# Fabrizio D'Errico

# The QFD4Mat User Manual

# Ver.0.2 (TESTING)

Annex to:

F.D'Errico, Material Selections by a Hybrid Multi-Criteria Approach

Springer

## NOTE: Only the white colored cells are editable

#### Active sheets:

- Define materials
- QFD4Mat
- Bubble Maps
- Value Curves
- Failure Modes
- Table 1 Conversion 0-5 scale
- Table 2 ASHBY Indexes
- Table 3 Symbols for Ashby Indexes

#### Step 1:

1.1) Activate "DEFINE MATERIAL" sheet

1.2) Define candidate material; write in cell the candidate material to screen (UP TO 4 materials can be contemporarily screened)

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### <u>Step 2:</u>

2.1) Activate the "QFD4Mat" sheet by click on the QFD4Mat tag;



2.2) Start to filling up white cells in the left shoulder of the matrix, the **Product Requirements** or **product key-features**; chose one of seven failure modes;

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2.3) Insert the relative importance score (0 to 5 values are allowed);

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2.4) Complete the left-shoulder of the QFD4Mat; a maximum of 29 product key-features are allowed in the free-excel version:

- 8 product key-features for Failure Modes;
- 6 product key-features for Material Cost subcategory;
- 8 product key-features for the Transformation Cost subcategory;
- 7 product key-features for the Receptiveness category;

**NOTE:** To the above **product key-features**, further **GLOBAL PERFORMANCE INDEX** can be added. To calculate it, when needed, you may refer to file **"Global Material Index-custom.xls"** provided.



### <u>Step 3:</u>

3.1) Start to fill up the top of the matrix by completing per column (20 columns are available in this free-excle version) as it follows:

3.1.1) Write the **Key-Factors for Material and Process Selection** (hereinafter key-factors or key-features of material) of your interest.

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<u>NOTE:</u> For the "Failure MODE" subcategory category, it is suggested to refer to the sheet "FAILURE MODE" (see figure below);

