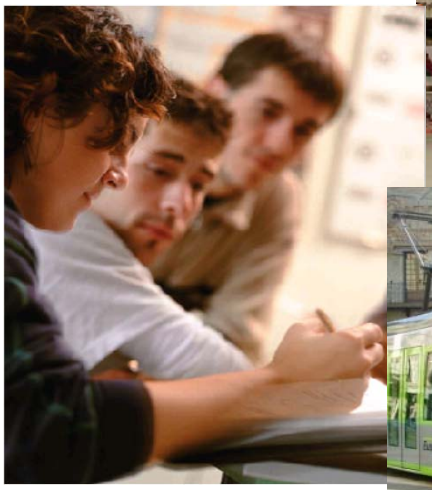
Fellows	*139*
PAS	*64*
Technical	*6*
Doctoral Fellows	*33*
Contracted Fellows	*39*
PDI	*170*
	451

Investment in scientific equipment: 1.042.000 €/year

Customer companies: 245

Agreements with foreign universities : 33

Students in Engineering: 1957



Partnership in large projects:

European: 9.

CENIT: 12.

INNPACTO: 9

Etortek: 7

R&T Dimension: 12.286.773 €.

Own research: 5.069.592 €

Research contracts and Transfer: 7.217.181 €

MGEP- High Performance Machining Lab: Relevant data

People: 24 (11 + 9 + 4)
- 4 Professors
- 5 Lecturers
- 2 Technical assistants
- 9 PhD Student
- 4 Undergraduate students and Master thesis

60% R+D and 40% Education (including training)

Fields of research:
1. FUNDAMENTALS OF CUTTING
   - CHIP FORMATION PROCESS
   - MODELLING
2. MACHINABILITY
3. HIGH SPEED CUTTING
4. MICROMACHINING
5. GRINDING
6. CAD-CAM-CNC
7. BIOMACHINING
8. INTELLIGENT MACHINING

Budget:
- Local Government
- Basque Government
- Spanish Government
- European Community
- Enterprises

Facilities:
- **Machining laboratory:**
  - •Micromillling machine: Kern Evo (160.000 rpm)
  - •HSM Milling Machine: LAGUN (18.000 r.p.m)
  - •C.N.C. Lathes : Danumeric...
  - •C.N.C. Vertical Lathe Danobat TV700
  - •C.N.C. Grinding Machine: GER
  - •Broaching Machine…
- **Equipment to study the cutting process:**
  - •KISTLER Dynamometers for turning, drilling...
  - •I.R.camera
  - •CCD camera: Photron FASTCAM-APXRS
  - •Acoustic emission
  - • Vibration sensors…
- **Software:** Unigraphics, Abaqus, Deform, AdvantEdge.
- **Materials Laboratory:**
  - •Mechanical testing: –80 y + 220ºC
  - •S.E.M., Microscopes
  - •Perfilometer
  - •Micro hardness
  - •Tribometer...

MGEP- High Performance Machining Lab: Relevant data

AERONAUTICS AUTOMOTIVE | CUTTING-TOOLS | MACHINE TOOL | STEEL MAKING | DIE AND MOULD MAKING

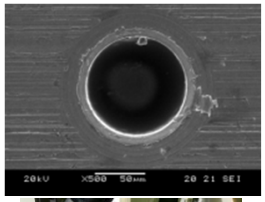
HIGH PERFORMANCE CUTTING

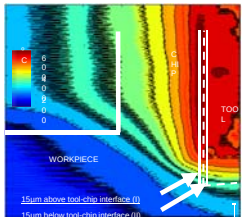
- CHIP FORMATION STUDY
- MODELING
- MICROMACHINING
- GRINDING
- MACHINABILITY
- HIGH SPEED MACHINING
- CAD-CAM-CNC
- BIOMACHINING
- INTELLIGENT MACHINING

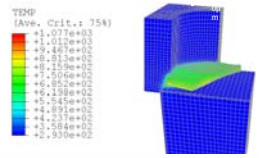
ORIENTED FUNDAMENTAL RESEARCH

APPLIED RESEARCH

IDUSTRIAL PROJECTS







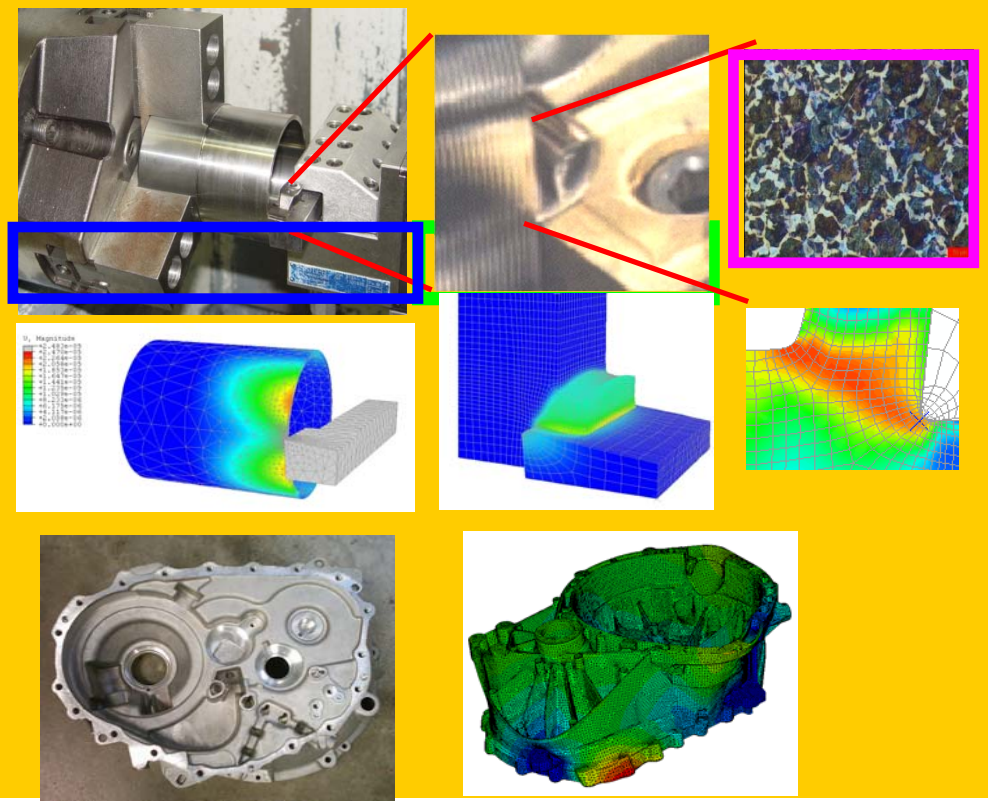
TURBINE DISCS,... | CÁRTER,... | CUTTING -TOOLS | INTELLIGENT MACHINE-TOOL | STEELS IMPROVED MACHINBILITY | MOULD

Fundamentals of cutting: Modelling

AERONAUTICS ***AUTOMOTIVE*** ***MACHINE-TOOL*** ***DIE AND MOULD MAKING***

HIGH PERFORMANCE CUTTING

MODELING
MACRO ***MESO*** ***MICRO***



DISCS,… ***CARTER,…*** ***MACHINE-TOOL,..*** ***MOULDS,..***

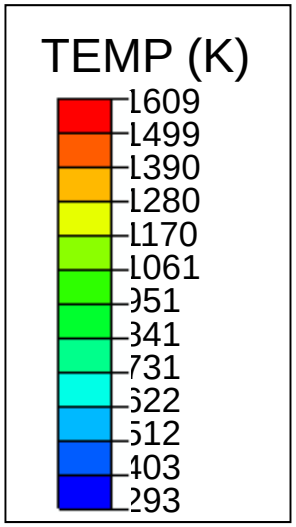
- ***IE: MARGUNE (EXACMED)***
- ***SAIOTEK: MTRES I y II***
- ***DPI: INVERMODEL***

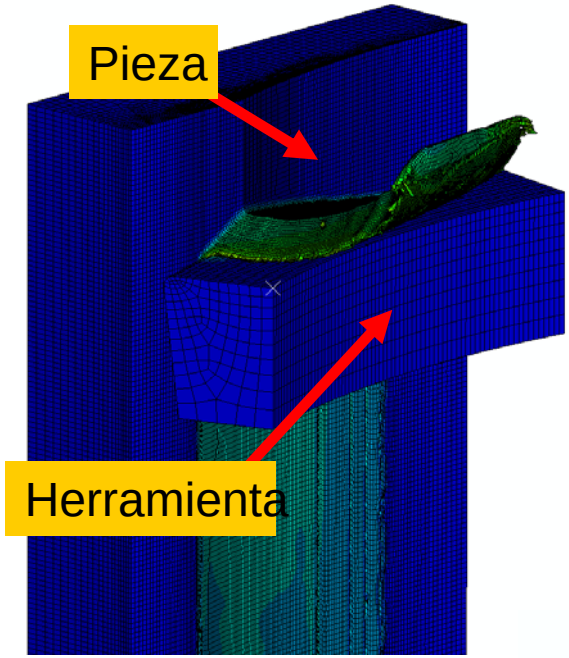
- ***PROFIT: BROMOD, OPTISER…***

- ***INTEK: EKOLAN***

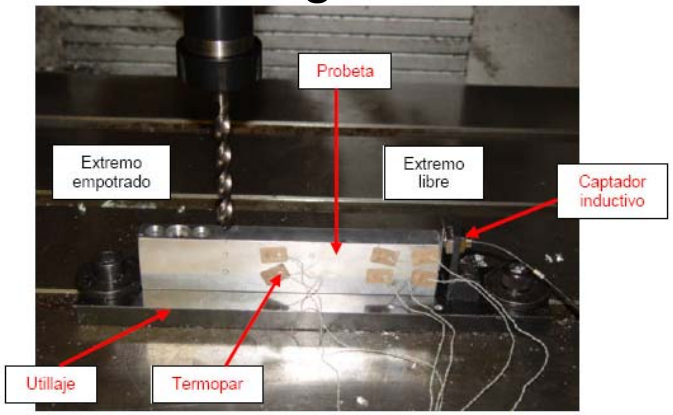
Fundamentals of cutting: Modelling

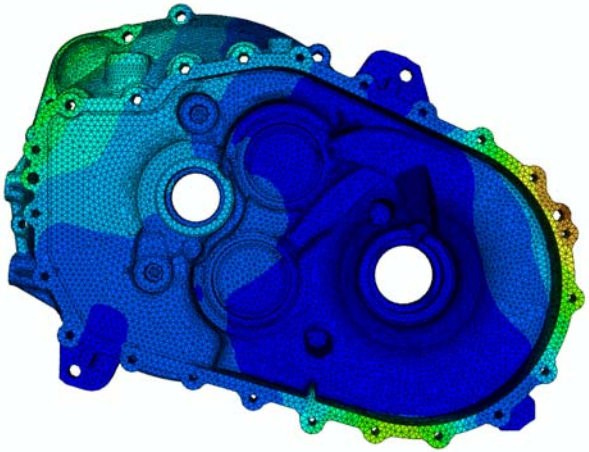
- Modelling: Meso





- Modelling: Macro



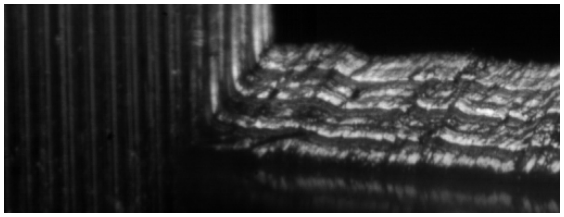


Fundamentals of cutting: Modelling

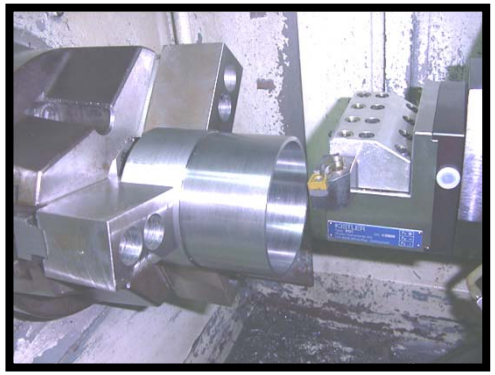
Torno Danumerik

Photron FASTCAM-APXRS:

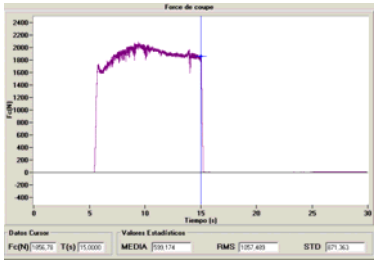
FEDER y C.I.C. MARGUNE



FUERZAS

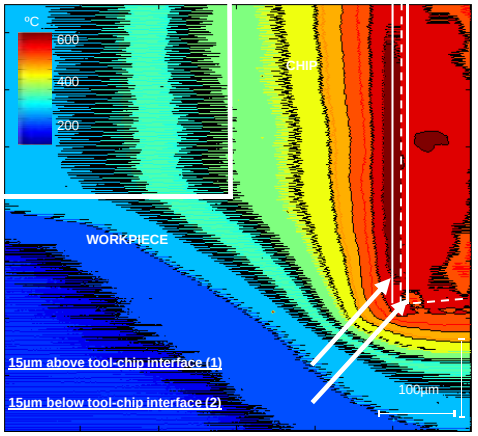


Captador Kistler 9121

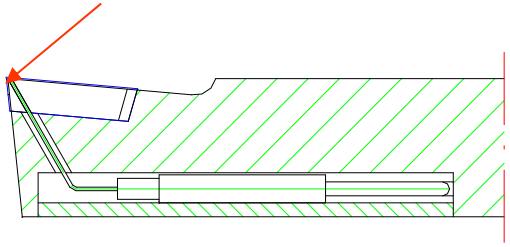


TERMOGRAFÍA

Titanium Series 550M



TERMOPAR

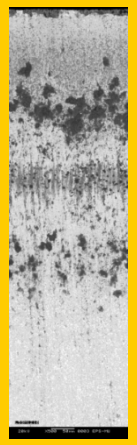


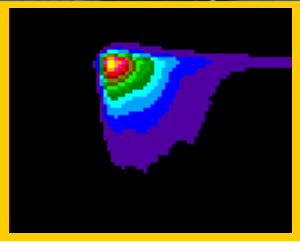
Machinability

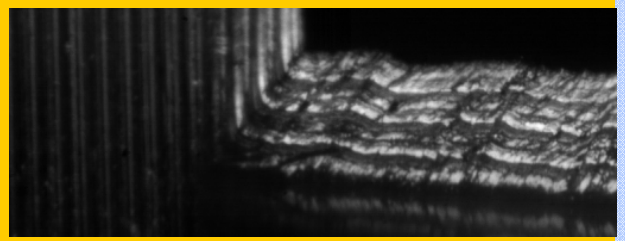
AERONAUTICS ***CUTTING TOOLS*** ***STEEL MAKING***

HIGH PERFORMANCE CUTTING

MACHINABILITY







- ***IE: MARGUNE (EXACMED)***
- ***DPI: MAQUIMODEL***

- ***Univ-Empresa: INCLUMEC***
- ***RFCS: PROMACH***
- ***PROFIT: VERMICAR***

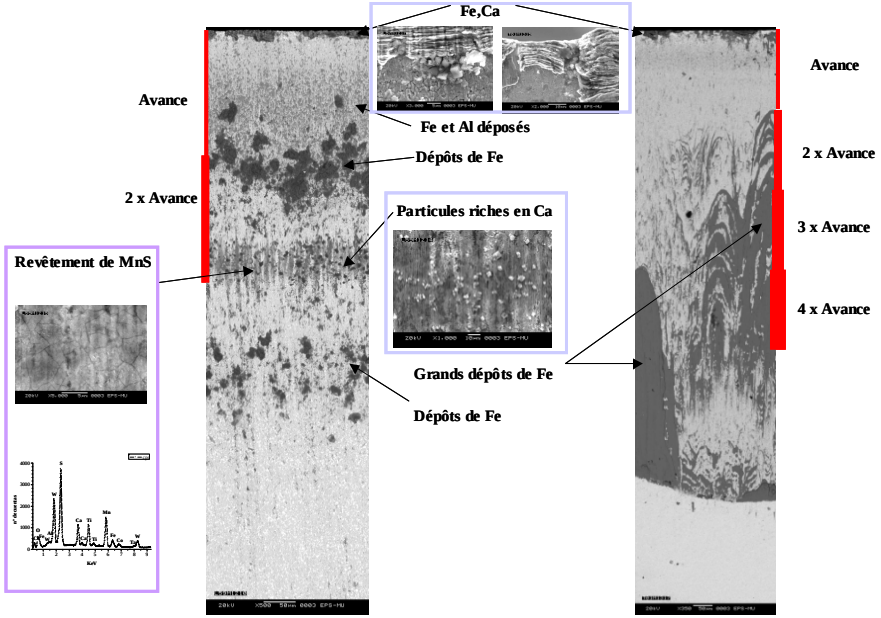
- ***MACHINABILITY TESTS: V15***

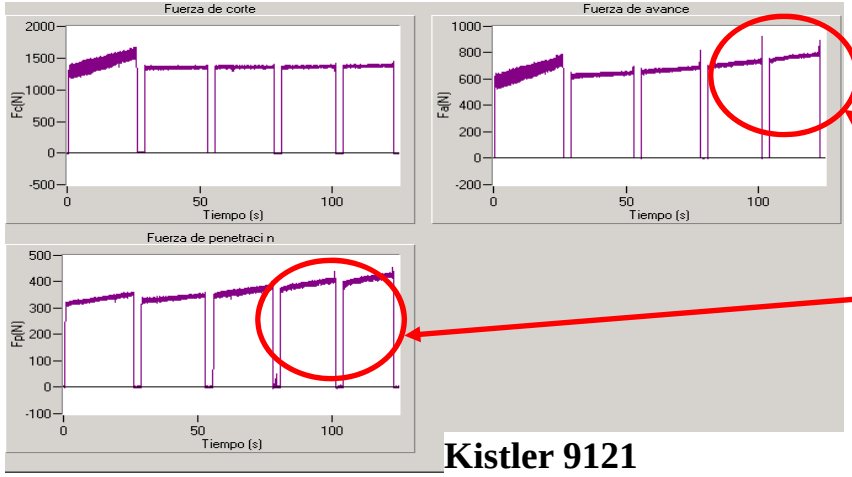
INCONEL 718
TITANIUM ALLOYS

STEELS WITH IMPROVED MACHINABILITY

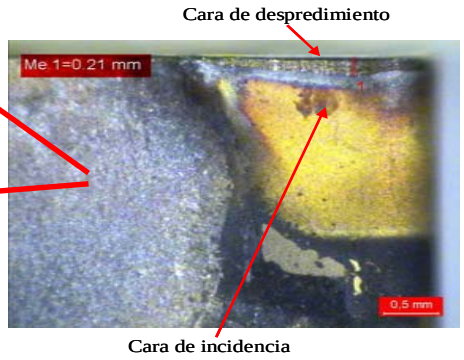
Machinability

- Steels with improved machinability
- Hardened steels 44 HRc
- Ti alloys
- Al alloys
- Nickel based alloys
- Gray Cast Iron
- Ductile Cast Iron
- Stainless steels



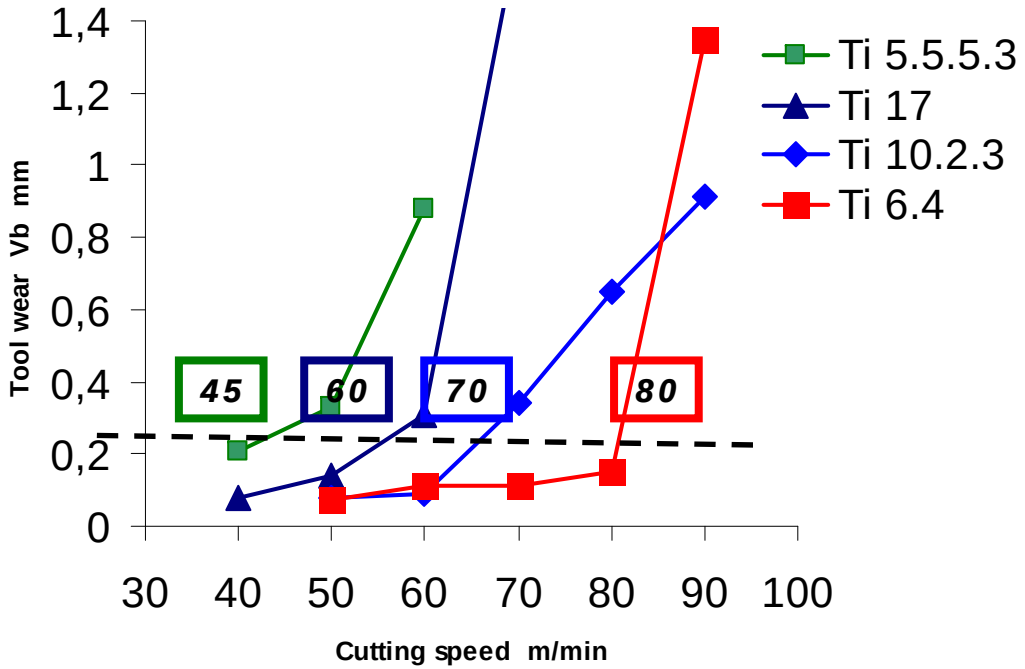


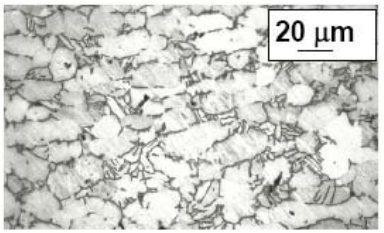
Kistler 9121



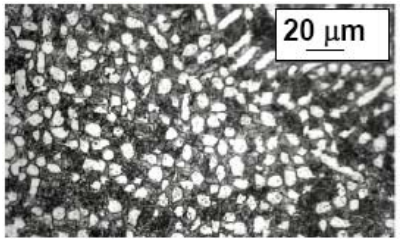
Machinability

- Near Beta Titanium Alloys: Experimental results in turning
- Flank wear land ($VB_{BMÁX}$) for $T=15$ min depending on the experimental cutting speed (V_C)

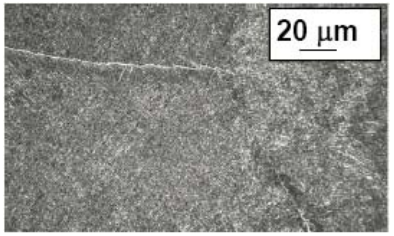




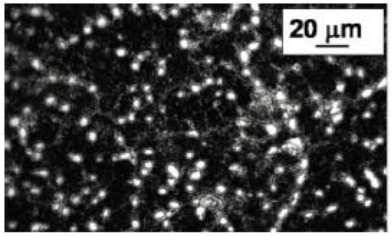
Ti6Al4



Ti10.2.3

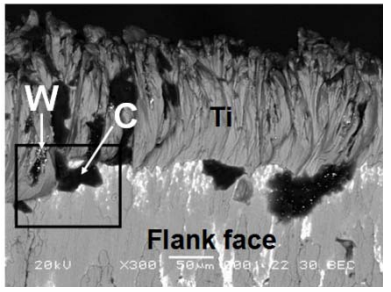


Ti17



Ti5.5.5.3

Titanium Alloy	Chemical composition (%)							Al Equ. value* (%)	Mo Equ. value** (%)	Transus Beta (°C)	TYS Mpa	UTS Mpa	Elong. %	Hard. HB ±5	Tensile strength 400 °C(MPa)
	Al	Mo	V	Fe	Cr	Sn	Zr								
Ti 6.4	6	-	4	-	-	-	-	7	2,5	995	900	1000	18	241	550
Ti 10.2.3	3	-	10	2	-	-	-	3	12	800	1100	1200	9	250	660
Ti 17	5	4	-	-	4	2	2	7	15	880	1060	1150	6	260	850
Ti 5.5.5.3	5	5	5	0.3	5	-	-	5	19	860	1050	1200	10	270	860



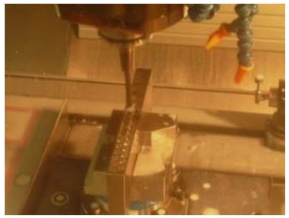
Machinability

- To understand the reasons for the better or worst machinability of a given Ti alloy
- To know about the physics of cutting process when machining Ti alloys: what are the most relevant input parameters and why?
- To determine the machinability rate of several Ti alloys (near β and α+β), compared to Ti64

OPERATION	MATERIAL	2D (ORTHOGONAL CUTTING)		3D	
		FORCES	TEMPERATURES	END TOOL LIFE	FORCES
TURNING (2D, 3D)	TI64				
	TI54M				
	TI 10.2.3				
	Ti 6.2.4.6				
	TI 17				
	TI 555.3				
DRILLING (3D)	TI64				
	CRFP+TI64				
MILLING (3D)	TI64				
	TI555.3				





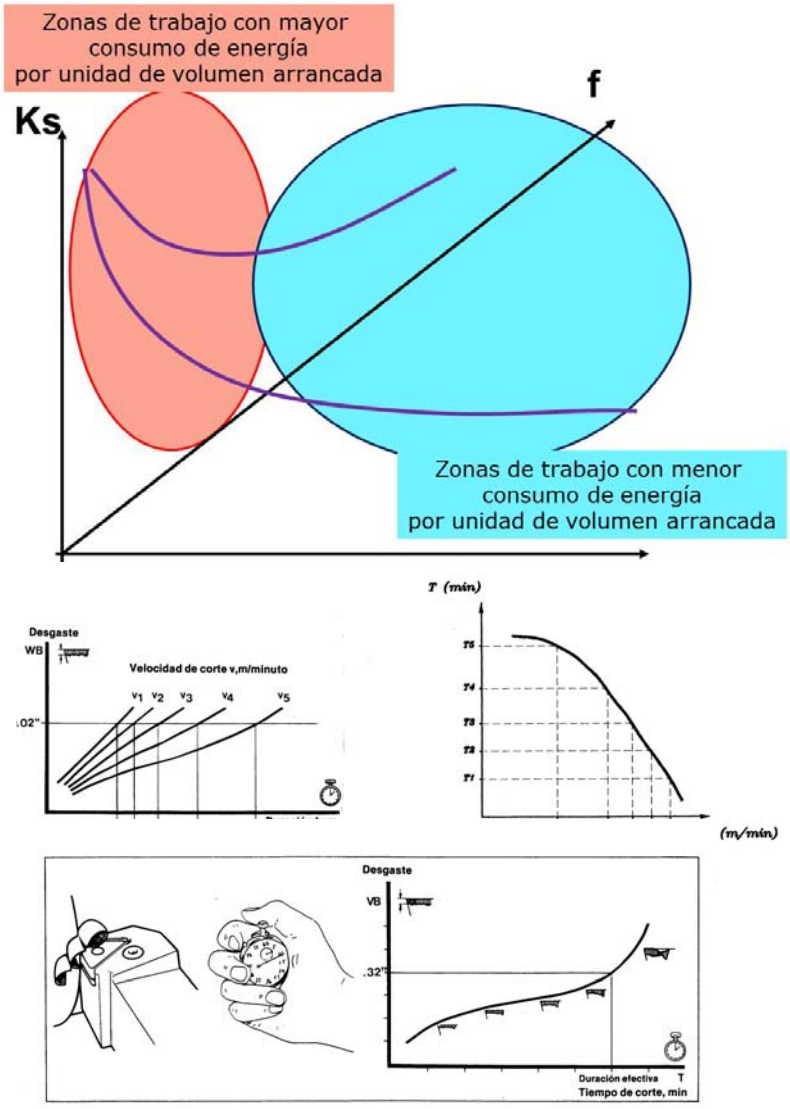


Machinability : Process window selection

- Cutting parameters selection

COM → **Cutting parameters**

END TOOL LIFE TESTS → ***- Tool Life***
- Material removal volume
- Performance



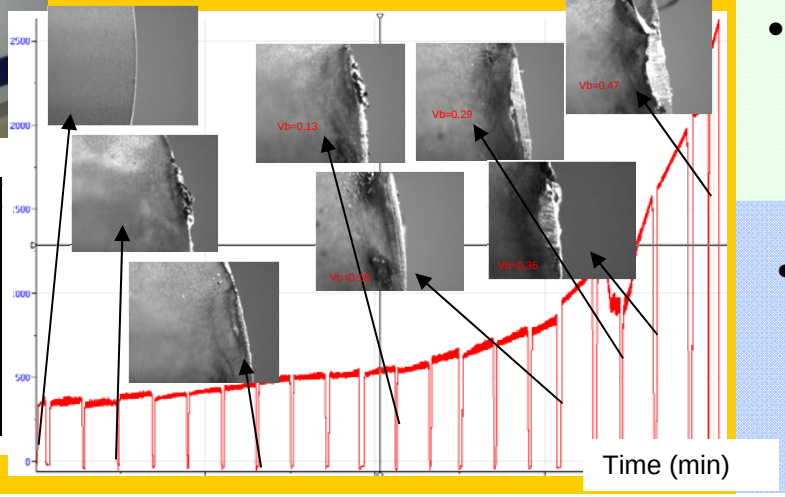
Intelligent Machining

AERONAUTICS

AUTOMOTIVE

HIGH PERFORMANCE CUTTING

INTELLIGENT MACHINING



- IE: MARGUNE (PROFUTURE)
- DPI e IBA: METINCOX
- FPVII: ADACOM yACCENT
- CENIT: OPENAER

TURBINE DISCS

Intelligent Machining

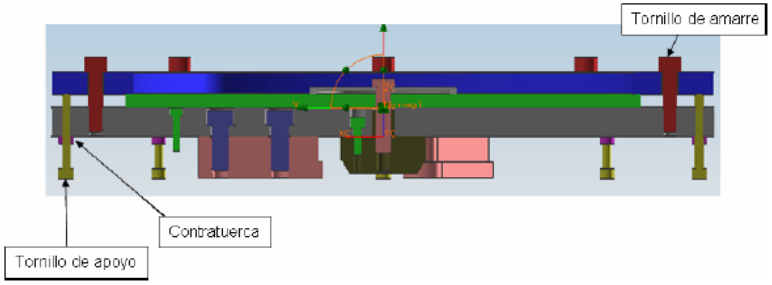
Experimental Equipment: Turning (Discs)

- *FORCES: KISTLER 9121*
  1. *Cutting Force*
  2. *Feed Force*
  3. *Pasive Force*

- *ACCELEROMETERS: Bruel & Kjaer 4321*
  4. *ax (m/s2)*
  5. *ay (m/s2)*
  6. *az (m/s2)*

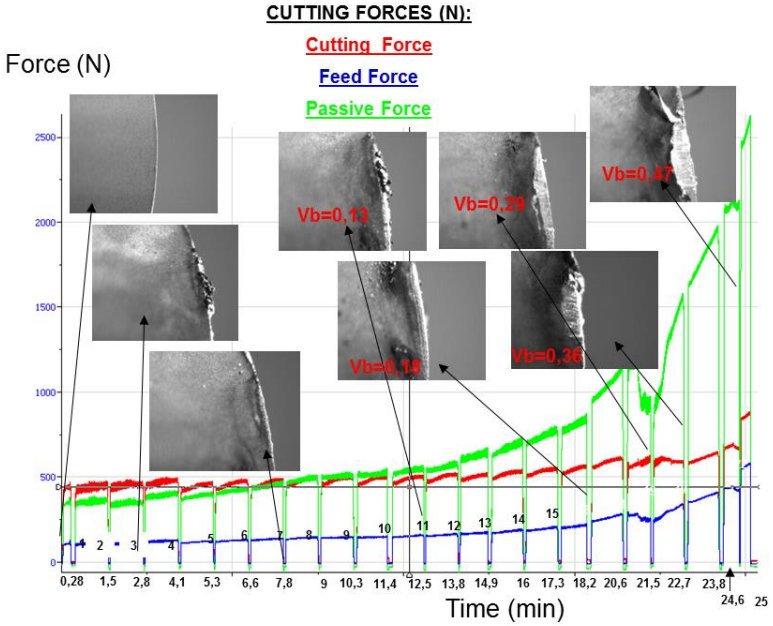
- *ACOUSTIC EMISSION: Kistler 8152B*
  7. *ax*

- FAGOR CNC8070:Variables name
  8. TV51: Spindle Electric Power signal
  9. SREAL: Spindle Angular Speed (r.p.m)



