

# Design for EDM manufacturing



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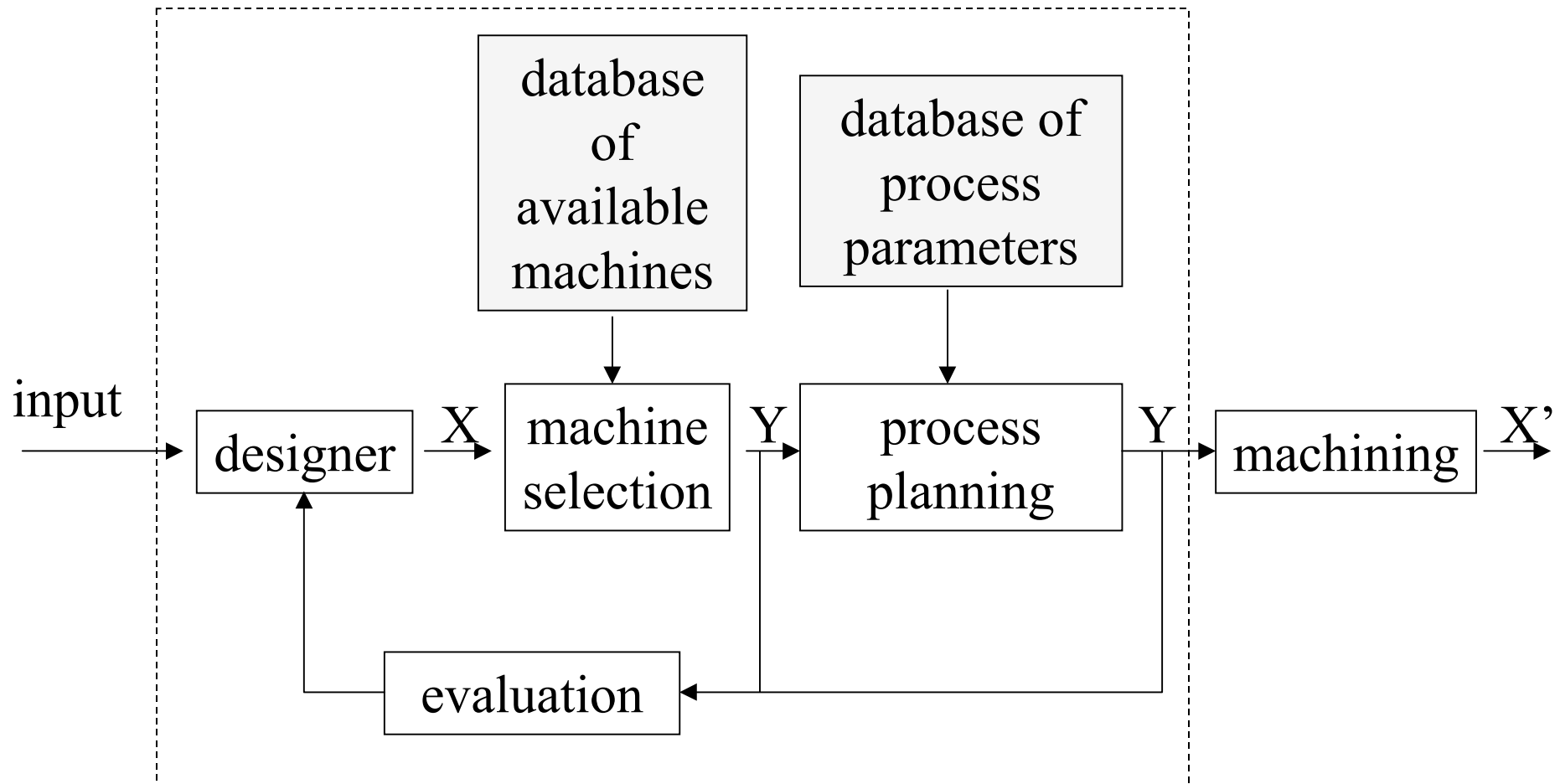