		Court and Court		
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	Failure modes	Description		
	A mure modes	Description		
	Plastic deformation and break by overload	due to overnass the yield strength or tensile strength:		
	Corrosion	due to chemical interactions with the environment		
	Wear	due to friction between two surfaces		
	Fatigue	caused by cyclic loading		
	Surface fations	caused by cyclic loading acting on ton surfac		
	Fact fractura	due to impact loading that can bring materials to brittle fracture up.	dar enacific circumstancas	
	Crean monture	due to impact loading that can oring materials to oritife matture day	over time when motels are	mbiastad
	Creep rupture	due to accumulation (time-dependent faiture) of plastic elongation	over time when metals are	subjected
	Failure damage	Key-features		
	Disstic deformation/break by quarload	Primary UTS (MDa)	VS [MDa]	KV [Ioula]
	Plastic deformation of eak by overload	V Ineul Competenceto	10 [aira]	Kv [Joure]
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	Wear	K [mpy], Corrosion rate H, hardness [e.g. Vickers]		
	Wear Fatigue	H, Impy, Corrosson rate H, hardness [e.g. Vickers] Se [MPa]	YS [MPa]	Ra, Surface roughness
	Vear Fatigue Surface fatigue	N. (Imp?), Corrosson rate H. Randress (e.g. Vickers) Se [MPa] Hsurface, surface hardness	YS [MPa] Effective case depth	Ra, Surface roughness Ra, Surface roughness
	Corrosion Wear Fatigue Surface fatigue Fast fracture	K (Imp?), Corrosson rate H, hardness (e.g. Vickers) Se (MPa) Hsurface, surface hardness K <sub>b</sub> (MPa \sqrt{m})	YS [MPa] Effective case depth KV [Joule]	Ra, Surface roughness Ra, Surface roughness YS [MPa]
	Corrosion Wear Fatigue Surface fatigue Fast fracture Creep rupture	K. [mp], Corrosson rate       H. hardness (e.g. Vickers)       Se [MPa]       Hsurface, surface hardness       K <sub>bc</sub> [MPa \sqrt{m}]       Tm, melting temperature [*C]	YS [MPa] Effective case depth KV [Joule] Q, activation energy for creep [KJ/mol]	Ra, Surface roughness Ra, Surface roughness YS [MPa]
	Corroson Wear Fatigue Surface fatigue Fast fracture Creep rupture	N (http:// Controlsen inter H. Kandenses (e.g. Vickers) Se [MPa] Hswifface, surface hardness K <sub>lz</sub> [MPa 'm] Tm, melting temperature ["C]	YS [MPa] Effective case depth KV [Joule] Q, activation energy for creep [KJ/mol]	Ra, Surface roughness Ra, Surface roughness YS [MPa]
	Corrosion Wear Fatigue Surface fatigue Fast fracture Creep rupture	N (Imp), Corroson nie H. Randense (e.g. Vickers) Se [MPa] Hsurface, surface hardness K <sub>h</sub> [MPa \m] Tm, melting temperature [*C]	YS [MPa] Effective case depth KV [Joule] Q, activation energy for creep [KJ/mol]	Ra, Surface roughness Ra, Surface roughness YS [MPa]
	Corrosion Wear Fatigue Surface fatigue Fast fracture Creep rupture	K. [mp], Corrosson rate       H. hardness (e.g. Vickers)       Se [MPa]       Hsurface, surface hardness       K <sub>tt</sub> [MPa \m]       Tm, melting temperature [*C]	YS [MPa] Effective case depth KV [Joule] Q, activation energy for creep [KJ/mol]	Ra, Surface roughness Ra, Surface roughness YS [MPa]
	Corroson Wear Fatigue Surface fatigue Fast fracture Creep rupture	N (http:// Controlsen inter H. kardenses (e.g. Vickers) Se [MPa] Hsurface, surface hardness K <sub>E</sub> [MPa \m] Tm, melting temperature ['C]	YS [MPa] Effective case depth KV [Joule] Q, activation energy for creep [KJ mol]	Ra, Surface roughness Ra, Surface roughness YS [MPa]
	Corroson Wear Fatigue Surface fatigue Fast fracture Creep rupture	N (Imp), Corroson nie H, Hardense (e.g. Vickers) Se [MPa] Hsurface, surface hardness K <sub>R</sub> [MPa \m] Tm, melting temperature [*C]	YS [MPa] Effective case depth KV [Joule] Q. activation energy for creep [KJ:mol]	Ra, Surface roughness Ra, Surface roughness YS [MPa]
	Corroson Wear Fatigue Surface fatigue Fast fracture Creep rupture	N (http:// Controlsen inter H. Bardness (E. Vickers) Se [MPa] Hsurface, surface hardness K <sub>in</sub> [MPa <sup>-/</sup> m] Tm, melting temperature ["C]	YS [MPa] Effective case depth KV [Joule] Q, activation energy for creep [KJ/mol]	Ra, Surface roughness Ra, Surface roughness YS [MPa]
	Corrosion Wear Fatigue Surface fatigue Fast fracture Creep rupture	N (Imp), Corroson nae H, Randess (E vickers) Se [MPa] Hsurface, surface hardness K <sub>K</sub> [MPa 'm] Tm, melting temperature [°C]	YS [MPa] Effective case depth KV [Joule] Q. activation energy for creep [KJ/mol]	Ra, Surface roughness Ra, Surface roughness YS [MPa]

3.1.2) Fill up for the **Key-Factors** identified the: a) the Direction of Improvement (choose " $\blacktriangle$ " if improvement increases as key-feature increase, or " $\blacktriangledown$ " in the opposite case); b) the category of the key-factors, distinguishing in: P = Performance, C = cost and R = Receptiveness; c) in the cells that build the **correlation matrix space**, scrolling down the column for the specific key-factor you are addressing, define the type of correlation (i.e. strong " $\bullet$ ", medium " $\circ$ ", weak " $\bigtriangledown$ ", left empty cell for no correlation) between the **key-Factor** (the column of correlation matrix space) of material you defined (e.g. UTS in the example here below) and the **Key-Product features** (the rows of correlation matrix space) defined at **Step 1**. Note that a multiple correlation is possible, since each key-factor (i.e. correlation matrix column) can be linked to multiple product key-features (i.e. correlation matrix rows).



