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*TMCE 2006 tutorial:*

# Non-conventional machining processes in view of modern production

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*Ljubljana, 18th April 2006*

# Content

**I.** Interdependence of design, materials and machining,

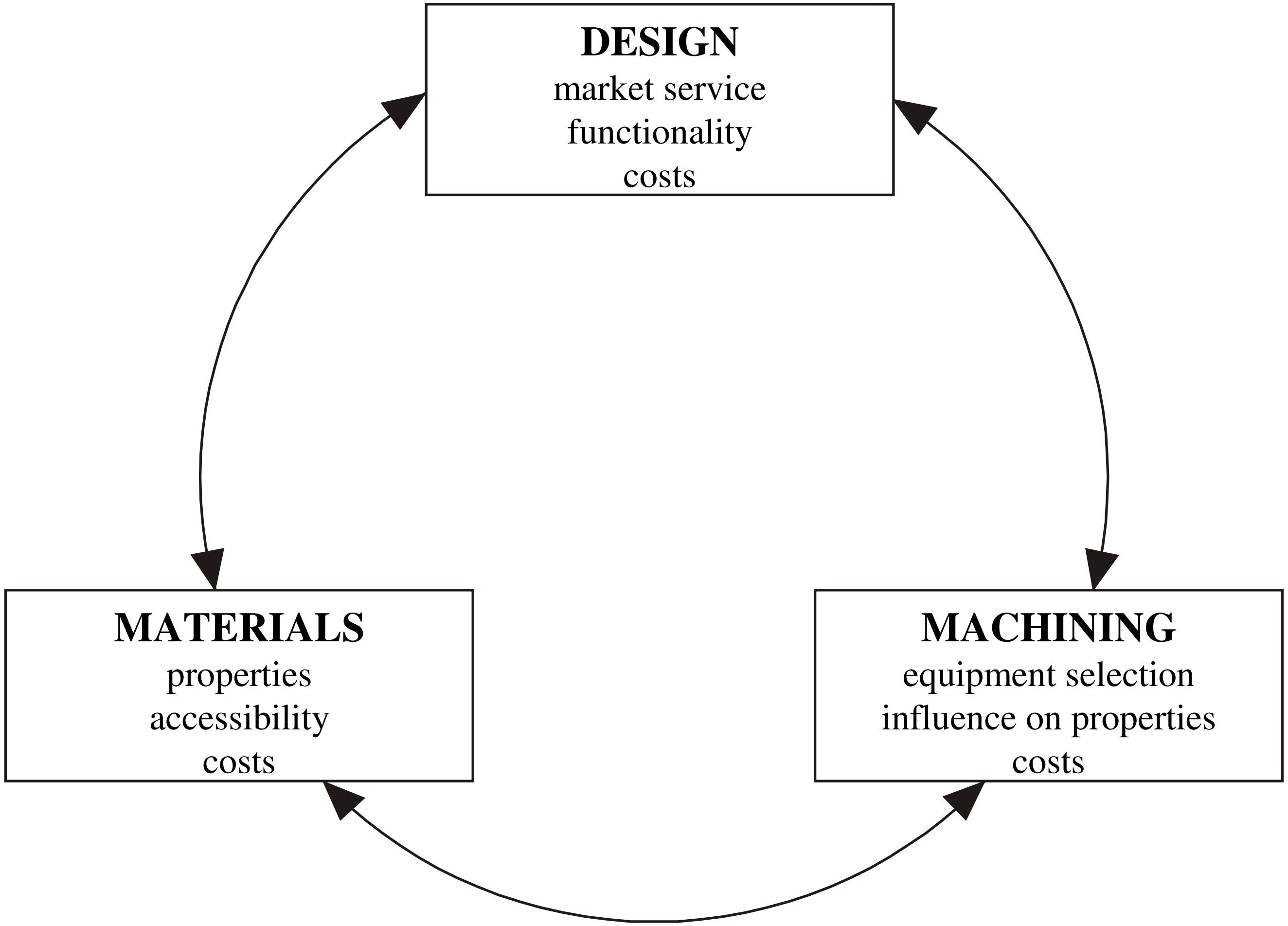
**II.** Product innovation process,

**III.** Matching the design and technology,

**IV.** Overview of basic non-conventional machining processes,

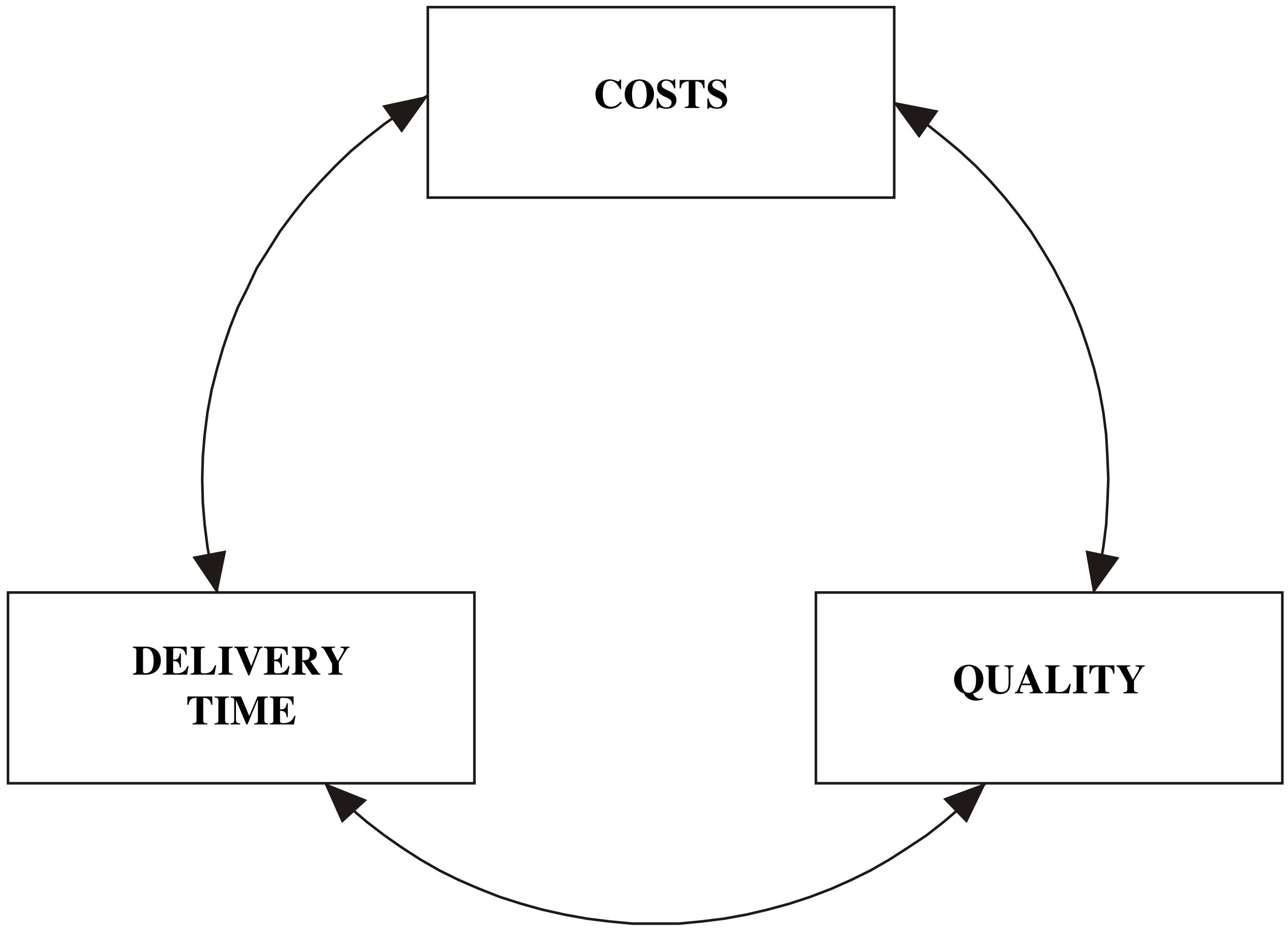
**V.** Future trends in machining.

# Interdependence of design, materials and machining

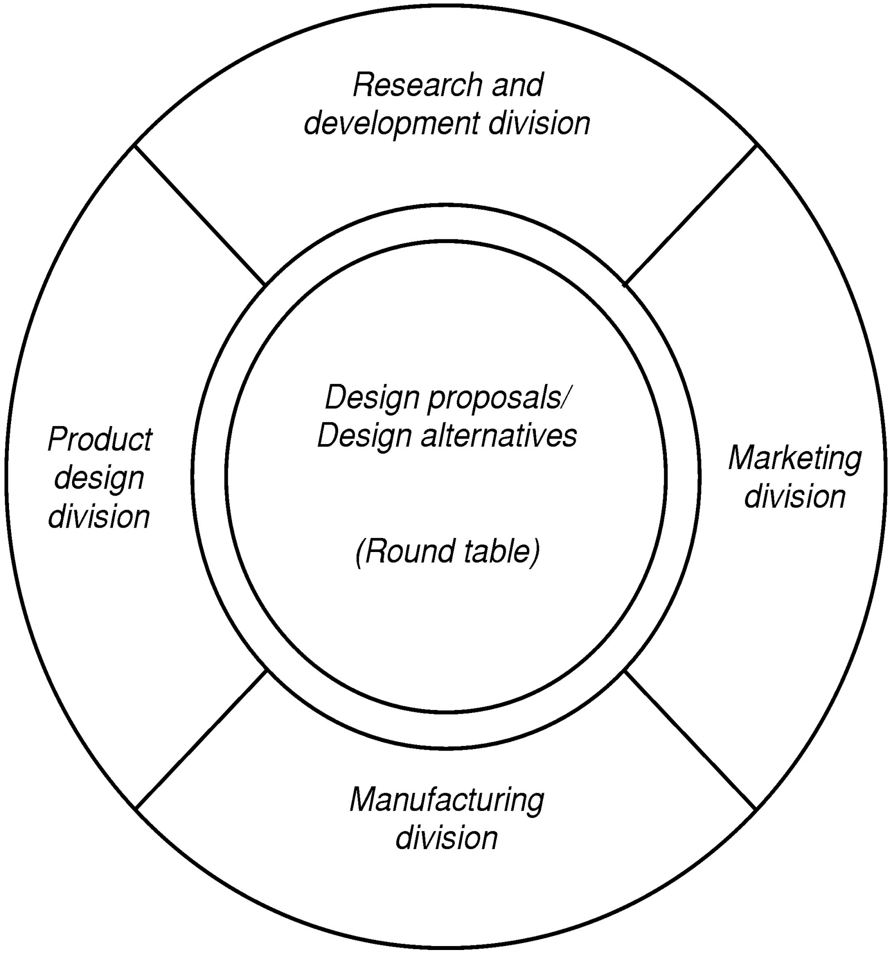



*Dieter, 1983*

# Interdependence of costs, quality and delivery time

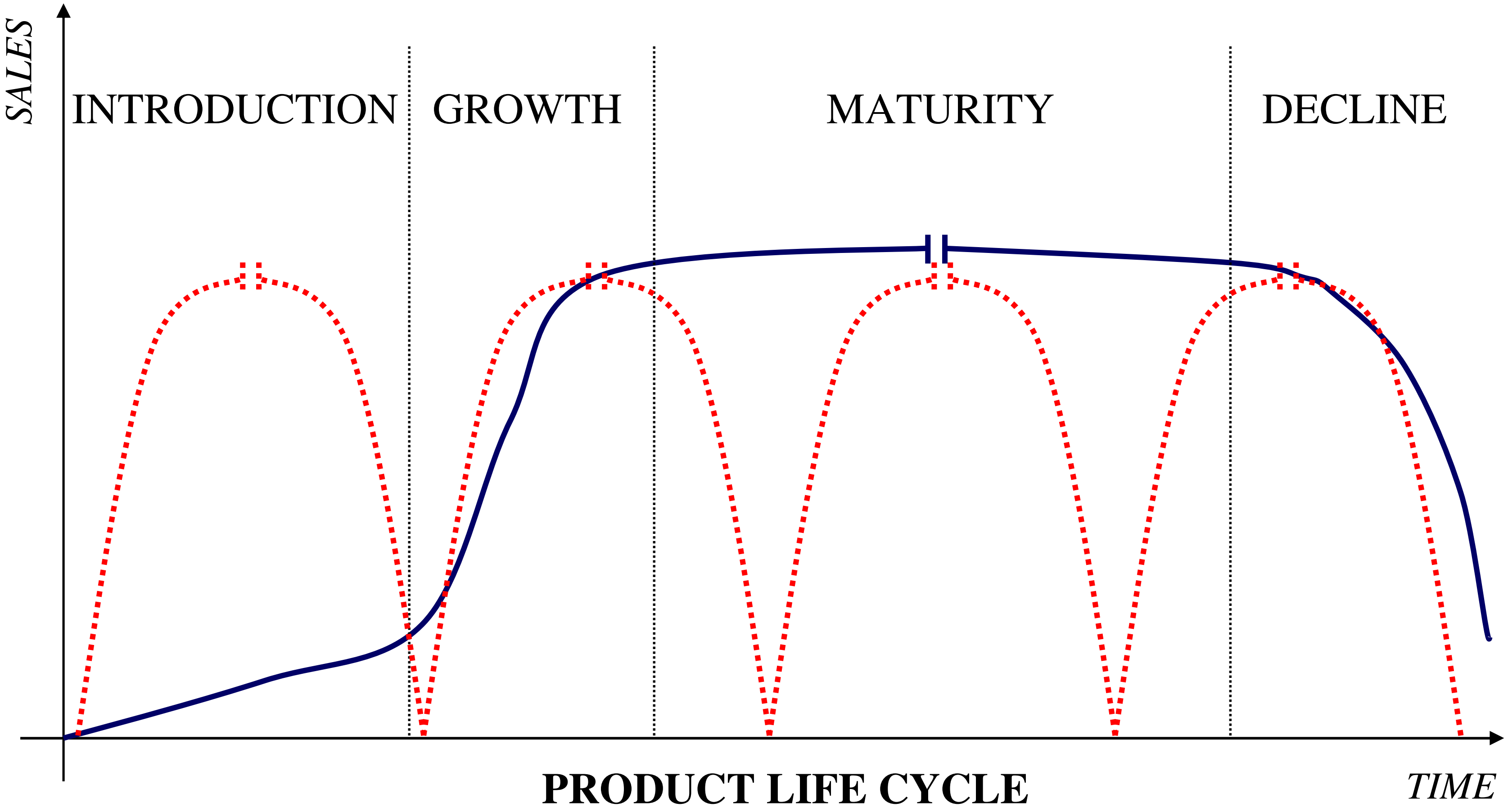


# Concurrent Engineering

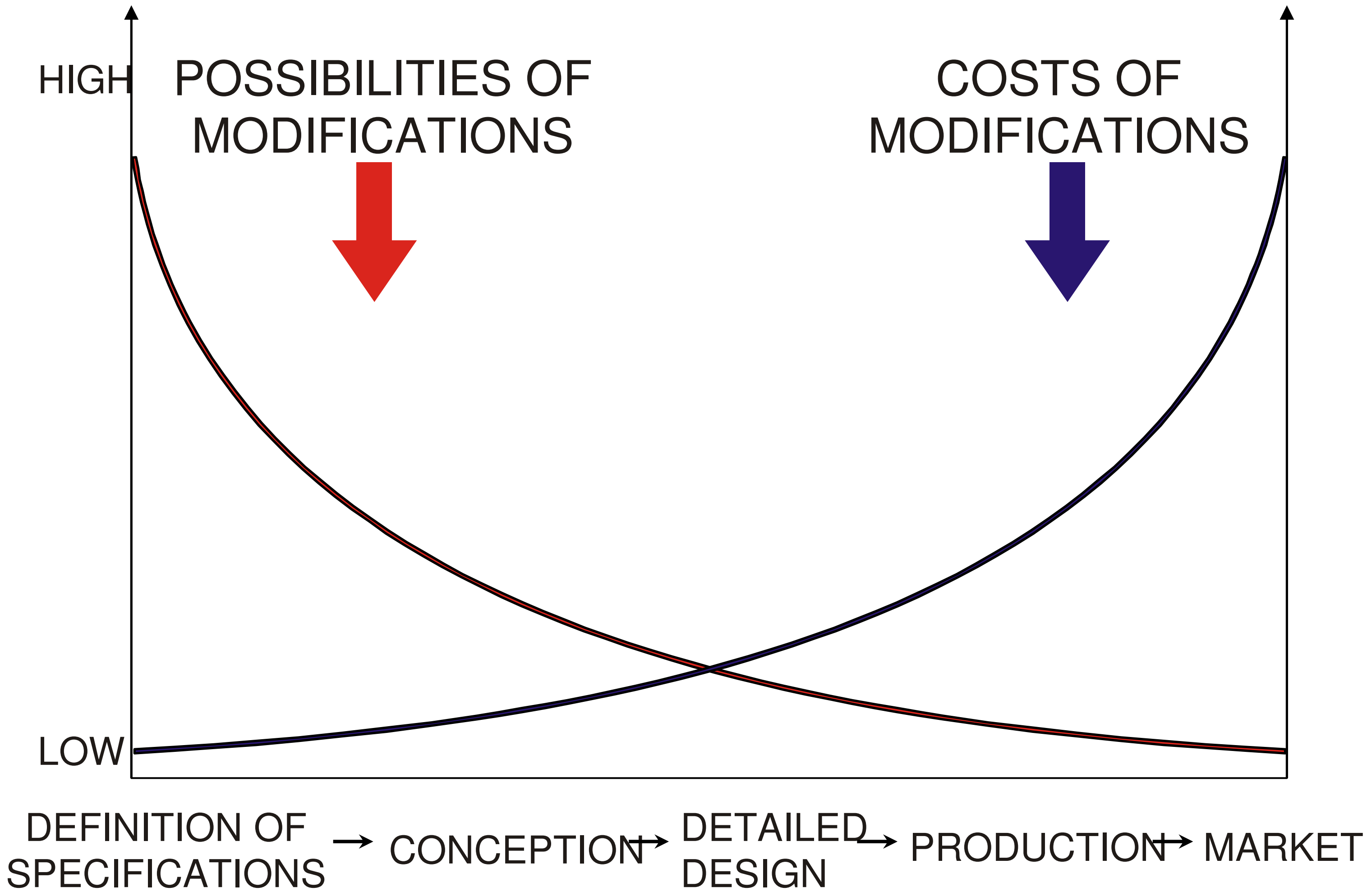



*Brainstorming activities* *(Shanker & Jansson, 1993)*

# Product innovation process



# Modification opportunities



# CREATIVITY MATRIX

| | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 1 st level | C | C | C | O | PRODUCT |
| 2 st level | C | C | O | O | TECHNOLOGY |
| 3 st level | C | O | O | O | PROCESS |

1 - TRADICIONAL CONTROL ORGANISATION

2 - PROCESS IMPROVEMENT ORGANISATION

3 - PROCESS MANAGEMENT ORGANISATION

4 - TRANSFORMATIONAL ORGANISATION

THE 'LEVELS OF CREATIVITY' WE FOUND IN SEVERAL UK COMPANIES WHO HAVE CURRENTLY ENGAGED IN ATTEMPTS TO IMPLEMENT ADVANCED TECHNOLOGIES.

WE HAVE, FOR WANT OF A BETTER PHRASE, TERMED THIS THE 'CREATIVITY MATRIX'!

*Levy, Junkar: Manuf. syst. (Aachen), 1995*

# CREATIVITY MATRIX

- PROVIDING ROUGH MEASURING OF CREATIVE INPUT IN RELATION TO MARKET COMPLEXITY "CLOSED" OR "OPEN" TO OPERATORS CREATIVITY

| PRODUCT COMPLEXITY / LEVEL | LOW | LEVEL OF COMPLEXITY → | | HIGH | CRITICAL ACTIVITY |
|---|---|---|---|---|---|
| 1 st | CLOSED | CLOSED | CLOSED | OPEN | TECHNOLOGY PLANNING |
| 2 st | CLOSED | CLOSED | OPEN | OPEN | PLANNING OF OPERATION |
| 3 st | CLOSED | OPEN | OPEN | OPEN | MACHINE PARAMETER SETTING |

*Levy, Junkar: Manuf. syst. (Aachen), 1995*

# A COMPARISON OF THE MANUFACTURING CONCEPTS

| AUTOMATIC MANUFACTURING | FEATURES | CUSTOMER ORIENTED |
|---|---|---|
| REPETITIVE PRODUCTS | PRIMARY GOAL | UNIQUE - CUSTOMER TAILORED |
| INTENSIVE PRE-PROCESSING | MAJOR FOCUS | CRAFT ORIENTED |
| COMPLEX | PROBLEM DOMAIN | NARROW (PROCESS SPECIFIC) |
| WELL DEFINED & STRUCTURED | INFORMATION SOURCE | OPENED & LEARNING |
| LIMITED | HUMAN INTERFACE | OPERATOR ORIENTED |
| CONCENTRATED | DECISION MAKING CAPABILITY | DISTRIBUTED |
| THE SYSTEM | SOURCE OF RECOMMENDATION | HUMAN - USING SYSTEM RESOURCES |
| AUTOMATION | OPERATOR ROLE | MACHINE MINDER |
| LOW | RESPONSE TO CHAOTIC ENVIROMENT | HIGH |
| *Classical* | | *Modern* |

# Product functionality

*Design functionality*

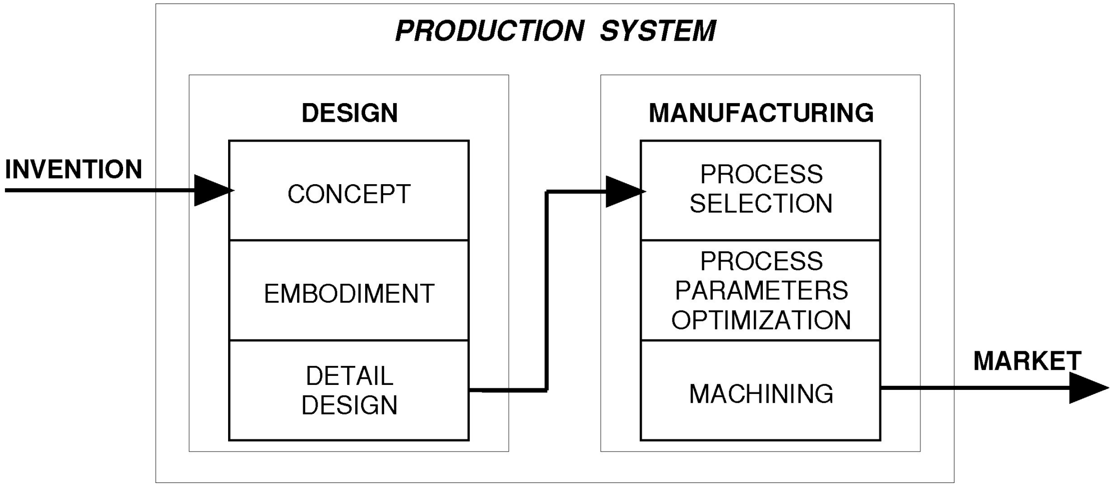
Aesthetic design

*Technical functionality*

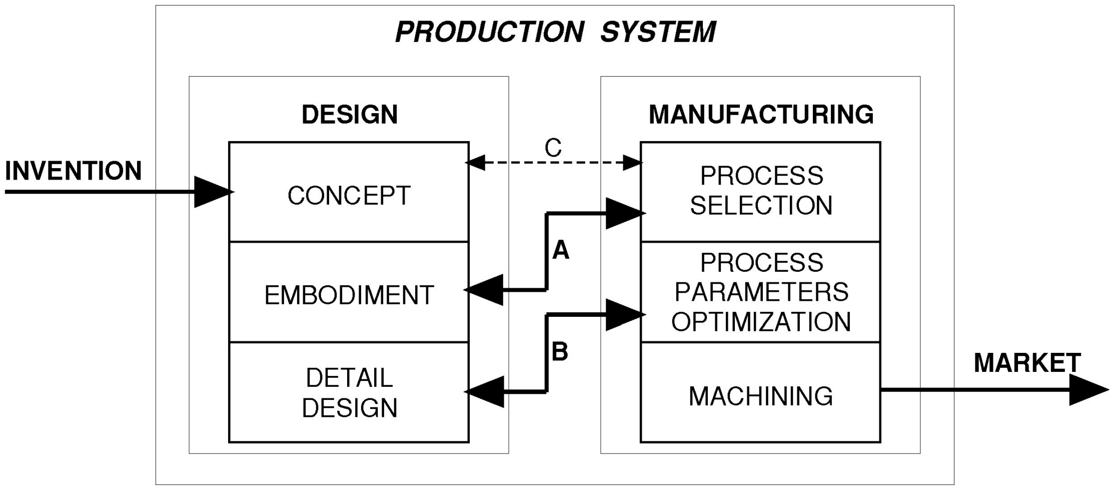
*Junkar, Kolaric, 2002*

# Matching the design and technology

Traditional:

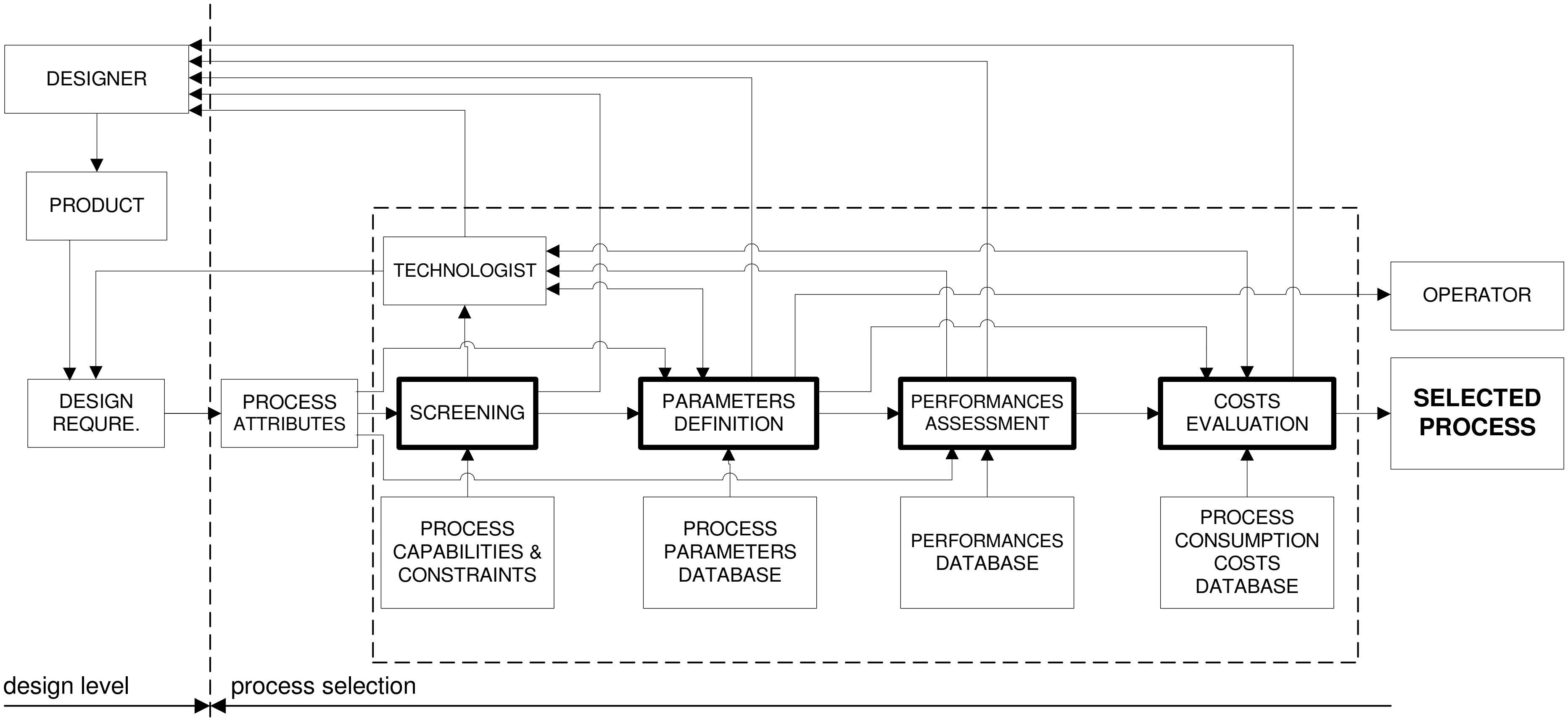



Concurrent:



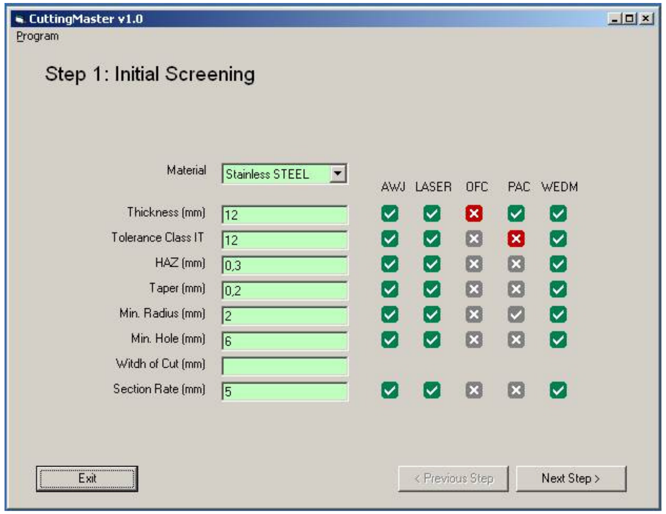

*Junkar, Jurisevic: C2I, 2002*

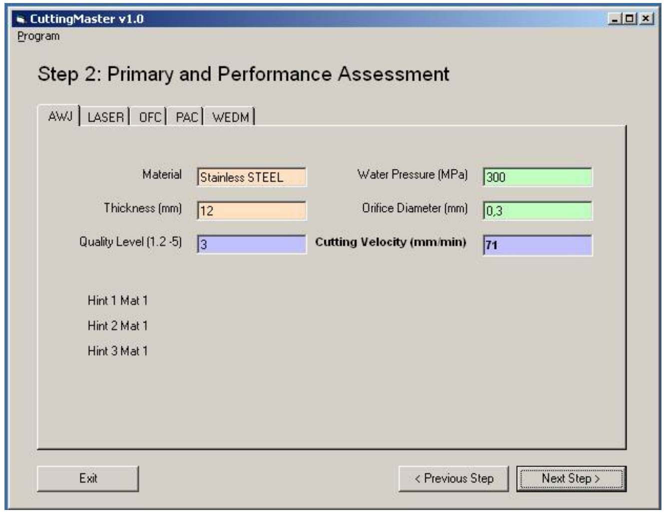
# Process selection procedure

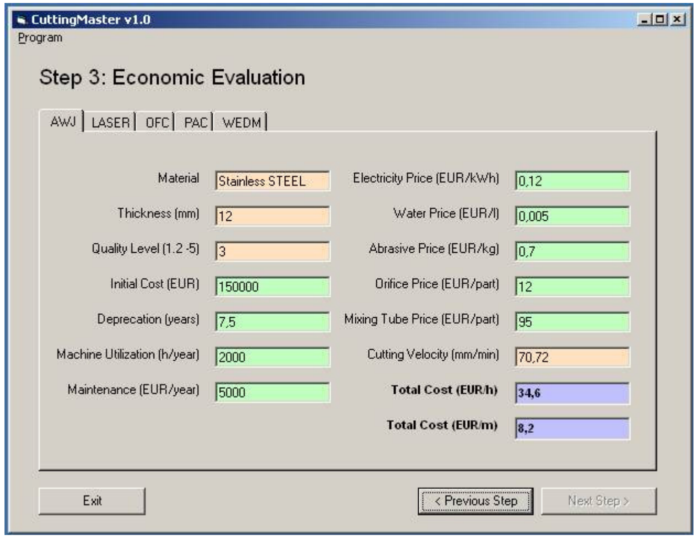



*Junkar, Kramar: CIRP J Manuf Sys, 2004*

# Process selection software

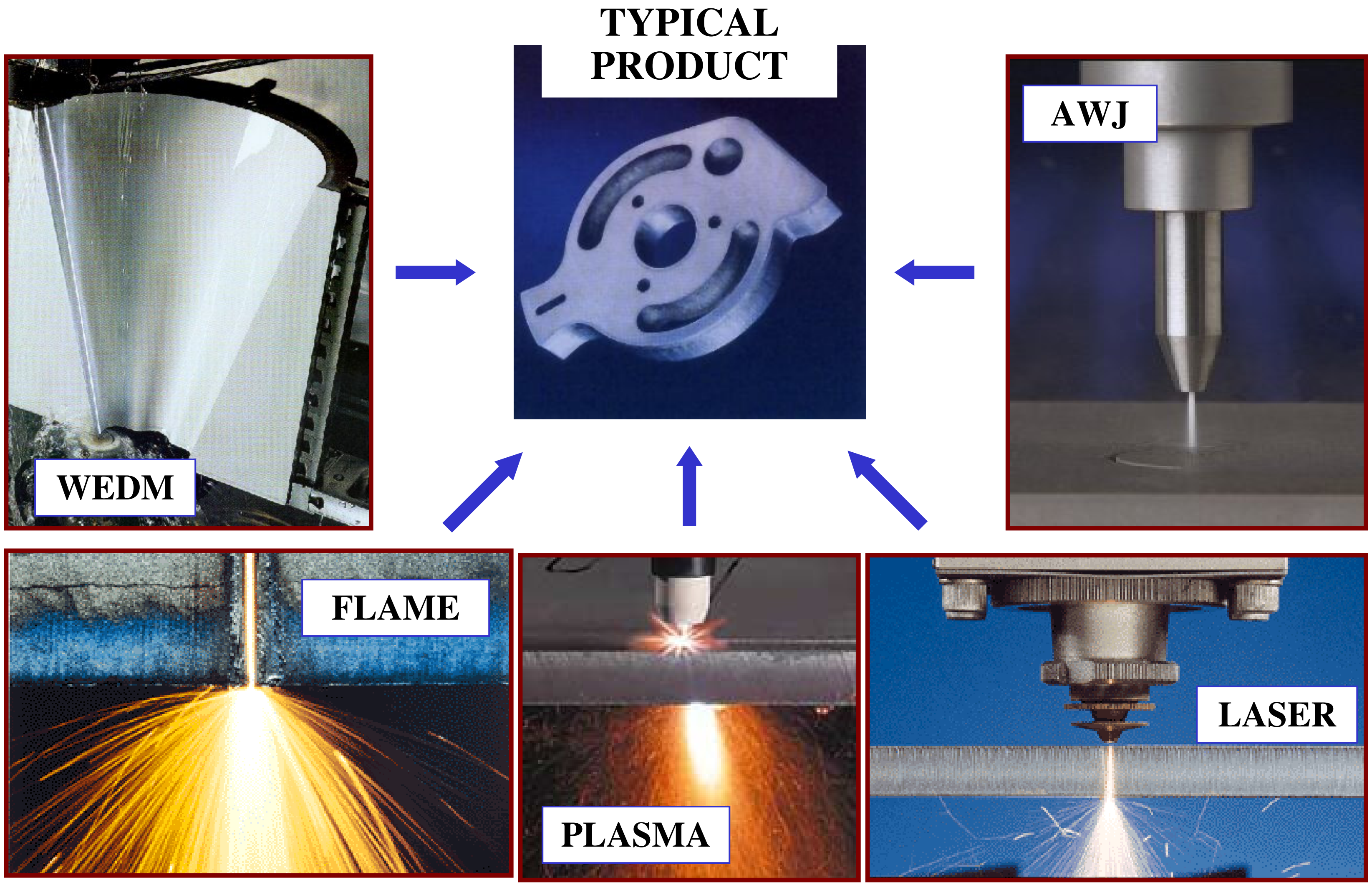


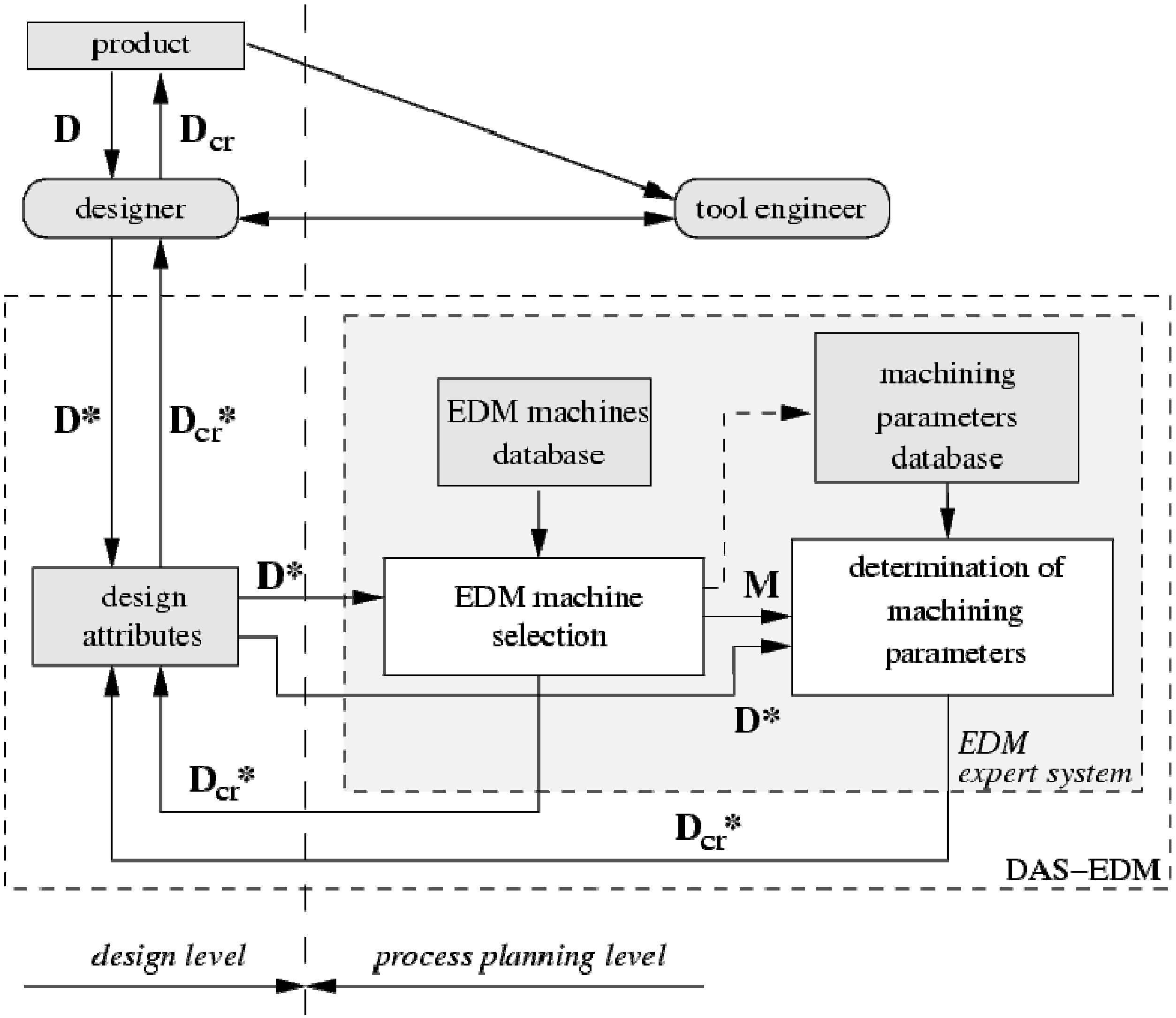




*Junkar, Kramar: CIRP J Manuf Sys, 2004*

# Contour cutting processes

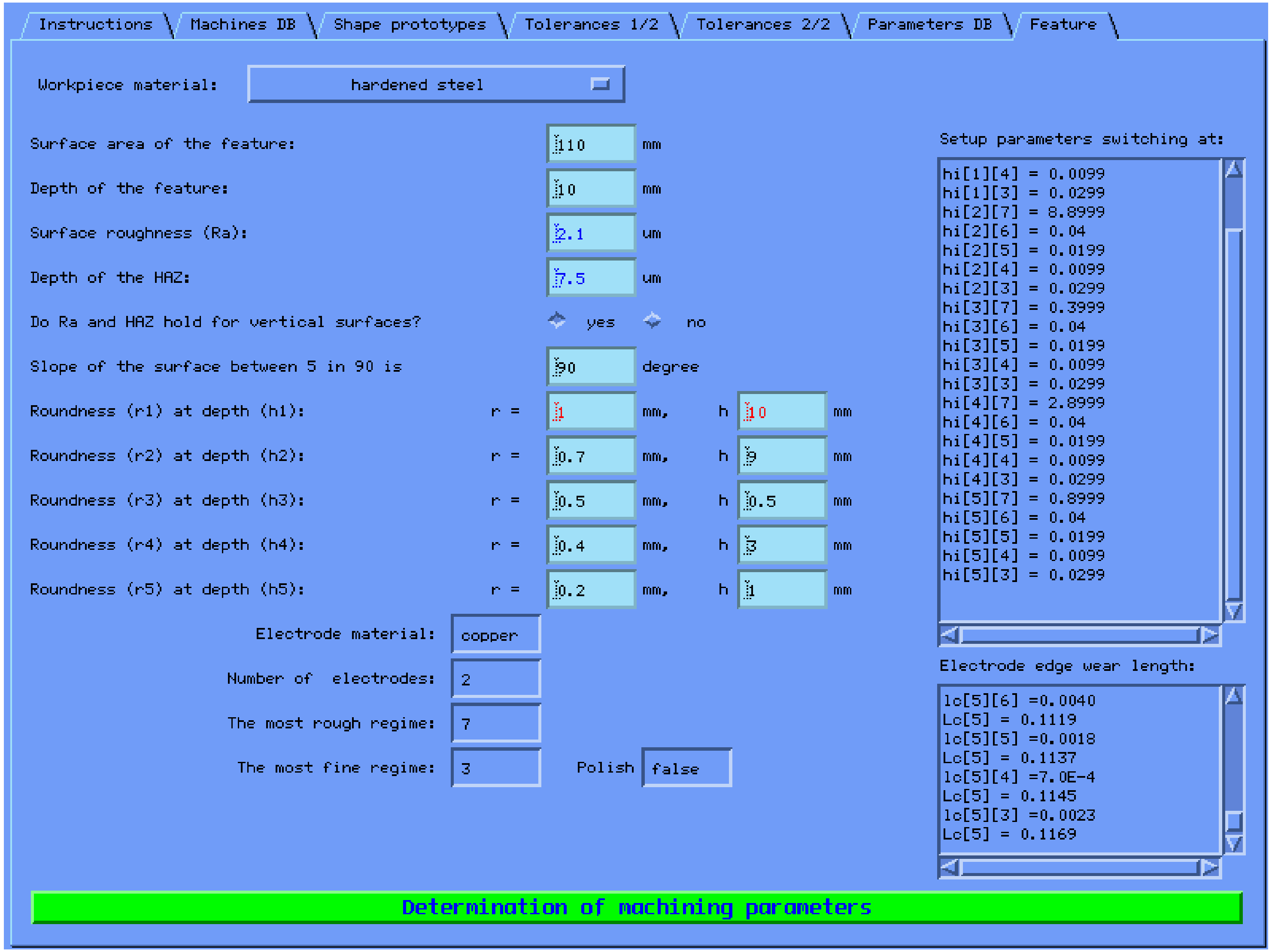


# Process optimization



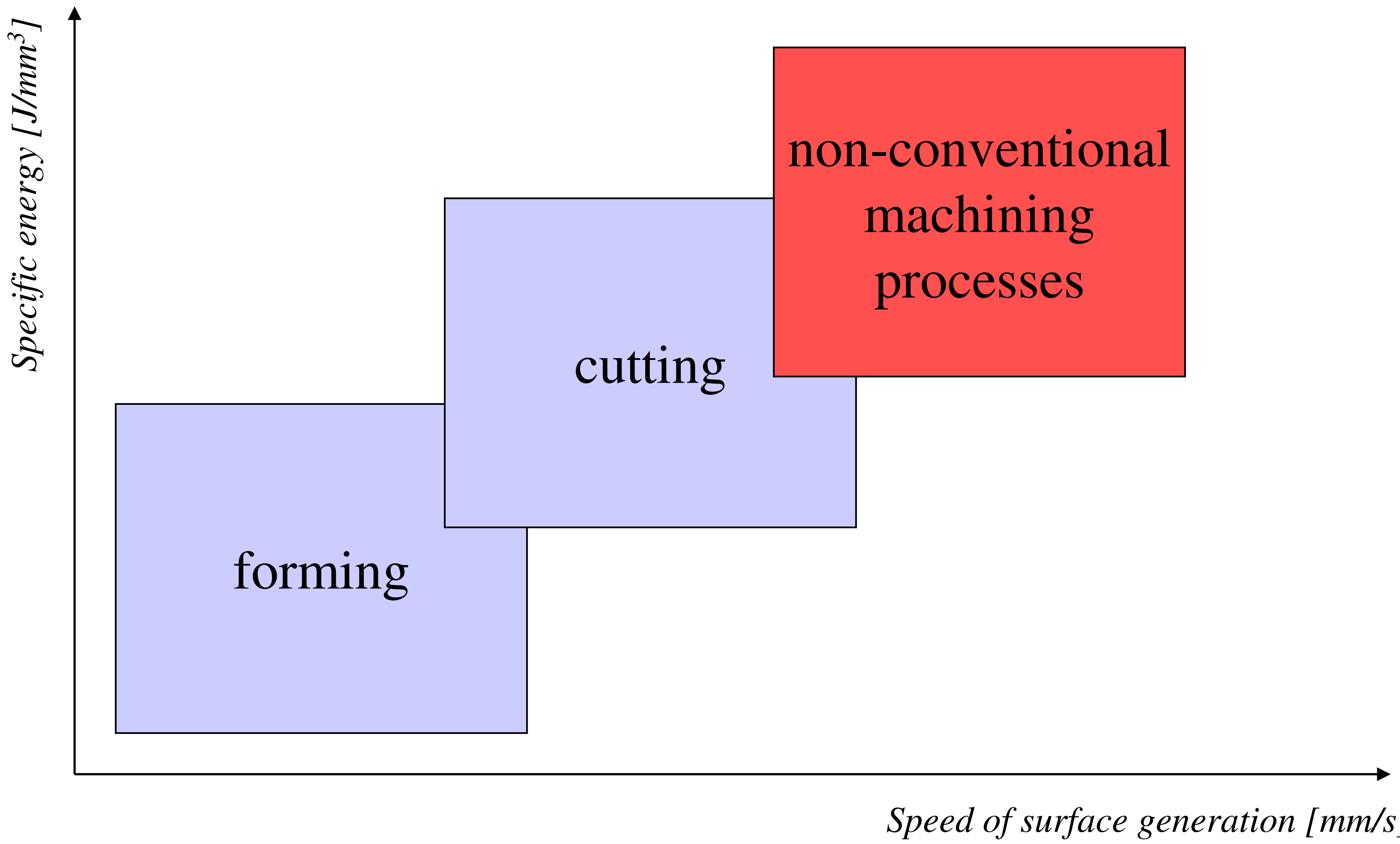

*Valentincic, Brissaud, Junkar: J Mater Proc Techn, 2006*

# Process optimization software

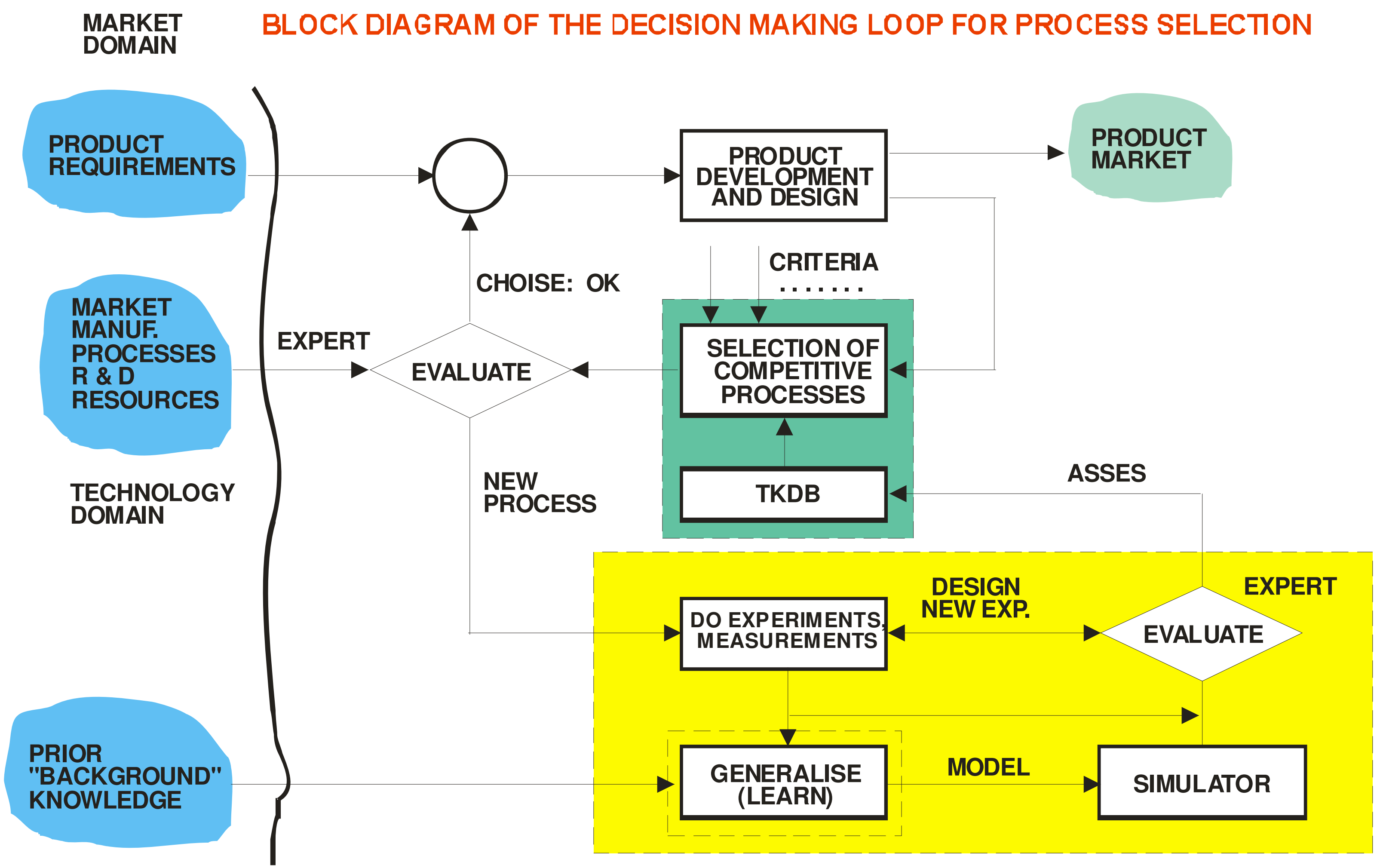



*Valentincic, Brissaud, Junkar: J Mater Proc Techn, 2006*

# Energy consumption for surface generation

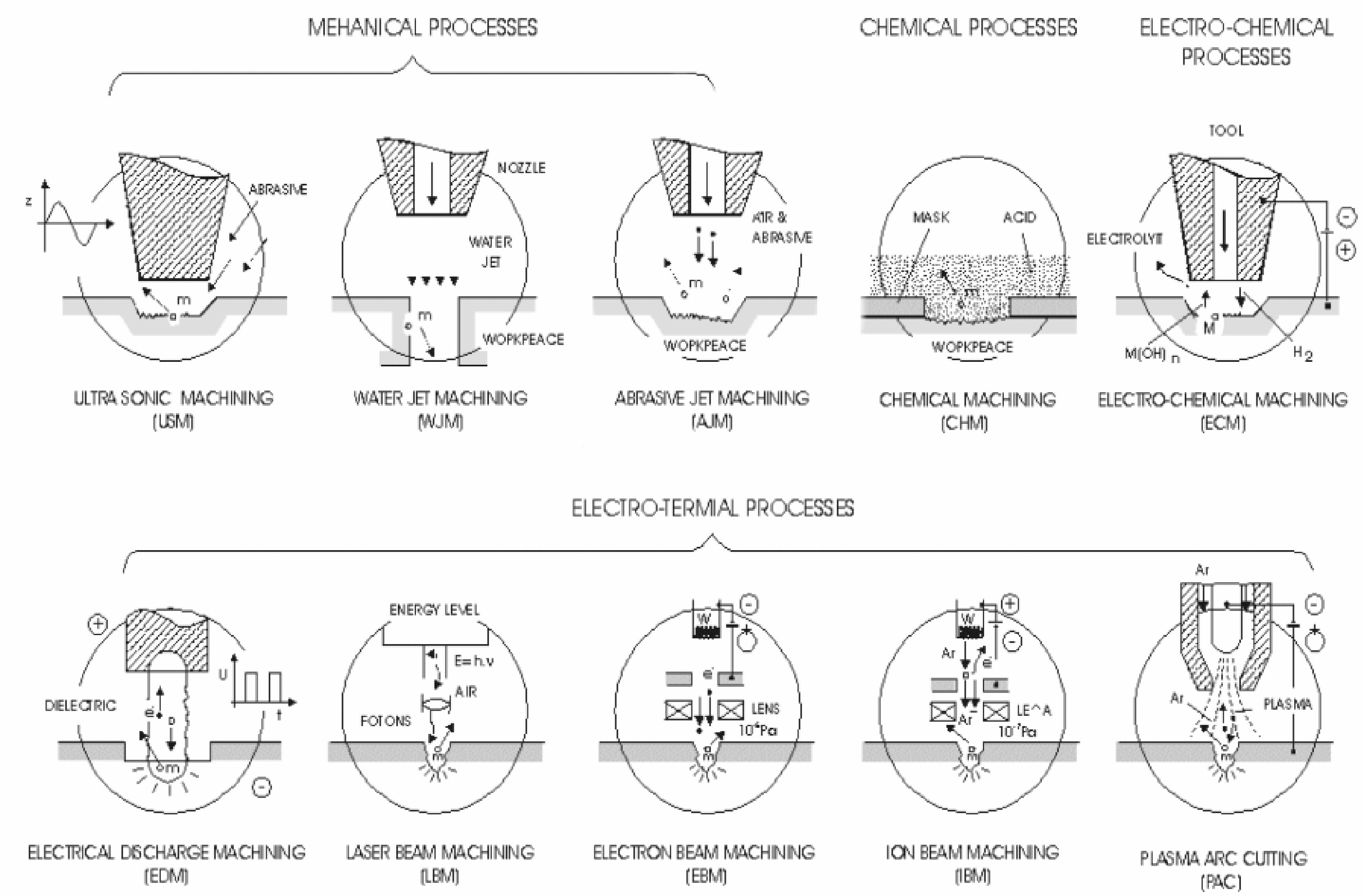


# Development of machining processes and technologies




*Junkar, Sluga: IASTED, 1992*

# Overview of basic non-conventional machining processes



# Machining features of non-conventional machining:

- High speed of surface generation,
- High specific energy,
- Atomic scale processing,
- Metal removal is based on several complex physical and chemical phenomena,
- Their development and applications are still increasing,
- They are suitable for machining hard, brittle and the so called ‘exotic’ materials,
- They are suitable for workpieces with high shape complexity,
- They are suitable for automation of data communication,
- They fulfill high surface integrity and precision requirements,
- They meet miniaturization requirements.

# The twelve death signs of a growing manufacturing company

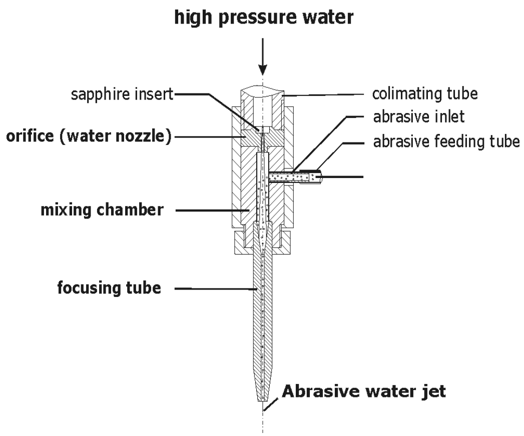
*(case study: "Boiling frog")*

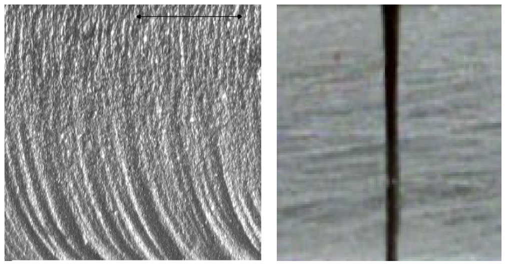