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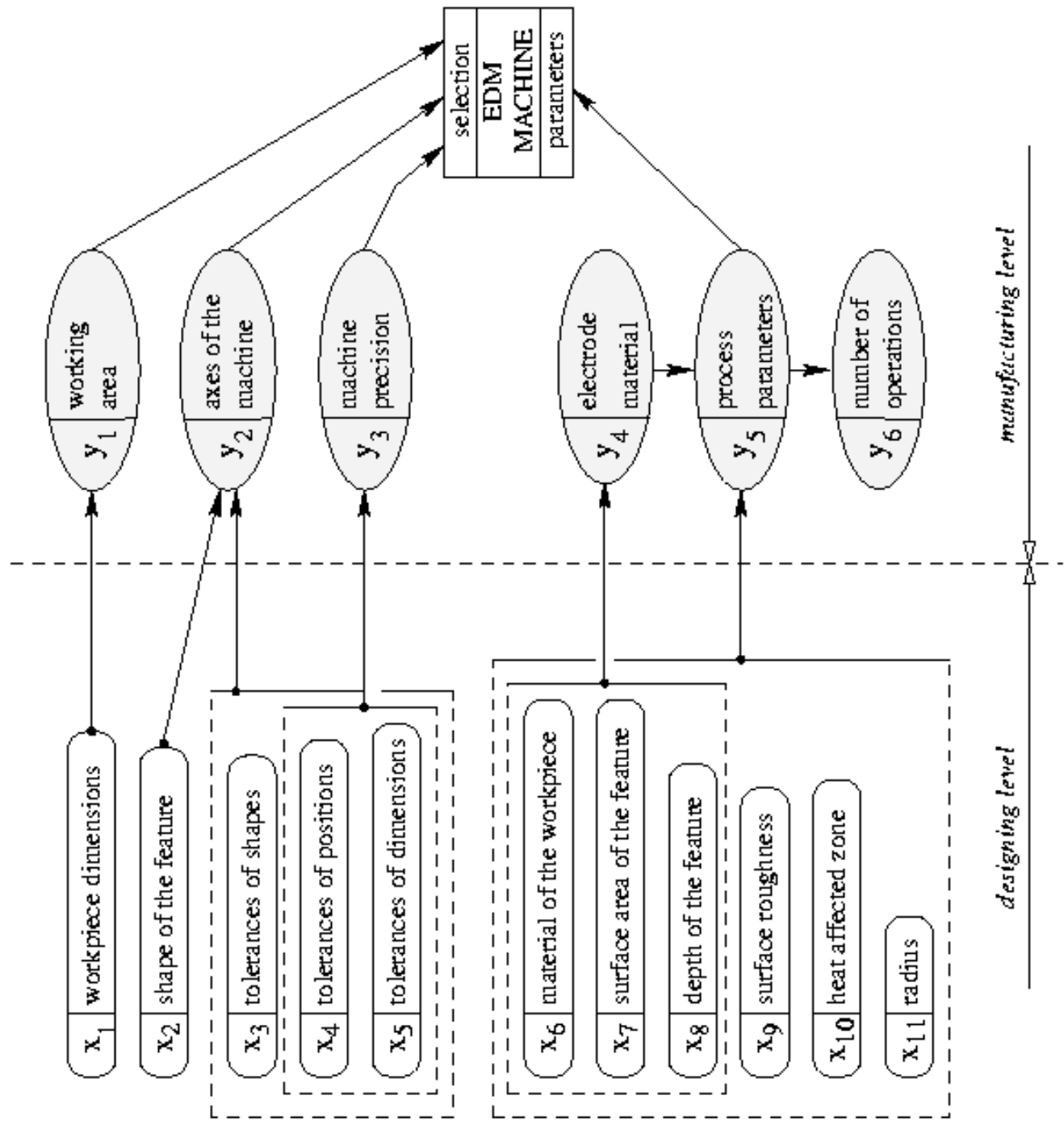
# Design for manufacturing