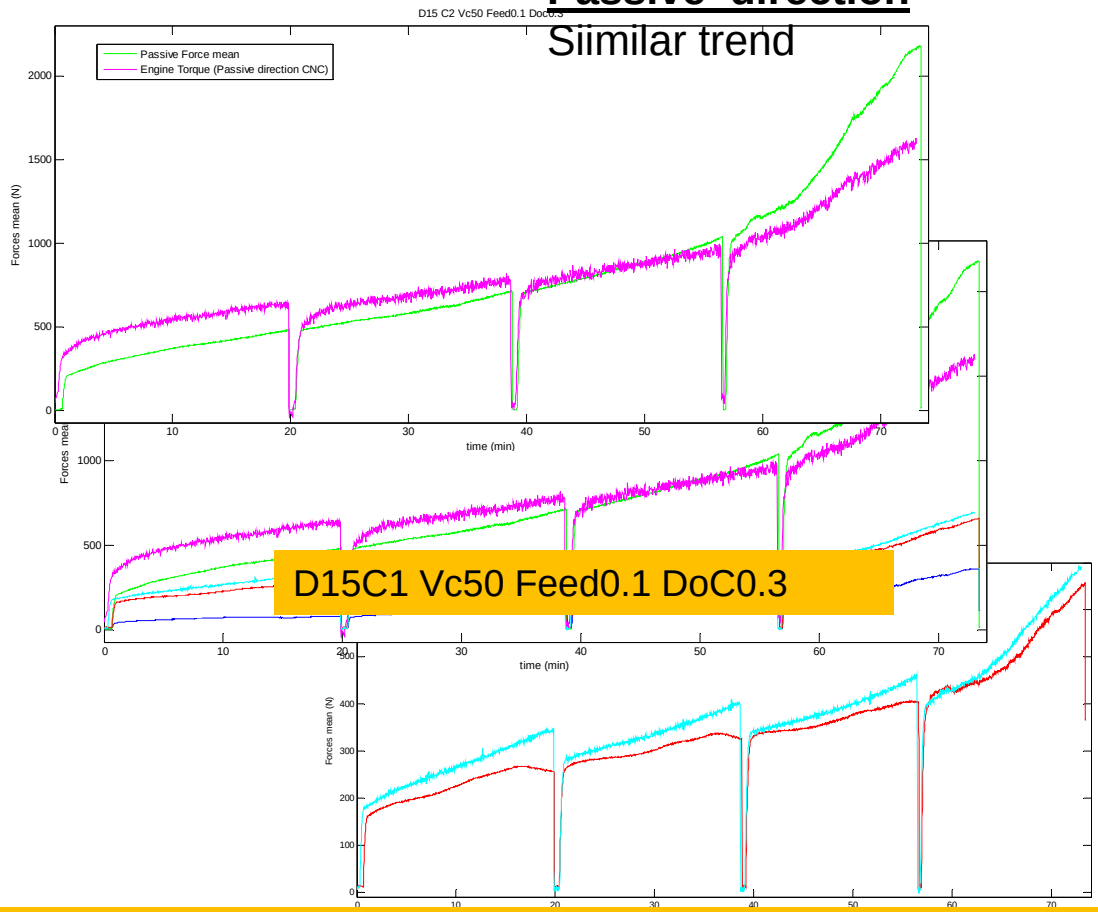
Intelligent Machining

- Process Monitoring: Forces from Kistler sensor and torque from spindle



Tv50 Vs Fc
Cutting direction
Similar trend

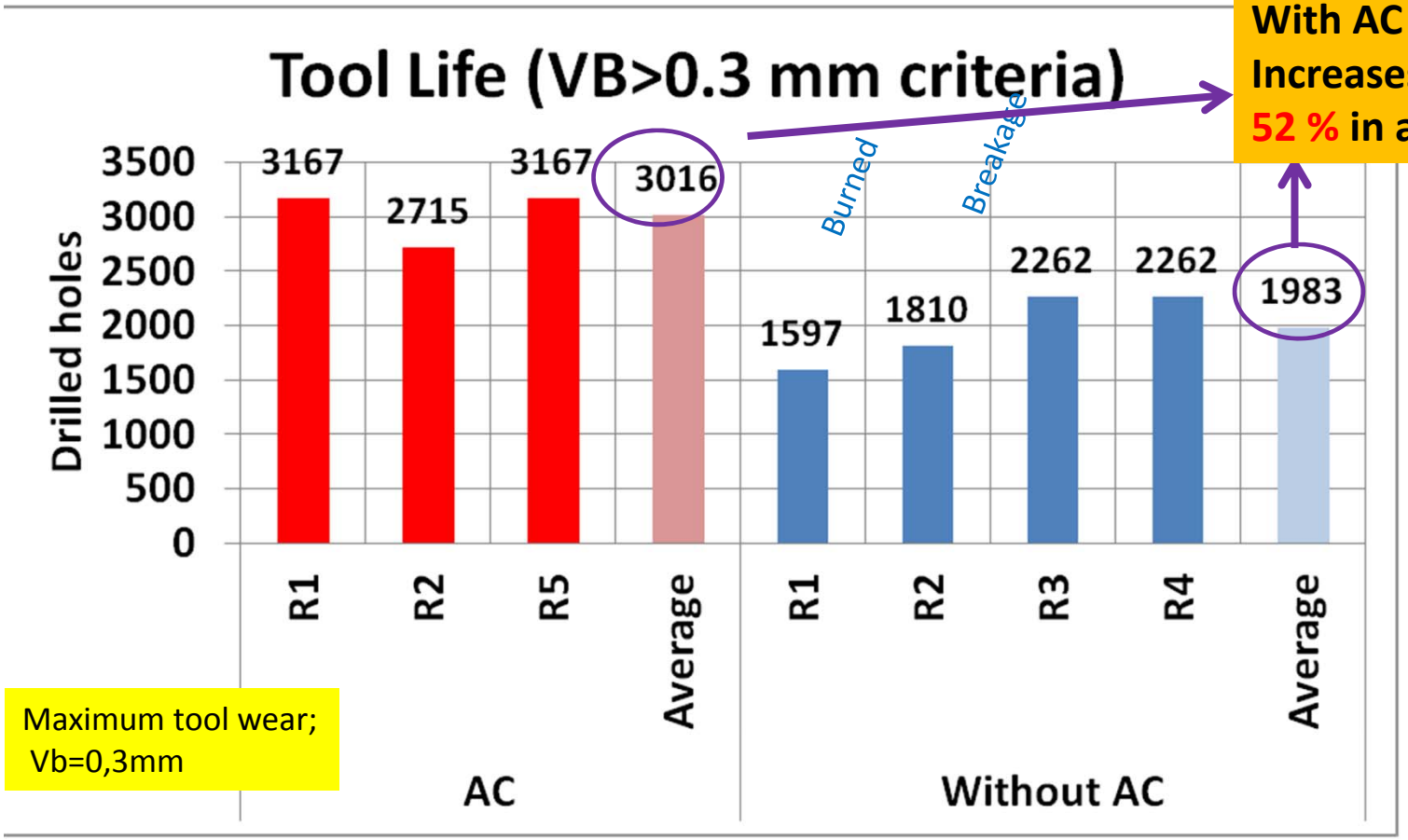
Tv2 Vs Fp
Passive direction
Siimilar trend



– Good agreement between the passive force, cutting force and CNC signals.

Intelligent Machining

- Drilling: With adaptive control/ without adaptive control end tool life tests



Drilling Depth:
20 mm => 5xØ

With CA, tool life is increased by roughly 52%

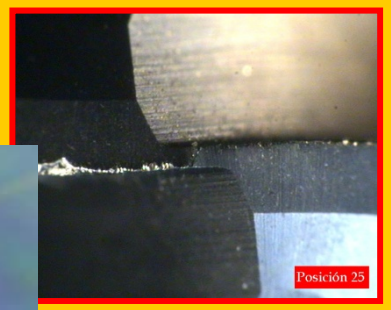
High Speed Machining

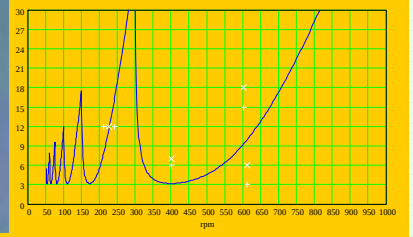
DIE AND MOULD MAKING

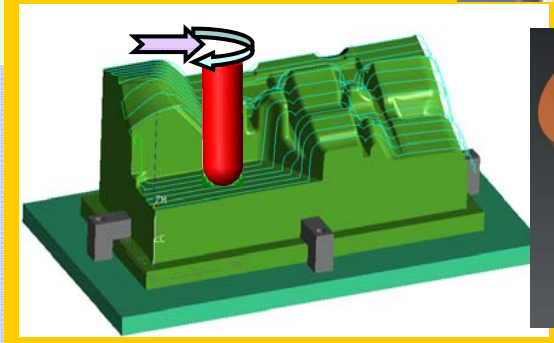
CUTTING TOOLS

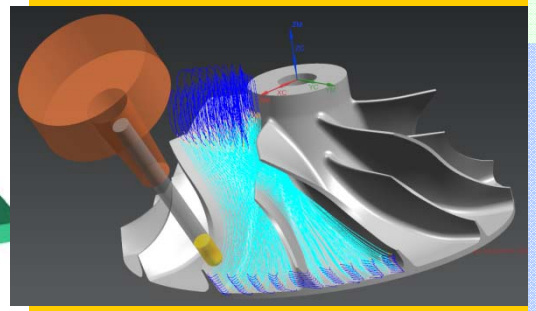
HIGH PERFORMANCE CUTTING

HSM-5Axis Machining









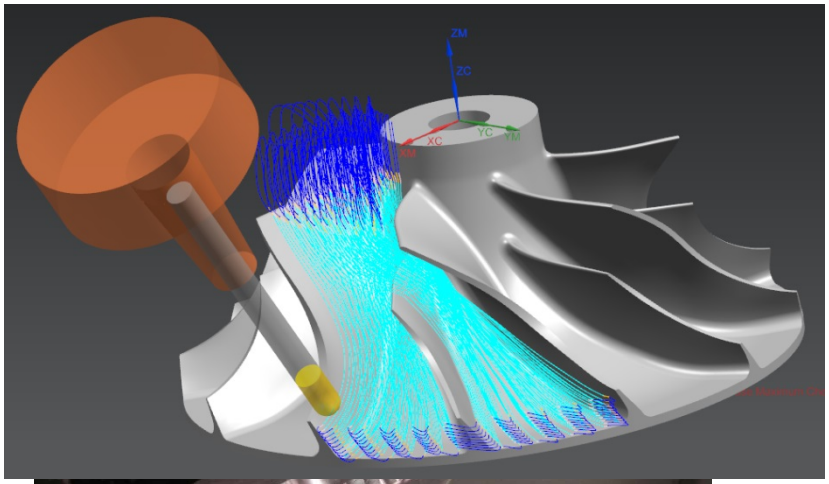
MOULDS

CUTTING TOOLS

- ***OFERTA-DEMANDA: ABIADAURA***
- ***PROFIT: ESBELTEC***
- ***MCC***
- ***INTEK: ABIACOOP***

High Speed Machining

- 5 Axis Machining

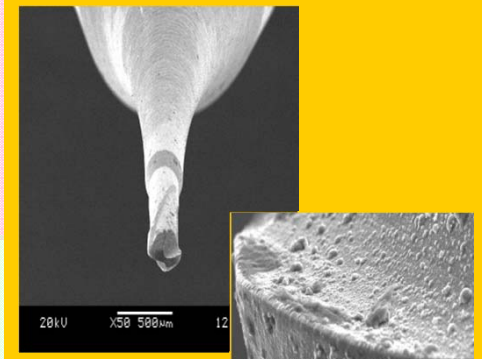


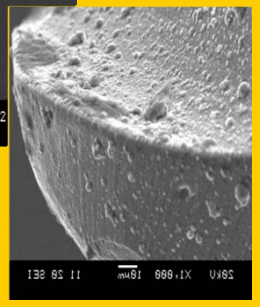
Micromachining

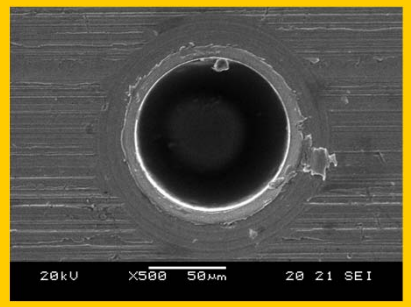
CUTTING TOOLS | ***DIE AND MOULD MAKING*** | ***HEALTH*** | ***MACHINE-TOOL***

HIGH PERFORMANCE CUTTING

MICROMACHINING







- ***DFG: MICROPRO***
- ***VIPM: IP-SME; LAUNCH-MICRO***
- ***PROYECTO SINGULAR ESTRATÉGICO: MICROMANUFACTURING***
- ***MCC***
- ***INTEK: MIKROPRO***