3.1.3) Proceed by this way to complete the analysis for each column, namely for each **Key-Factor** you might consider, the direction of improvement (e.g. either  $\blacktriangle$  or  $\triangledown$ ), the category (**P**, **C** or **R**) and the correlation type (strong " $\bullet$ ", medium "o", weak " $\nabla$ ", strength, no correlation). See the final result in the example just below.



#### <u>Step 4</u>

Now you need to score the 4 candidate materials per each key-factor by a 0-5 nondimensional scale. To this scope, for each column representing the key-factor you included in the analyses at STEP 3 (see the task 3.1.1), and per each candidate material you have to express the rate basing on a 0-5 scale. Because key-factor are usually measureable or quantifiable, you may use the **conversion module** provided in the sheet **"TABLE 1 – Conversion 0-5 scale"**, as shown in the example just below (as usual, consider white cell as the only editable cells):

4.1) Activate the "TABLE 1 – Conversion 0-5 scale" that reports the conversion table module;

4.2) Define from left to right:

4.2.1) the quantifiable key-factor you want to convert in 0-5 non dimensional scale (in the example we set the UTS measured in MPa);

4.2.2) the direction of improvement, by selecting **"direct"** in case the higher is the quantified keyfactor, the higher is the product performance (e.g. ultimate tensile strength, UTS, of material for a structural component) or "inverse" in case the higher is the key-factor value, the lower is the performance of product (e.g. material density for lightweight component).

4.2.3) The data values (from table, database, etc.) for each candidate material;



The final result is shown in figure below.

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		key-feature	Improvement		Input Data						
		Material Key- Features	Direction of improvement versus improvement of performance	Material	Data Measured	Average value of measured data	Converted value on 1-5 scale				
		UTS [Mpa]	Direct	UNI EN 18 NiCrMo 5 - Carburized UNI EN 42CrMo4 - Induction hardened UNI EN 42CrMo4 - Nitrided Ductile cast iron - induction hardened	380,0 450,0 450,0 125,0	351,25	3,2 3,8 3,8 1,1				
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	(eq.27)	Converted	$Value_{inverse} = 3 - 0$	Converted value <sub>direct</sub> $-3$ )							
-									2		

4.3) Copy the values obtained by task 4.2.3 in the sheet **QFD4Mat**, specifically in the first column of BOX 2, as it is shown below:



4.4) Proceed as for the task 4.3 to complete the BOX 2 data. The final result is shown below. **Final Score** are calculated, the **comparative diagram** is drawn and the **Bubble Maps** have been automatically drawn (carefully verify, before to check the **BUBBLE MAPS** by activating the "BUBBLE MAP" sheet that you have assigned to each Key-Factor (i.e. each column) the category **P**, **C** or **R**, as you should have done in task 3.1.3.





#### Step 5

To draw the product VALUE CURVE, proceed as follows:

5.1) Activate the "VALUE CURVES" sheet (note that data in BOX 2 have been automatically reported in the VALUE CURVES sheet). These CURVES are not yet sorted by the lowest to highest value by the RELATIVE IMPORTANCE expressed in percentage. This is clearly visible if you refer to dotted line ("relative importance" data series) in the diagram below.



You just need to sort correctly data, as it is follows:

5.3.1) select all the data in the BOX 3 (see above);





The final result is shown in figure below:

