



# Workshop "Material"

FEMFAT User Meeting 2021 Klaus Hofwimmer/ECS

June 21

### Content



- Required Material Data
- Generation of Material Data
- Calibration of Material Data from Tests
- Plastic Material Data Generation
- Material Data for Elastomers



# Required Material Data ...for fatigue/safety factor analysis with FEMFAT

Date: June 21 / Author: ECS St. Valentin

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### **Measuring what matters**

**MAGNA** 



### **Parameters for Haigh-Diagram**

**MAGNA** 



**B C**... derived from dynamic tests

**E G** ... derived from static tests



Define Material Parameters Select Material Class:						
General Structural Carbon Steels						
Material Parameters						
	Tension	Pressure	Bending	Shear		
Ultimate Strength	400.0	400.0	478.8	230.9		
Yield Strength	239.6	239.6	303.1	138.3		
Pulsating Strength	346.2	0.0	423.1	221.5		
Alternating Strength	180.0	180.0	200.9	103.9		

 Parameters are determined for unnotched specimen in tension and compression, bending and shear from static and dynamic tests.

Date: December 2020

S/N curves



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Tension/compression test rig with heat chamber



• The inclination k of S/N curve, endurance limit  $\sigma_{end}$  and cycle limit  $N_D$  are determined from tests at R=-1 for unnotched specimen.

### Flexible Definition of Slope for the Infinite Life Domain



 For "MINER Modified" the slope for the infinite life domain can be flexible defined with parameters a and b:

 $k_2 = a^*k_1 + b$ 

• Default settings according original Miner modified:



Type-Code of S-N Curve: Linear Model	(
Slope of S/N Curve: 12.00	
Cycle Limit of Endurance: 2000000	
Stress Limit of Endurance: 225.0 [N/	mm2]
Cycles at Failure: 0 (no	tused
Ultimate Strength: 0.0 [N/	mm2]
Survival Probability: 97.5000 [%]	
Slope of S/N Curve for Shear Loading: 0.00	
Cycle Limit of Endurance for Shear Loading: 0	
MINER Modified Parameter a: 2.00	
MINER Modified Parameter b: -1.00	



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# Notch influence – Stress gradient



- For taking the effect of stress gradient into account notched specimen are used at R=-1.
- The influence of relative stress gradient  $\chi'$  is taken into consideration for endurance limit  $\sigma_{end}$  and the slope k of S/N curve.





• The relative stress gradient is generated by using different notched geometries for the test specimens as well as alternating tensile and bending strength.

**MAGN** 



Date: January 2021 / Author: ECS St. Valentin

## Notch influence – Stress gradient



 Material data can be used to adjust the gradient influence

$$f_{GenDur} = 1 + \frac{(\sigma_{altBending}/\sigma_{altTC} - 1)}{(2/b)^{\nu}} \chi^{\nu}$$

	user	serdefparam.dbs						
\$	MATER	IAL-CLA	SS-DE	PENDE	ENT P	АКАМИ	ете	
ş Ş								
\$	Material	Exponent for	Slope	Exponent	Diameter	Diameter	Constant	Constant
\$	Class	Gradient -	Limit	I I	deff,N,m	deff,N,p	ad,m	ad,p
\$	1	Influence	AK2	AK3	in mm	in mm	for Kd,m	for Kd,p
\$	=======		======	========	=======	======	======	======
	1	0.30	3.0	2.0	40.0	40.0	0.15	0.30
	3	0.30	3.0	2.0	16.0	16.0	0.30	0.40
	6	0.30	3.0	2.0	40.0	40.0	0.15	0.30
	11	0.30	3.0	2.0	70.0	40.0	0.20	0.30
	16	0.00	3.0	2.0	16.0	16.0	0.30	0.40

Parameters for Stress Gradient Influence (optional)

Data Source:	Test	
Exponent nue:	0.30	]
Slope limit IFK2:	3.0	
Slope exponent IFK3:	2.0	

= G	eneral S/N-Data				
	Stress Condition Code:	Tension/Compress	ion	~ (1	not used for analysis)
	Stress Ratio:	-1.000	(not us	ed for analysis	5)
	Notch Factor:	0.00	(not us	ed for analysis	5)
	Relative Stress Gradient:	0.00	[1/mm]	(not used for	analysis)
	Thickness of Specimen:	7.5	[mm]		
	Roughness of Specimen:	1.0	[µm]		

Select Material Class:	eters			
General Structural C	arbon Steels		~	
Material Parameters -				
	Tension	Pressure	Bending	Shear
Ultimate Strength	690.0	690.0	826.0	398.0
Yield Strength	360.0	360.0	455.0	208.0
Pulsating Strength	540.0	0.0	660.0	331.5
Alternating Strength	310.0	310.0	340.0	180.0
Info				

Define Metarial Decemeters

### Notch influence – Support number as polygonal line

- Notch support number  $f\chi$  = Influence factor on endurance strength.
- Notch support number table for FEMFAT analysis: New dataset **237** in **ffd-file**.
  - No GUI representation of the dataset.
  - If dataset exists, analysis will be performed using this dataset.
  - If dataset does not exist, selected FEMFAT method will be used.
  - When gradient larger than last point, then support number of last point will be used.

### -1 237

Support Number dependent on relative stress gradient Source: 6 0.00 1.00 0.30 1.30 1.00 1.50 2.00 2.00 3.00 2.50 3.00 5.00



## **Cyclic stress strain curve**

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- The cyclic coefficient of hardening K' and the cyclic exponent of hardening n' are utilized in the FEMFAT plast module for consideration of mean stress redistributions by local plastification.
- K' and/or n' have not been defined, they will be automatically generated by FEMFAT based on the Uniform Material Law, as a function of the material group and the ultimate tensile strength Rm.









### **Neuber correction of mean and amplitude stress**



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### Scaled normal stress in critical plane

- Alternating shear stress is used for equivalent stress calculation:
  - Calculation of principal stresses  $\sigma_1 > \sigma_2 > \sigma_3$
  - 2 Calculation of the ratio of minimum/maximum principal normal stress at all times.

 $\sigma_3$ 

 $V = -1 \mid \tau$ 

V = 0

 $\sigma_3$ 

Material Parameters

 $\sigma_1$ 

$$V = \frac{\sigma_3}{\sigma_1} \text{ for } |\sigma_1| > |\sigma_3|$$
$$V = \frac{\sigma_1}{\sigma_3} \text{ for } |\sigma_3| > |\sigma_1|$$



$$f = 1 + (1 - k)V \qquad k = \frac{\sigma_A}{\tau_A}$$



The critical plane procedure is performed with normal stress component.

$$\sigma_{eq} = f \cdot \sigma_n = (1 + (1 - k)V) \cdot \sigma_n, \qquad \sigma_n = \sigma_{ij} n_j n_i$$

	Tension	Pressure	Bending	Shear
Ultimate Strength	690.0	690.0	826.0	398.0
Yield Strength	360.0	360.0	455.0	208.0
Pulsating Strength	540.0	0.0	660.0	331.5
Alternating Strength [	310.0	310.0	340.0	180.0

 $\sigma_1$ 



V = +1

τ

 $\sigma_{\scriptscriptstyle H}$ 

### **Necessary Material Properties for FEMFAT**

 Depending on the requested calculation output, specific material parameters need to be defined or measured:
 Requested Calculation Output

			Damage	Endurance Safety Factor	Static Safety Factor
	UTS	Tension			
	UTS	Compression			
ទ	UTS	Bending			
nete	Yield	Tension			
aran	Yield	Shear	*	*	
al Pê	Tension/Compression S/N Curve	Endurance Limit			
teri		Inclination			
/ Ma		Cycle Limit			
sary	Endurance Limit Pulsating	Tension			
seces	Endurance Limit Alternating	Bending			
ž	Endurance Limit Alternating	Shear			
	n' and K'				
	Quasistatic Stress-Strain Curve				

### \*... Not defined for Grey Cast Iron

Absolutely needed		
Absolutely needed if Mean stress is On		
Value is generated by FEMFAT if not defined by User		
Based on analysis target option (Static Safety Factor Yield or Safety factor User defined Cycles)		
Author: EEMEAT SUDDORT		



# Generation of Material Data ...based on known values

Author: FEMFAT SUPPORT

# I: Uniform Material Law and FKM Guideline

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- **MAGNA**
- The Uniform Material Law was developed on the basis of specimen tests for specific material classes to generate a correlation based on the material class and the UTS of the material.
- The UML can be used to produce values for creating a material file for FEMFAT (\*.ffd).
- For unalloyed or low—alloyed steels, aluminium and titanium the cyclic stabilized data can be calculated.
  - All these values can be calculated by the help of UTS and the young's modulus.
  - Further cyclic strength data (endurance limit,...) are calculated based on FKM Guideline.

Cyclic Stabilized Data Cyclic Hardening Coefficient K': Cyclic Hardening Exponent n': Fatigue Strength Coefficient Sigma'f. Fatigue Strength Exponent b: Fatigue Ductility Coefficient Epsilon'f: Fatigue Ductility Exponent c:

[more information about the UML in e.g. MATERIALS DATA FOR CYLCIC LOADING Supplement 1]

### **FKM Guideline**

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- The FKM is a standard which is very common in Europe and used by many European manufacturers.
- In general it can be seen as a conservative way of analysis.
- The material generator's formulae (FKM setting) calculates fatigue limits and cycle limit for a survival probability of 97.5%.
- Based on the FKM, several setting and influences can be used and activated in every analysis (stress gradient, mean stress, surface roughness,....).