1. The rate of sales/demand acceleration has begun to decline - even though the curve still increases - the rate of increase is declining - not easy to see unless you do the calculation,
2. Things are described as "nice", as "very comfortable" - here there is a danger of a collusion of mediocrity,
3. A small increase in complaints or dissatisfaction - either internally or externally,
4. There is an increase in loyalty from existing customers, but a tiny decline in the number of NEW customers or clients,
5. People don't get in as early as they used to, arrive and leave on time, more often,
6. An increase in the level of inventory/safety stock - either materials, products, ideas not yet put into action,
7. A feeling of "drag" - harder to get enthused, to get going, to be inspired,
8. One or several ideas/practices from the "early days" are still in place, and really shouldn't be,
9. The organization is stifled in terms of innovation through over-dependence on technology or one or two people/small groups,
10. A small but perceptible rise in complaints about the product, service or the relationship. One or two important "first" customers have moved on,
11. Costs are eating a little more each month into profitability through a "slackness" with resources,
12. There is a hint of "sameness" of boredom, even in an apparently exciting and changing environment. A lack of real "buzz".

*Junkar, Levy: MIT, 2005*

# Non-conventional machining process

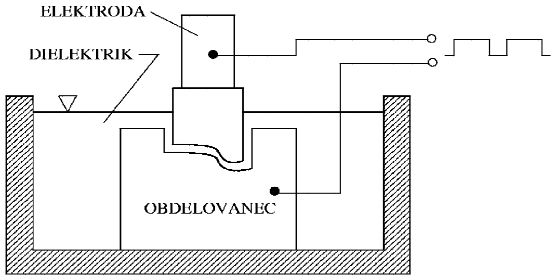
## Abrasive Water Jet (AWJ)

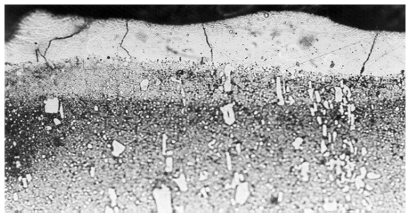


- all materials,
- no HAZ.

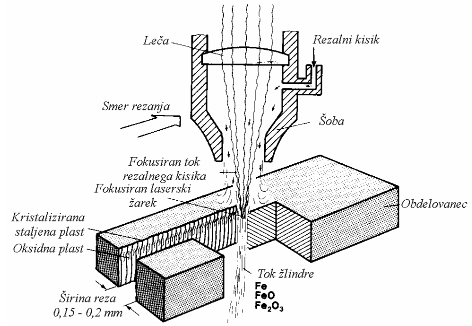
## Electro Discharge Machining (EDM)

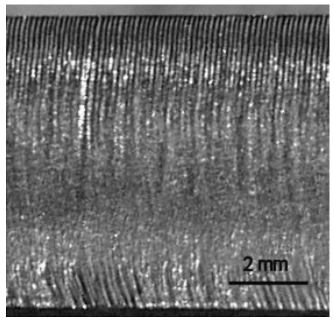


- all electrically conductive materials.

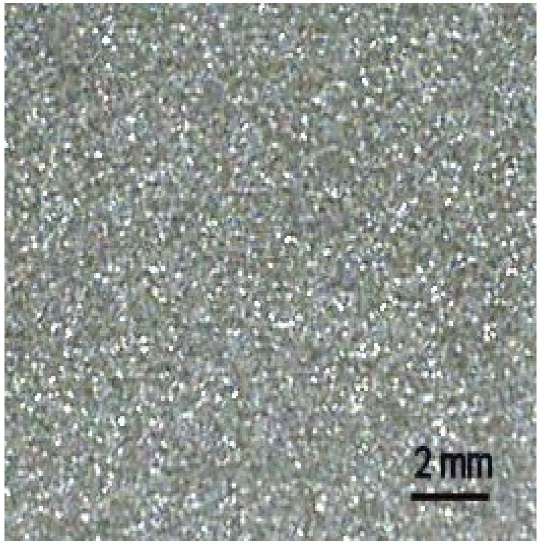
## LASER machining



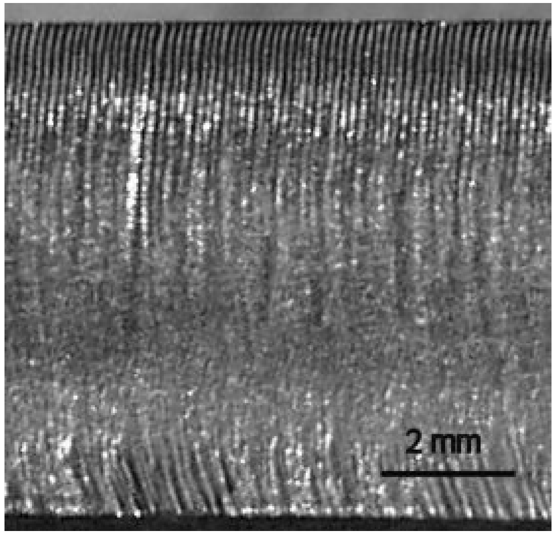

- high cutting velocity (thin materials).