- *Manufacturing parameters  $X$  are dependant on the design parameters  $Y$ :  $Y=F(X)$*
- *To present technological knowledge on the design level:  $X=F^{-1}(Y)$*
- *For each manufacturing parameter  $y_j$  is necessary to find mapping  $f_j$  between design parameters  $x_i$  and other manufacturing parameters  $y_k$ :  $y_j=f_j(x_i, y_k)$*

# Achieving the inverse function





# Mathematical description of the connections

■  $y_1 \geq x_1$

■  $y_2 = f(x_2, x_3, x_4, x_5)$

| $y_2$          | machine can manufacture primitives $x_2$                                      | machining |
|----------------|---|-----------|
| <i>code_s1</i> | <i>primitive1</i>   | orb=0     |
| <i>code_s2</i> | <i>primitive1, primitive5, primitive6</i>                                     | orb=0     |
| <i>code_s3</i> | <i>primitive1, primitive2, primitive4</i>                                     | orb=0     |
| <i>code_s4</i> | <i>primitive1, primitive2, primitive3, primitive4, primitive6</i>             | orb=0,1   |
| <i>code_s5</i> | <i>primitive1, primitive2, primitive3, primitive4, primitive5, primitive6</i> | orb=0,1   |

$$\text{orb} = f(d_{vx}, d_{mx}, o_{vx}, o_{mx}, p_{vx}, p_{mx})$$

# Mathematical description of the connections

- $y_3: \text{geo} = f(d_{vx}, d_{vy}, d_{mx}, d_{my}, p_{vx}, p_{vy}, p_{mx}, p_{my})$   
 $\text{poz} = f(d_{mx}, d_{my}, p_{mx}, p_{my})$

- $y_4 = f(x_6, x_7)$

$$x_6 = (\text{code\_m1}, \text{code\_m2}, \text{code\_m3}) \ \&$$

$$x_7 < 10.000 \text{ mm}^2 \Rightarrow y_4 = (\text{code\_e1})$$

$$x_6 = (\text{code\_m1}, \text{code\_m2}, \text{code\_m3}) \ \&$$

$$x_7 > 10.000 \text{ mm}^2 \Rightarrow y_4 = (\text{code\_e2})$$

$$x_6 = (\text{code\_m4}, \text{code\_m5}, \text{code\_m6})$$

$$\Rightarrow y_4 = (\text{code\_e1})$$

$$x_6 = (\text{code\_m7}, \text{code\_m8}) \Rightarrow y_4 = (\text{code\_e3})$$

# Mathematical description of the connections

$$\blacksquare y_5^1, y_5^2, \dots, y_5^N$$

N ... number of operations

$$y_5^1 = f(x_6, x_7, y_4)$$

$$y_5^N = f(x_6, x_7, \dots, x_{11}, y_4)$$

$$y_5^i = f(y_5^1, y_5^N)$$

$$\blacksquare y_6 = f(y_5)$$

# Database of EDM machines

| code of the machine<br><i>code_s</i> | machining in axes | positioning precision<br>[mm] | geometrical precision<br>[mm] | priority |
|--------------------------------------|-------------------|-------------------------------|-------------------------------|----------|
| 1                                    | Z                 | 0.03                          | 0.01                          | 1        |
| 2                                    | Z-C               | -                             | -                             | -        |
| 3                                    | Z-X               | -                             | -                             | -        |
| 4                                    | Z-X-C             | -                             | -                             | -        |
| 5                                    | Z-X-Y-C           | 0.01                          | 0.01                          | 2        |
| 5                                    | Z-X-Y-C           | 0.005                         | 0.005                         | 3        |

# Database of EDM parameters and process performances

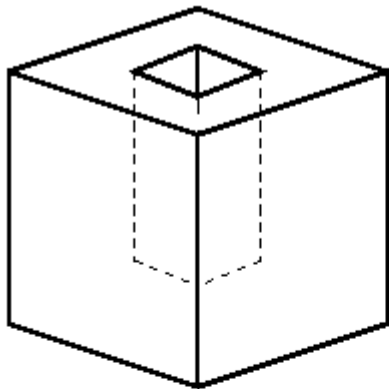
| workpiece material: HARDENED STEEL ( <i>code_m3</i> ) |       |       |            |                                 |                               |            |             |
|---|-------|-------|------------|---------------------------------|-------------------------------|------------|-------------|
| electrode: ELECTROLYTIC COPPER ( <i>code_e1</i> )     |       |       |            |                                 |                               |            |             |
| regime  |       |       |            | $V_w$<br>[mm <sup>3</sup> /min] | $\vartheta_{LC}^{**}$<br>[mm] | Ra<br>[μm] | HAZ<br>[μm] |
| <i>code_r</i>   | I [A] | U [V] | $t^*$ [μs] |                                 |                               |            |             |
| 1   | 0.8   | 180   | 56         | 0.289                           |                               | 0.29       | 4.50        |
| 2   | 2     | 180   | 91         | 0.814                           |                               | 0.81       | 9.17        |
| 3   | 4     | 140   | 270        | 9.261                           |                               | 9.26       | 16.25       |
| 4   | 11    | 140   | 350        | 22.511                          |                               | 22.5       | 27.50       |

\* pulse duration

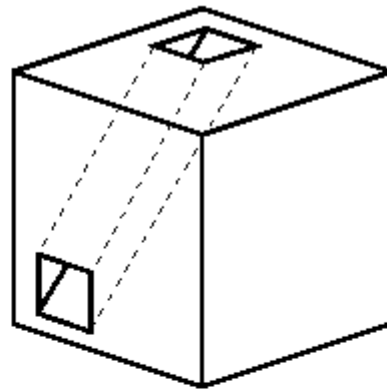
\*\* edge wear still to be acquired

| <i>code_e</i> | Electrode material        |
|---------------|---------------------------|
| 1             | Electrolytic copper (ECu) |
| 2             | graphite                  |
| 3             | Wolfram-ECu               |

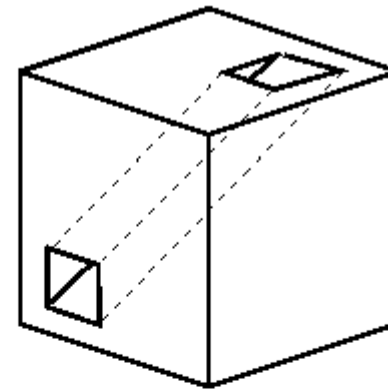
# Primitives of features



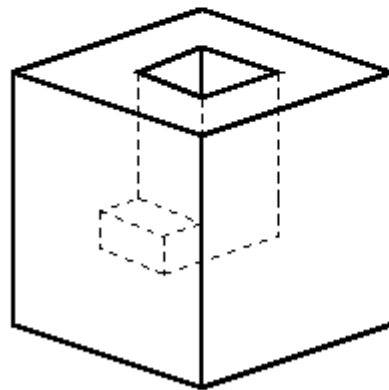
Primitive 1



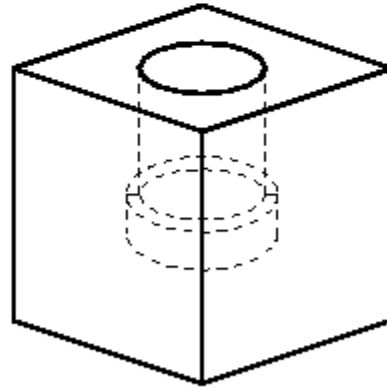
Primitive 2



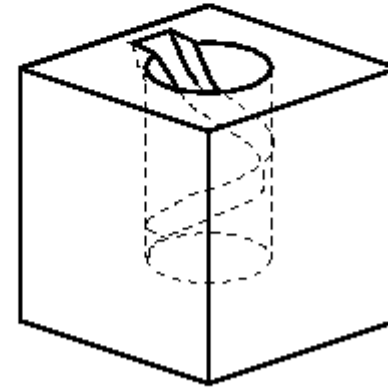
Primitive 3



Primitive 4

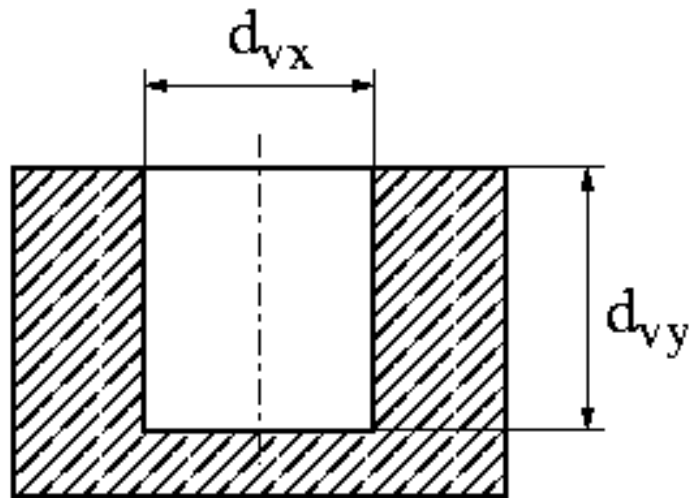


Primitive 5

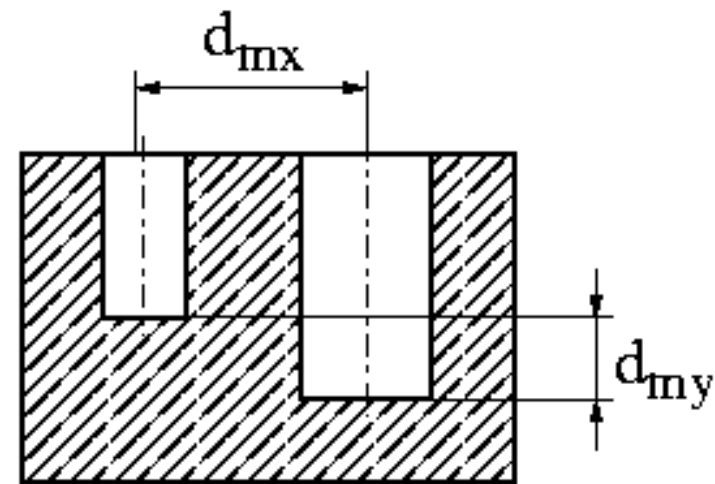


Primitive 6

# Dimensional tolerances



(a) Dimensional tolerances in one feature



(b) Dimensional tolerances between features

# Designing protocol

1/2

- Considering the guidelines for workpiece material and shapes of the bottom of the feature
- Designer defines:  
material, size of the workpiece, shapes of the features -  
software checks if the part can be machined with available machines → corrections
- Defining tolerances - software determines the critical parameters
- Designer considers values of critical parameters and, (if possible) makes corrections
- Designer can change non-critical parameters according to software proposals

# Designing protocol

2/2

- Determining surface roughness, radius and depth of heat-affected zone
- Software suggests electrode material and specifies critical parameters
- Designer considers values of critical parameters and (if possible) makes corrections
- Designer can change non-critical parameters according to software proposals

# Conclusions



- Introducing the manufacturing point of view to the designer - enabling design for manufacturing
- Instead of covering many technologies (wide) we study only EDM manufacturing technology (deep)
- System is based on finding the critical design parameters