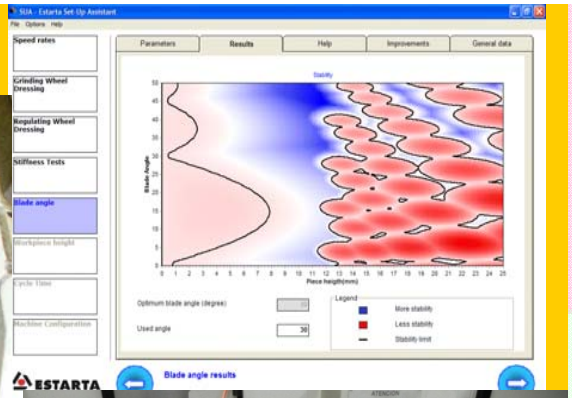
CUTTING TOOLS | ***MICROMOULDS*** | ***DENTAL IMPLANTS,..*** | ***TOOL MONITORING***

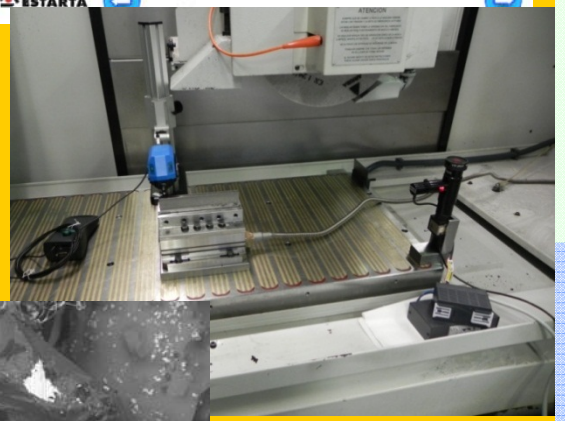
Grinding

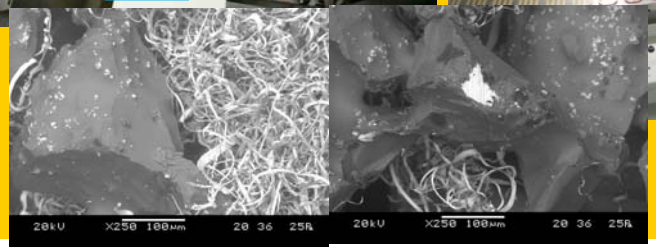
MACHINE-TOOL ***AUTOMOTIVE*** ***COMPONENTS***

HIGH PERFORMANCE CUTTING

GRINDING



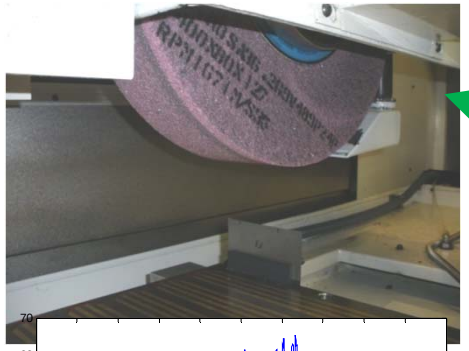


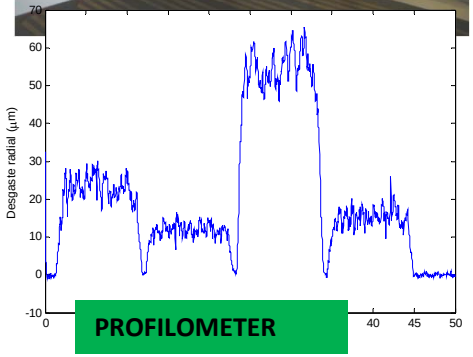


- ***IE: AEFAR***
- ***PROFIT: SIMUREC, GRINDOTEC***
- ***Univ-Empresa: DINASUP***
- ***INTEK: RECFORCE, CADIMEDES, SINVIREC***
- ***CENIT: eEe***

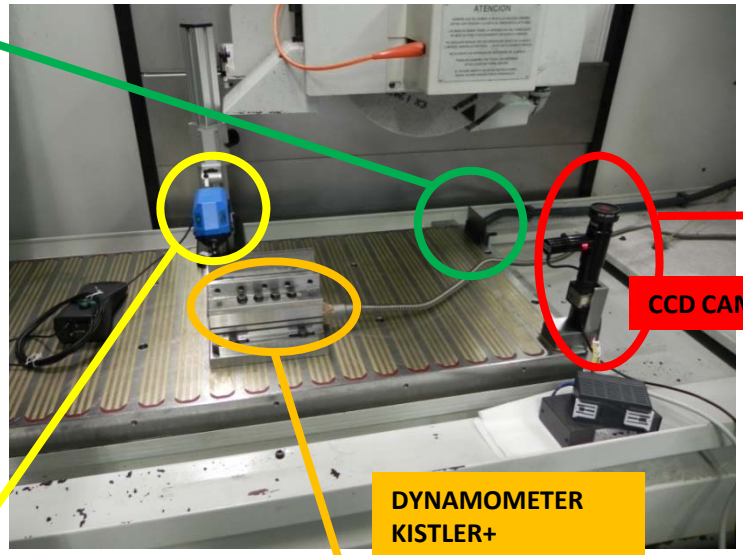
INTELLIGENT MACHINE ***WHEELS*** ***BEARINGS***

Grinding





PROFILOMETER

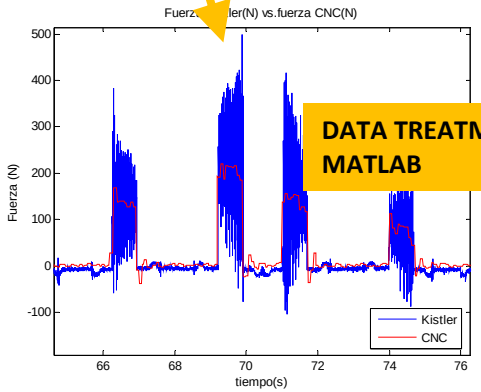


CCD CAMERA

DYNAMOMETER KISTLER+ CNC 8070

IMAGE TREATMENT

PORTABLE ROUGHNESS TESTER



DATA TREATMENT - MATLAB

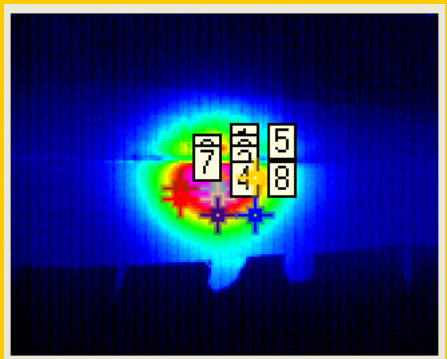
PORTABLE HARDNESS TESTER

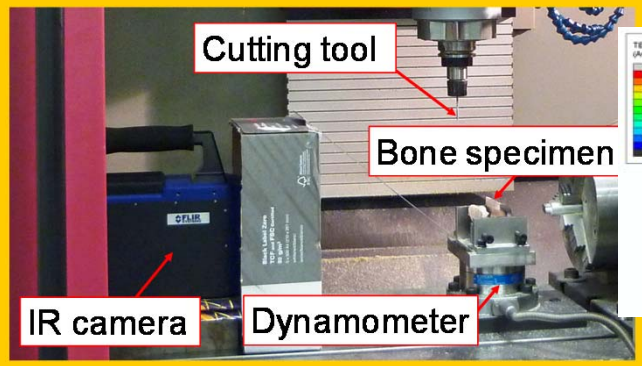
Biomachining

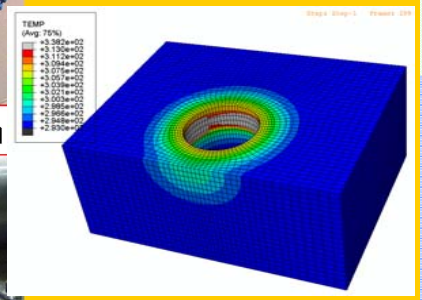
HEALTH

HIGH PERFORMANCE CUTTING

BIOMACHINING







- ***SAIOTEK: CUTBONE I y II***

DENTAL IMPLANTS

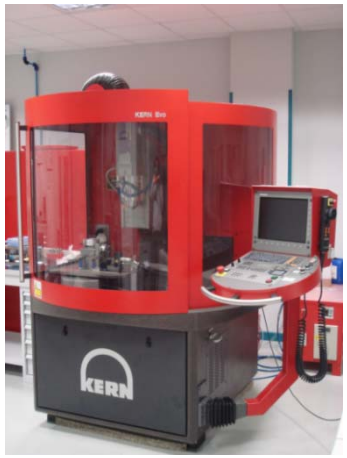
Facilities and Equipment

CNC Lathe Danumerik-2

Milling Machine tool: LAGUN

Milling Machine tool: KONDIA

Micromilling Kern EVO



Surface Grinding
Machine tool: GER

Vertical CNC Lathe
TV 700 Danobat

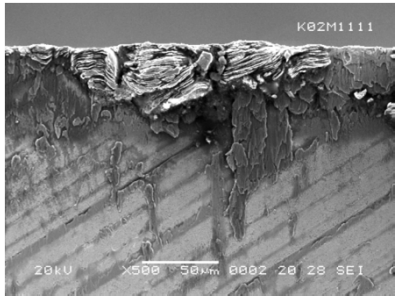
Vertical Broaching Machine
EKIN RAS 10x1600x320

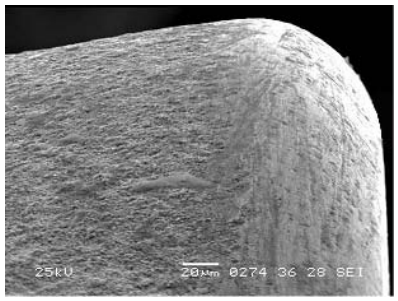
Facilities and Equipment

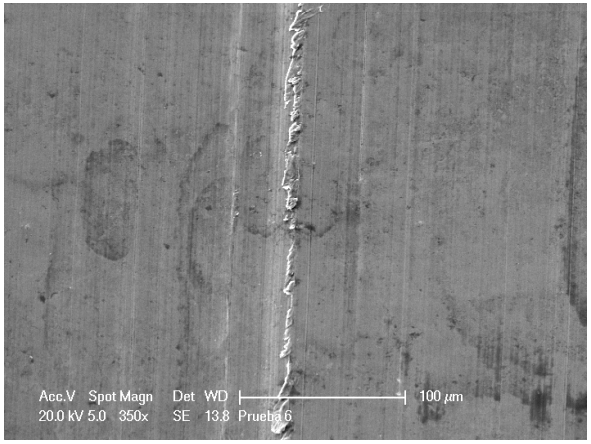
MACHINE-TOOLS AT MONDRAGON UNIVERSITY / HIGH PERFORMANCE MACHINING LABORATORY								
	1-Vertical CNC Milling Machine Lagun	2-Vertical CNC Milling MachineC Kondia	3-Micromilling Machine Kern Evo	4-Vertical CNC Lathe Danobat TV700	5-Horizontal CNC Lathe Danumeric 2	6-Horizontal CNC Lathe Danobar	7- Surface Grinding machine GER	8-Broaching Machine Ekin RAS
Trade Mark	Lagun	Kondia	Kern Evo	Danobat	Danumeric 2	Danobar	GER	EKIN
Number of Axys	3 +2	3 +2	3 (+ 2 = 5)	2	2	3 (XZ+C)	3	
Rango de trabajo	1000x500x620	1000x500x610 mm	300x280x250 mm	Ø725X350	Ø600X487	158*685	1000x500X550	10x1600x320
CNC Controller	Fagor 8070	Fagor 8070	denhain iTNC 530 smartT	Fagor 8070	Fagor 8070	Fagor 8070 T	Fagor CNC8070	
Torque and Power	80 Nm until 1800 rpm / 15 Kw RPM máx. = 18.000	76,4N/m until 4000rpm//19 Kw RPM máx.= 12.000	500-50000 rpm 3,4 kW - 0,8 Nm	678N.m - 71kW-1000 rpm (Higher value of rpm are posible with a new balanced chuck)	294 N.m &45Kw in S6. 191 N.m & 30Kw in S1	Nmax 4500 rpm - 104.4 Nm 1800 rpm 19.8 kW	11 kw a 1500rpm	10 Tn
Positioning Error	VDI/DGQ 3441, Año 2000 X=5µm, Y=6µm, Z=2µm	±0,01 mm	VDI/DGQ 3441 --> ±1µ		-	-	0,001 mm	
Repeteability Error	VDI/DGQ 3441, Año 2000 X=1µm, Y=3µm, Z=0,6µm	0,005 mm	VDI/DGQ 3441 --> ±0,5µ	±0,004 mm	-	-	0,001 mm	
Tape	HSK- A63	HSK- A63	HSK E25	VDI 40	VDI 40	VDI 30	Grinding Wheel diameter: 400, width: 80; internal diameter: 127	
Tape Run Out	0,005 mm			DIN 69880	DIN 69880		-	
Cooling	------						-	
Internal Cooling Pressure	------	until80 bars	no	30bars	20 bars	Standard	-	
Internal Cooling Flow	------			40l/min			-	
External Pressure Cooling	Standar (drive power 0,35 Kw)	6 bars	standard + MQL	Until 80 bars	Until 80 bars	Standard	2 bares	
External Flow Cooling	Standard	28 l/min	standard + MQL	26l/min	26l/min	70 l/min	75 l/min.	
Coolant	QUAKERCOOL 7101	QUAKERCOOL 7101 o EMATER 30 TDS	Quakercool 7101H	HOUGTON 3380	HOUTON 3380		MK-SOL SV	
Others	MQL External, INTZA-WOERNER 4º y 5º Axys = SPIRSIN, Chuck diameter ø200, Rotational resolution 0,001º, Precision ±25 seg.							

Facilities and Equipment

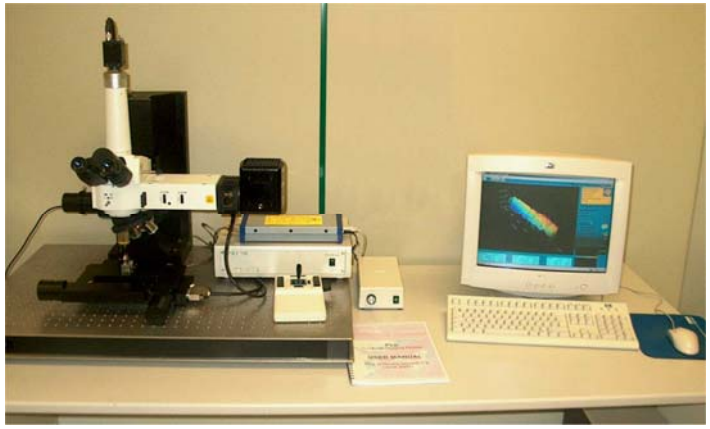
- SEM : FE-Nova Nano SEM (FEI)

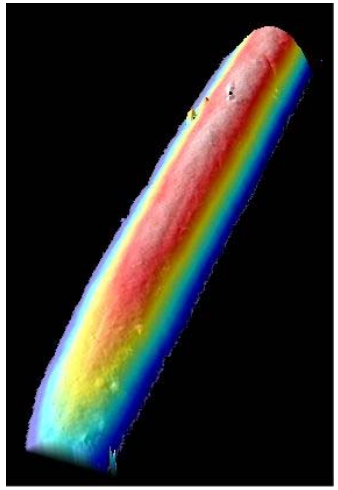






- CONFOCAL PERFILOMETER





Partnership - Collaborations

- RTD and Universities
  - *AMRC (UK): Machinability of Ti Alloys*
  - *DAMRC (Denmark): Machinability of difficult to cut materials*
  - *WZL (Germany): 5 Axys machining*
  - *NIST (USA): Material Characterization (Hopkinson Bar)*
  - *UNCC (USA) : Temperature measurements*
  - *ENISE (France): Friction identification*
  - *Ljubiana University (Slovenia): Cryogenic Machining*
  - *Calabria University (Italy): Modelling*
  - *Tokio Denki University (Japan): Micromilling*
  - *Université de Mons (Belgium): Modelling*
  - *Swerea / Kimab (Sweeden) : Machinabity of Steels*
  - *Trinity College of Dublin (Ireland) : Process Monitoring*
  - *UNCC (USA): Temperature measurement*
  - *Kentucky University (USA) : temperature measurement*
  - *ENSAM Angers (France) : material constitutive law identification*
  - *Others: marGUNE, Ideko, Tekniker, Ikerlan…*

Partnership - Collaborations

- Companies
  - *Aeronautic sector: ITP, Novalti, Mecatecnic, Alfa Microfusión, Aubert& Duval, Airbus, Aratz…*
  - *Steel /Ti makers sector: Gerdau-Sidenor, Timet, Ascometal, Ovako...*
  - *Automotive sector: Fagor Ederlán, Bosch, CRF, Daimler*
  - *Machine-Tool manufacturing sector: Danobat group, Gurutzpe, Ibarmia, Fagor automation, Ekin, D+S, Estarta, Goratu, AVS …*
  - *Tool makers sector: Sandvik, Kendu, Latz, Zubiola, Seco …*
  - *Moulds and dies manufacturing: Maier, Aurrenak*
  - *Energy: Ulma piping,...*
  - *Health: Bti*

Publications

1. A. Madariaga, J.A. Esnaola, E. Fernandez, P.J. Arrazola, A. Garay, F. Morel. Analysis of residual stress and work-hardened profiles on Inconel 718 when face turning with large-nose radius tools. International Journal of Advanced Manufacturing Technology. Volume 71. Issue 9-12. (2014) Pages 1587-1598.
2. P.J. Arrazola, A. Kortabarria, A. Madariaga, J.A. Esnaola, E. Fernandez, C. Cappellini, D. Ulutan, T. Özel. On the machining induced residual stresses in IN718 nickel-based alloy: Experiments and predictions with finite element simulation. Simulation Modelling Practice and Theory, Volume 41, (2014), Pages 87-103.
3. J. Soriano, A. Garay, P. Aristimuño, L. M. Iriarte, J. A. Eguren, P. J. Arrazola. Effects of rotational speed, feed rate and tool type on temperatures and cutting forces when drilling cortical bone. Machining Science and Technology: An International Journal- 17:4, (2013). Pages 611-636.
4. P.J. Arrazola, A. Garay, E. Fernandez, K. Ostolaza. Correlation between tool flank wear, force signals and surface integrity when turning bars of Inconel 718 in finishing conditions. Int. J. Machining and Machinability of Materials, Volume 15. N 1/2. (2013).84-100.
5. J. Rech, P.J. Arrazola (2), C. Claudin, C. Courbon, F. Pusavec c, J. Kopac. Characterization of friction and heat partition coefficients at the tool-work material interface in cutting. CIRP Annals - Manufacturing Technology 62 (2013) 79–82.
6. P.J. Arrazola, T. Özel, D. Umbrello, M. Davies, I.S. Jawahir. Recent advances in modelling of metal machining processes. CIRP Annals - Manufacturing Technology 62 (2013) 695–718; http://dx.doi.org/10.1016/j.cirp.2013.05.006
7. T. Matsumura, Patxi Aristimuño, Endika Gandarias, Pedro J. Arrazola. Cutting process in glass peripheral milling. Journal of Materials Processing Technology 213, Issue 9 (2013) 1523– 1531
8. J. Soriano, A. Garay, K. Ishii, N. Sugita, P.J. Arrazola, M. Mamoru. A new surgical drill bit concept for bone drilling operations Materials and Manufacturing Processes Volume 28, Issue 10 (2013) 1065– 1070
9. Tamura, Shoichi; Matsumura, Takashi; Arrazola, Pedro J. Cutting Force Prediction in Drilling of Titanium Alloy. Journal of Advanced Mechanical Design Systems and Manufacturing. 2012. Vol6. 753-763.
10. Iraola J.; Rech J.; Valiorgue F., Arrazola P-J. Characterization of Friction coefficient and heat partition coefficient between and austenitic steel AISI304L and TiN-coated carbide cutting. Machining Science and Technology. Volume: 16 Issue: 2 Pages: 189-204 DOI: 10.1080/10910344.2012.673965,2012
11. A. Egaña, J. Rech & P. J. Arrazola (2012): Characterization of Friction and Heat Partition Coefficients during Machining of a TiAl6V4 Titanium Alloy and a Cemented Carbide, Tribology Transactions, 55:5, 665-676.
12. M. Armendia, P. Osborne, A. Garay, J. Belloso, S. Turner & P.-J. Arrazola (2012): Influence of Heat Treatment on the Machinability of Titanium Alloys, Materials and Manufacturing Processes, 27:4, 457-461

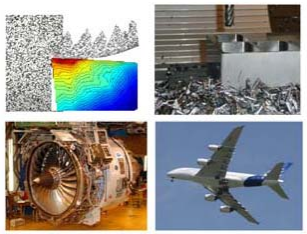
Publications

14. I. Arriola Aldamiz, E. Whitenton, J. Heigel, P.J. Arrazola. Relationship between machinability index and in-process parameters during orthogonal cutting of steels. CIRP Annals - Manufacturing Technology 60 (2011), pp. 93-96.
15. T.Ozel, I. Llanos, J. Soriano, and P.-J. Arrazola. 3D Finite Element Modeling of Chip Formation Process for Machining Inconel 718: Comparison of FE software predictions. Machining Science and Technology, (2011) Vol 15:1; pp. 21–46.
16. M. Armendia, A. Garay, A. Villar, M.A. Davies, P.J. Arrazola, High Bandwidth Temperature Measurement in Interrupted Cutting of Difficult to Machine Materials. CIRP Annals - Manufacturing Technology 59 (2010), pp. 97-100.
17. E.Ruiz de Eguilaz, J. Rech, P. Arrazola. Characterization of friction coefficient and heat partition coefficient between an AISI4140 steel and a TiN-coated carbide – influence of (Ca,Mn, S) steel's inclusions. Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology. Volume 224, Number 10 1115-1127.
18. P. J. Arrazola, T.Ozel. Investigations on the Effects of Friction Modeling in Finite Element Simulation of Machining. International Journal of Mechanical Science. Volume 52/1, January 2010, Pages 31-42.
19. M. Armendia, A. Garay, L.-M. Iriarte, P.-J. Arrazola. Comparison of the machinabilities of Ti6Al4V and TIMETAL® 54M using uncoated WC–Co tools. Journal of Materials Processing Technology.
210 (2010) 197-203.
20. I. Llanos, J. A. Villar, I. Urresti, P. J. Arrazola. Finite Element Modeling of Oblique Machining using an Arbitrary Lagrangian-Eulerian Formulation. Machining Science and Technology, Volume 13/1, 2009 , Pages 385 - 406
21. P.J. Arrazola, I. Arriola, M.A. Davies. Analysis of the influence of tool type, coatings, and machinability on the thermal fields in orthogonal machining of AISI 4140 steels. Cirp Annals – Manufacturing Technology 58/1 (2009). 85-88.
22. J.C. Aurich, D. Dornfeld, P.J. Arrazola, V. Franke, L. Leitz; S.Min, Burrs. Analysis, Control and Removal. Cirp Annals – Manufacturing Technology. 58/2(2009). 519-542.
23. P.J. Arrazola, A. Garay, L.M. Iriarte, M. Armendia, S. Marya, F. Le Maître. Machinability of Titanium alloys (Ti6Al4V and Ti555.3). Journal of Materials Processing Technology 209/5 (2009). 2223-2230.
24. P.J. Arrazola, I. Arriola, M.A. Davies, A.L. Cooke, B.S. Dutterer. The Effect of Machinability on Thermal Fields in Orthogonal Cutting of AISI 4140 Steel. Annals of the CIRP 57/1 (2008). 65–68.
25. P.J. Arrazola, D. Ugarte, X. Domínguez. A new approach for the friction identification during machining through the use of finite element modelling. International Journal of Machine Tools & Manufacture 48 (2008). 73–183.
26. P. J. Arrazola, A. Villar, D. Ugarte and S. Marya. Serrated chip prediction in finite element modeling of the chip formation process. Machining Science and Technology 11/3 (2007). 367-390.

Publications

27. K. Jemielniak , , P. X. Aristimuno.Tool Condition Monitoring in Micromilling Based on Hierarchical Integration of Signal Measures. Annals of the CIRP, 57/1.
28. J Pujana, L. del Campo, R. Perez-Saez, M.J. Tello, P.J. Arrazola, I. Gallego. Radiation thermometry applied to temperature measurement in the cutting process. Measurement Science and Technology 18 (2007). 1-8.
29. J. Pujana, P.J. Arrazola, R. M'Saoubi, H. Chandrasekaran. Analysis of the inverse identification of constitutive equations applied in orthogonal cutting process. International Journal of Machine Tools and Manufacture 47 (2007). 2153–2161.
30. E. Gandarias, S. Dimov, D.T. Pham, A. Ivanov, K. Popov, R. Lizarralde, P.J. Arrazola. New methods for tool failure detection in micro-milling. Journal of Engineering Manufacture 220 (B2) (2006). 137-144.
31. J. Pujana, A.Villar, P.J. Arrazola. In-Process High Speed Photography Applied to Orthogonal Turning. Journal of Material Processing Technologies. 2008, Vol. 202, no1-3, pp. 475-485
32. I. Gallego, R. Lizarralde, D. Barrenetxea, P.J. Arrazola. Precision, Stability and Productivity Increase in Throughfeed Centerless Grinding. Annals of the CIRP 55/1 (2006). 351-354.
33. P.J. Arrazola, F. Meslin, S. Marya. Numerical cutting sensitivity study of tool-chip contact. Material Science Forum 426/432 (2003).4519-4524.

Continuous Training – Conferences – Seminars - Congresses



WORKSHOP ON TITANIUM MACHINING FOR AERONAUTI

DATE: 14th April 2011
SCHEDULE: 8:45h – 17:00h
SEMINAR VENUE: Garaia Innovation Pole – Mondragón (Basque Country,

www.mondragon.edu/muplus/mecanizadotitanio

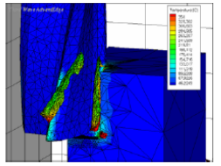
Jornadas de Especialización en Mecanizado:

Modelizado del Mecanizado con Third Wave *AdvantEdge*™ FEM y *AdvantEdge* Production Module™

Fechas : 7 - 8 de Junio, 2007
Horario : 9:00 a 13:00 y de 14.30 a 18:00 (comida de trabajo incluida)
Lugar : Escuela Politécnica Superior, Mondragon Unibertsitatea, Mondragón
Ponente : Third Wave Systems, USA (las jornadas son en inglés)

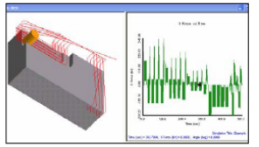
7 de Junio

***AdvantEdge*™ FEM**



8 de Junio

***AdvantEdge* Production Module™**



JORNADA SOBRE

TECNOLOGÍAS DE MICROFABRICACIÓN

Nuevas oportunidades de negocio para las empresas

FECHA: 2 de Julio de 2008
HORARIO: 9:00h – 18:15h
LUGAR: Polo de Innovación GARAIA – Mondragón (Guipúzcoa)

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12th CIRP Conference on Modeling of Machining Operations

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