# Surface texture after non-conventional machining



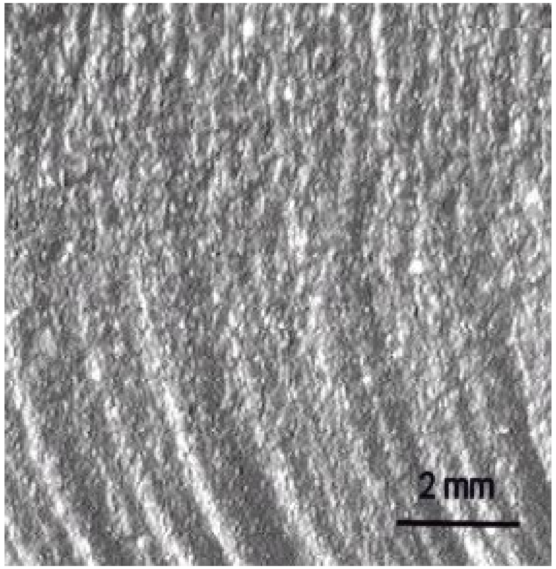

**EDM**

**Ra = 2,5 µm**




**LBM**

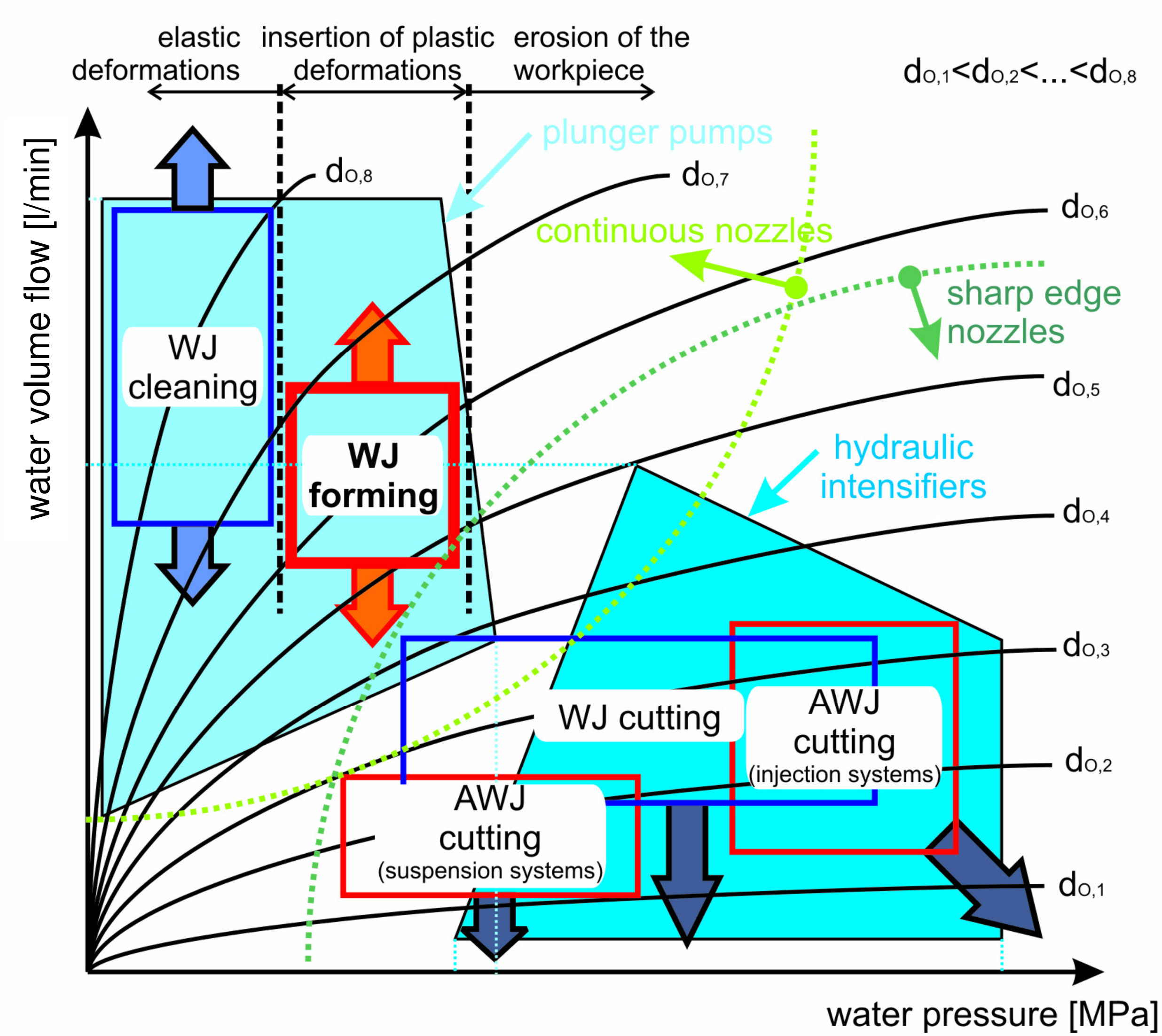
**Ra = 6 µm**



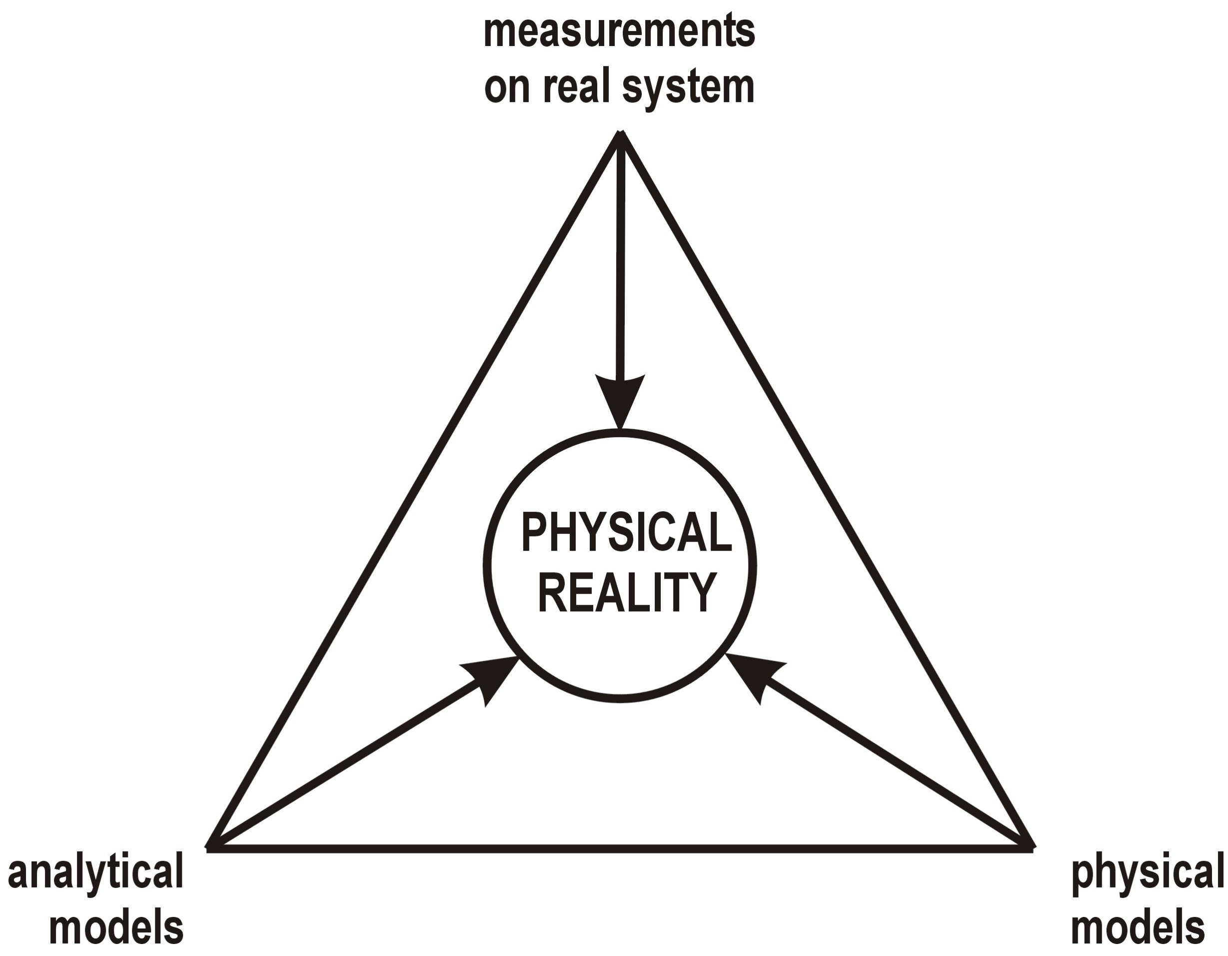

**AWJ**

**Ra = 6 µm**

# Applications of jet based technologies

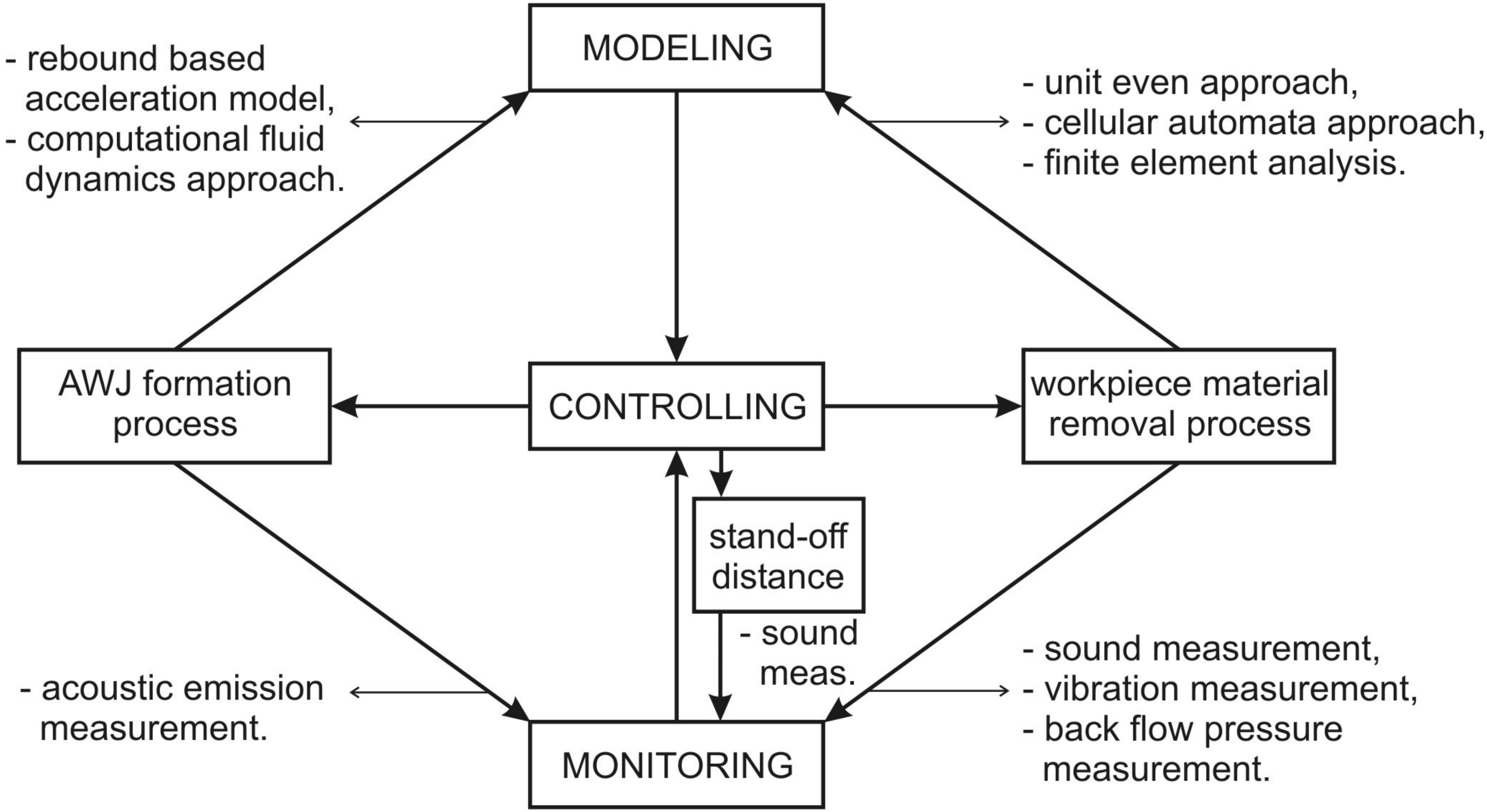


# Approach to understanding the machining process



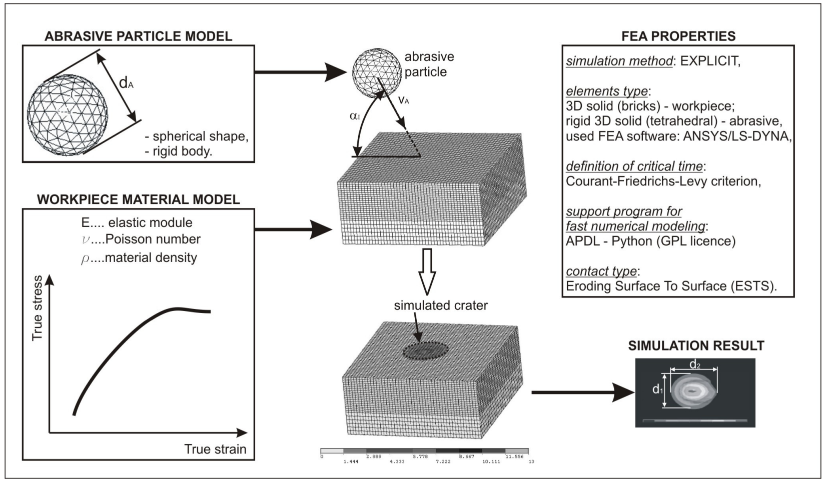

*Gunasekara, 1982*

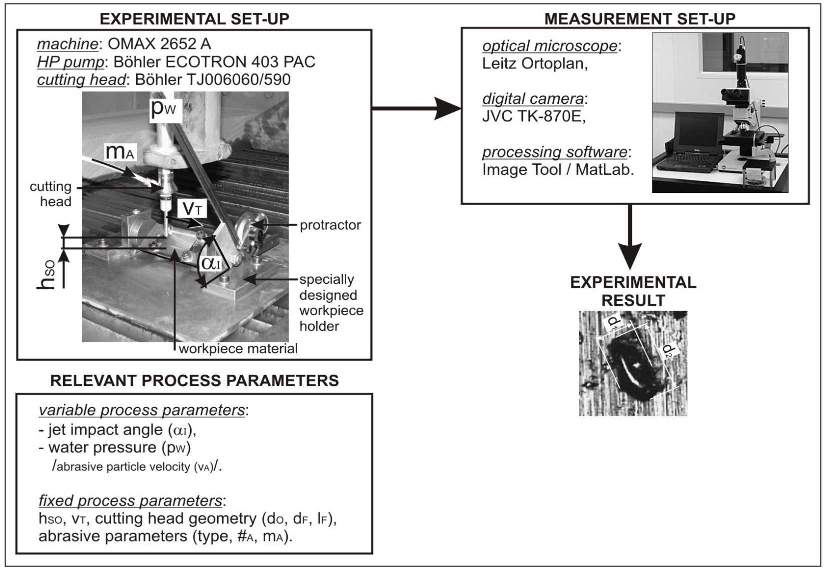
# Monitoring and modeling of AWJ process

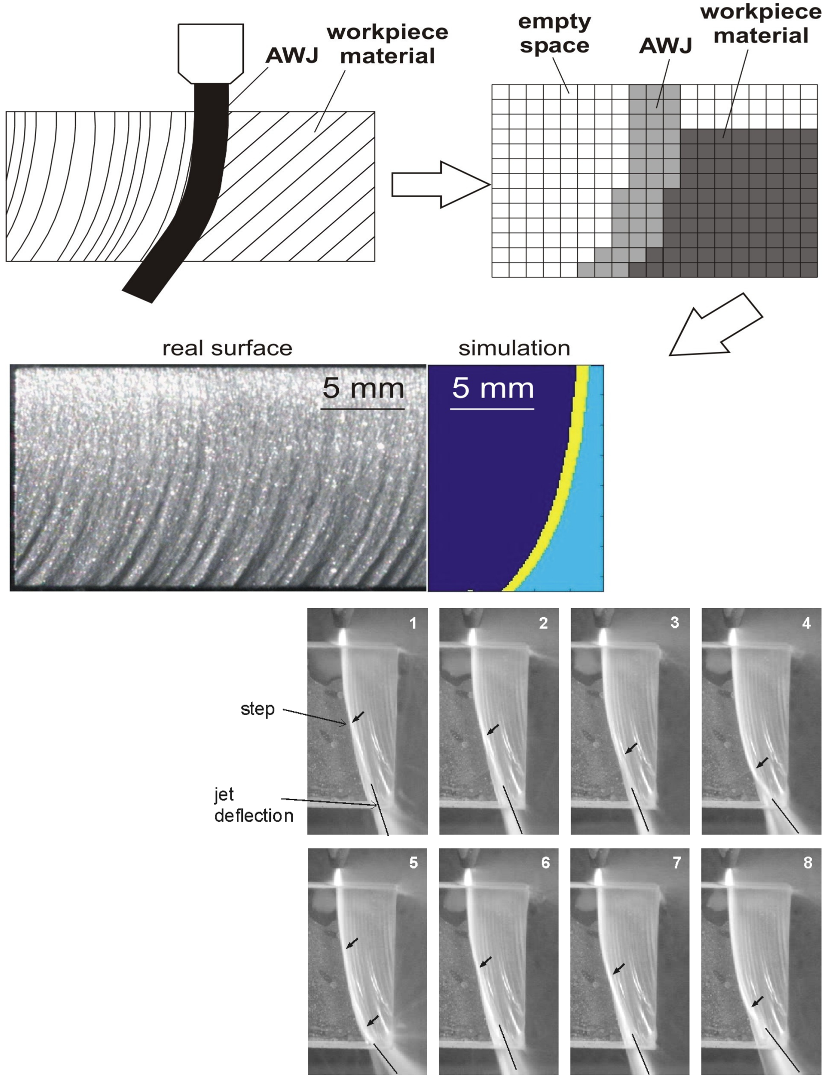



*Jurisevic et al: 37th CIRP ISMS, 2004*

# Examples of modeling the AWJ process



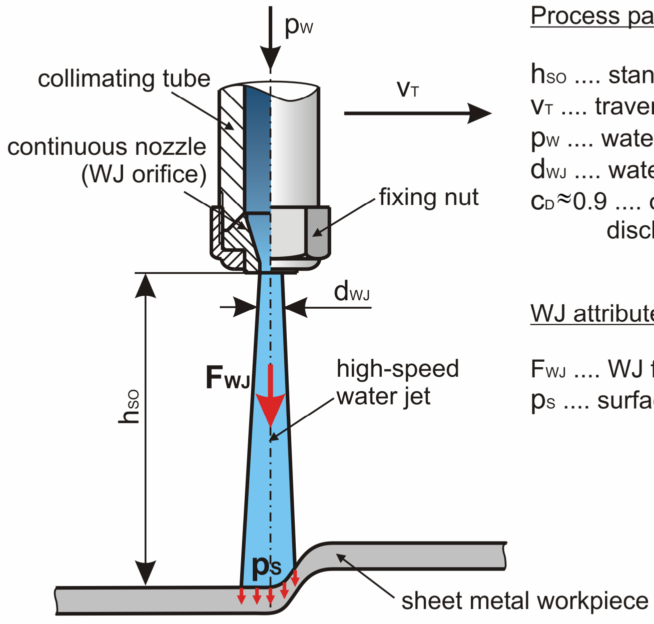




*Junkar et al: I J Imp Eng, 2006*

*Orbanic, Junkar: WJTA, 2005*

# Future trends in machining
# Water Jet Incremental Sheet Metal Forming - WJISMF

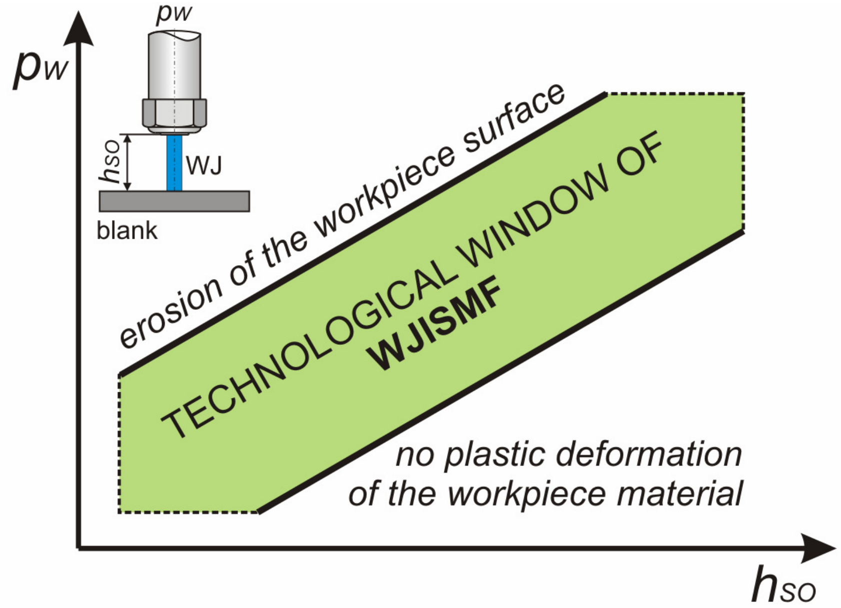


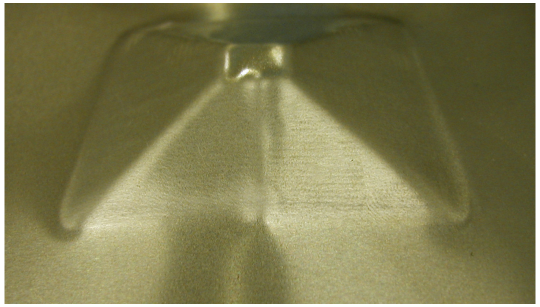

Process parameters:

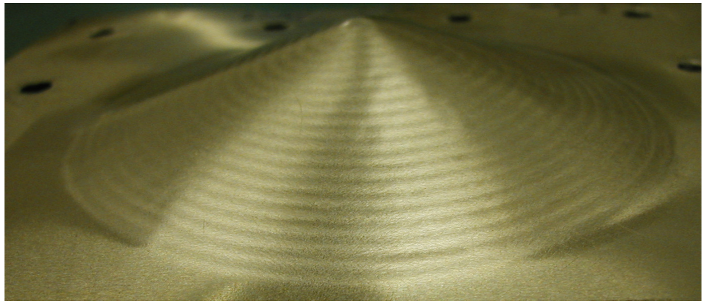
$h_{SO}$ .... stand-off distance [mm]
$v_T$ .... traverse rate [mm/s]
$p_W$ .... water pressure [MPa]
$d_{WJ}$ .... water jet diameter [mm]
$c_D \approx 0.9$ .... continuous nozzle discharge coefficient [-]

WJ attributes:

$F_{WJ}$ .... WJ force [N]
$p_S$ .... surface pressure [MPa]

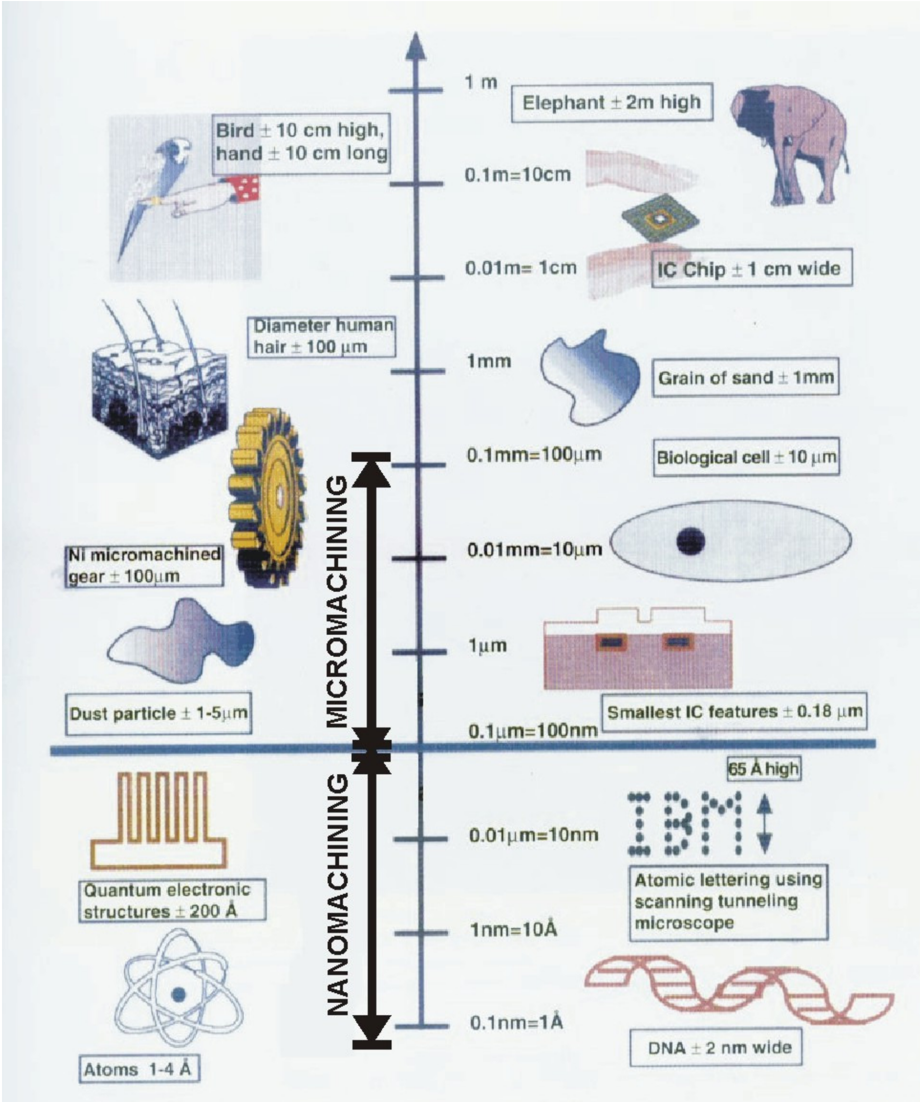




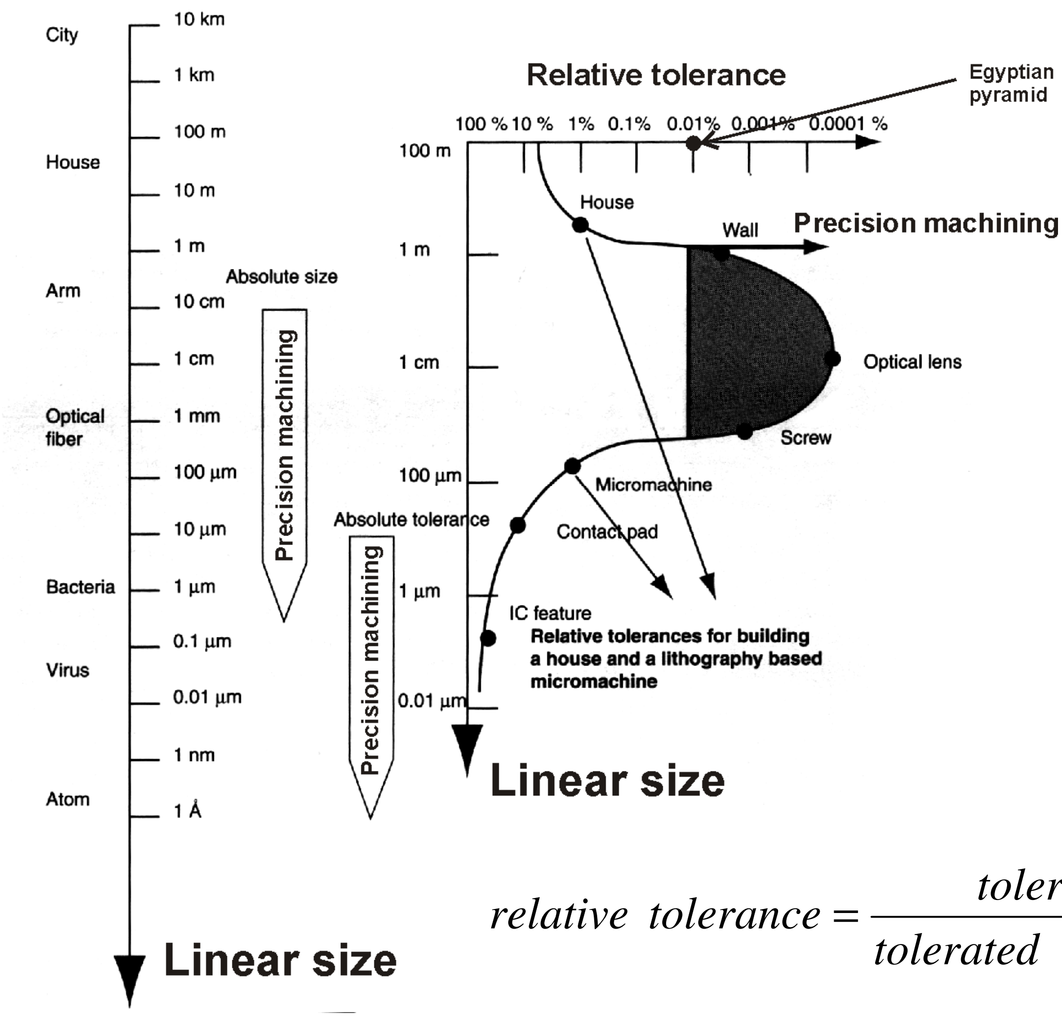
*Jurisevic, Kuzman, Junkar: I J Adv Manuf Tech, 2005*

# Future trends in machining: Multi-Material Micro Manufacture




*Madou, 2002c*

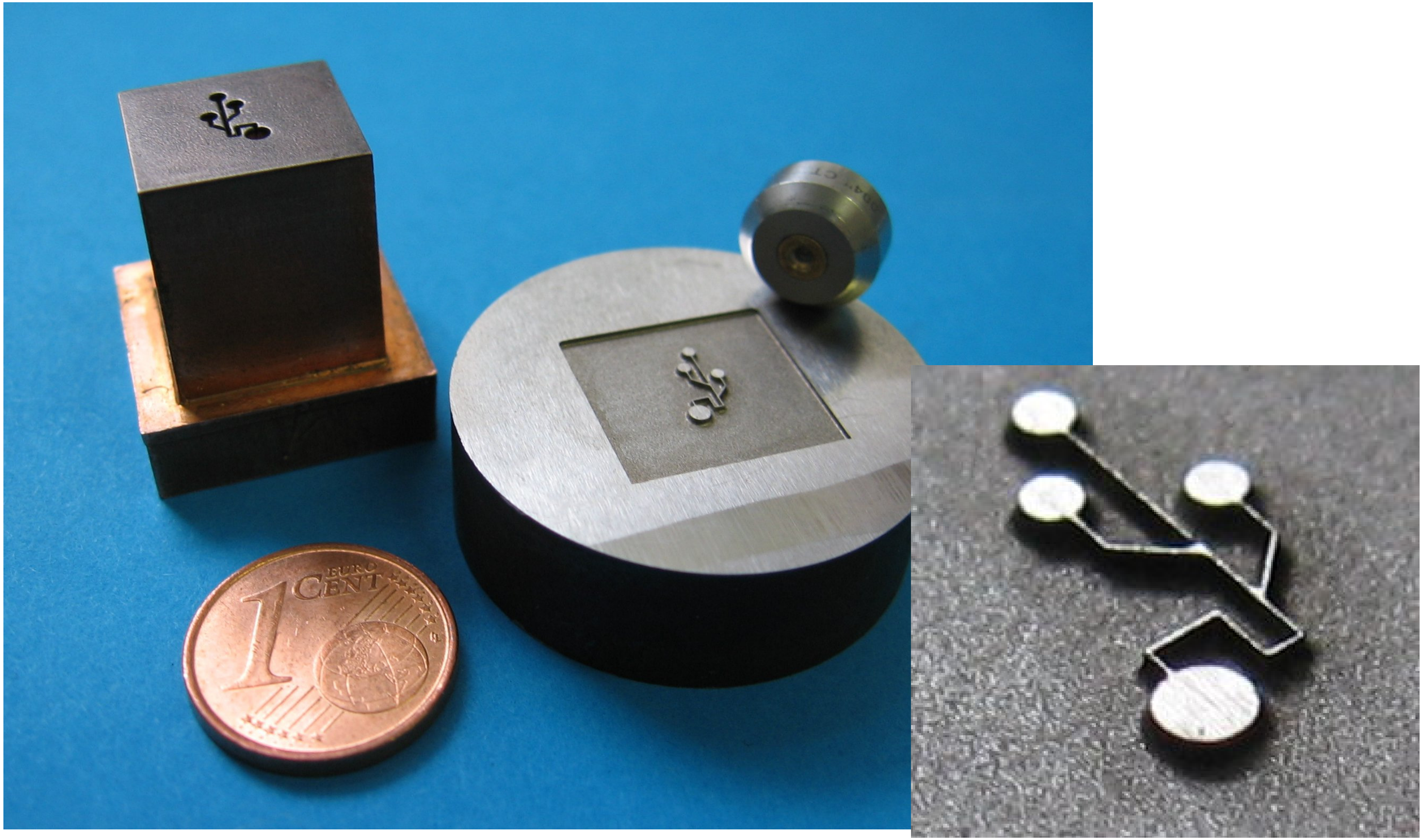
# Future trends in machining: Multi-Material Micro Manufacture




$$relative\ \ tolerance = \frac{tolerance}{tolerated\ \ dimension} \cdot 100\%$$

*Madou, 2002*

# Future trends in machining: Micro tooling




*Jurisevic et al: 4M Workshop Budapest, 2006*