Influence Factors	
General Factors Surface Treatment WELD SPOT	
Stress Gradient	
Endurance Limit Slope / Cycle Limit	FKM-Guideline 👻
Mean Stress	
Endurance Limit	FKM-Guideline (mod.)
Slope / Cycle Limit	FEMFAT 5.1
Surface Roughness	FKM / IABG (Rz)
Constant Stresses	FEMFAT 2.0
Mean (and Amplitude) Stress Rearrangement PLA	ST Mean: Without Sequence Influence 👻
	Max./Min. Principal Stress
Modified Haigh Diagram (Ultimate Tensile Strength)	Stress Gradient Influence 👻
Technological Size Influence	FKM-Guideline -
Statistical Influence	Gauss (LogN)
✓ Isothermal Temperature Influence	FKM-Guideline 👻

[more information about the FKM can be found in FKM-Guideline-Analytical-Strength-Assessment-of-Components-in-Mechanical-Engineering-6th-Revised-Edition]



# II: Material Generator

### **Material Generator**

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 A material data record is created for FEMFAT analysis based on the material class and several strength data and characteristics.

Standard	FKM (default)	TGL	
Approach	stress-based	strain-based	

### FEMFAT entry screen

Material Data	
Manage Materials	New Copy Defect Definition

### userdefparam\_2021.dbs

¢			********	********						
5	DATAS	BASE FOR	USER-DEFI	NED PARAM	ETERS					
¢	1	for Fati	gue Solve	r FEMFAT	1					
6										
5										
c										
FEMFAT-Vers	10n	: 2021.	Sept. 20	21						
Filename		: /mate	rial data	base/user	defparam 2	1021.dbs				
8										
MATERT	AL-CIAS		DEND	FNT D	APAMI					
\$										
\$	Function for				Disester	Constant	Constant			
Material	Exponent for	Slope	Exponent	(Diameter	Diameter	Constant	Constant			
S	Exponent for   Gradient -	Slope Limit	Exponent	(Diameter  deff,N,m	Diameter	Constant    ad,m	Constant   ad,p			
C Material     Class   Class	Exponent for   Gradient - Influence	Slope Limit AK2	Exponent     AK3	Diameter  deff,N,m   in mm	Diameter  deff,N,p   in mm	Constant    ad,m    for Kd,m	Constant ad,p for Kd,p	   	   	1
Class   	Exponent for Gradient - Influence	Slope Limit AK2	Exponent     AK3	Diameter  deff,N,m   in mm	Diameter  deff,N,p   in mm	Constant   ad,m   for Kd,m	Constant ad,p for Kd,p		····       	····       
6 6 Material     7 Class   1	Exponent for Gradient - Influence 0.30	Slope Limit AK2 3.0	Exponent AK3	(Diameter (deff,N,m ) in mm 40.0	Diameter (deff,N,p)   in mm 40.0	Constant ad,m for Kd,m 0.15	Constant ad,p for Kd,p 0.30		     	
<pre>0</pre>	Exponent for   Gradient - Influence 0.30 0.30	Slope Limit AK2 3.0 3.0	Exponent   AK3   2.0 2.0	(Diameter (deff,N,m ) in mm 40.0 16.0	Diameter (deff,N,p)   in mm 	Constant ad,m for Kd,m 0.15 0.30	Constant ad,p for Ed,p 0.30 0.40	····       	···· [ ] ]	····       
C	Exponent for Gradient - Influence 0.30 0.30 0.30	Slope Limit AK2 3.0 3.0 3.0	Exponent AK3 2.0 2.0 2.0	(Diameter  deff,N,m   in mm   40.0  6.0  40.0	Diameter [deff,N,p]   in mm 	Constant  ad,m   for Ed,m  0.15 0.30 0.15	Constant ad,p for Ed,p 0.30 0.40 0.30	····       	···· 1 1 1	····       
Class   Class   Class	Exponent for Gradient - Influence 0.30 0.30 0.30 0.30	310pe Limit AK2 3.0 3.0 3.0 3.0 3.0	Exponent AK3 2.0 2.0 2.0 2.0 2.0	(Diameter  deff,N,m   in mm 40.0 16.0 40.0 70.0	Diameter (deff,N,p) i n mm 40.0 16.0 40.0 40.0	Constant   ad,m   for Ed,m  0.15 0.30 0.15 0.20	Constant ad,p for Ed,p 0.30 0.40 0.30 0.30	···· ]     	···· 1 1 1	····       
C	Exponent for Gradient - Influence 0.30 0.30 0.30 0.30 0.30	310pe Limit AK2 3.0 3.0 3.0 3.0 3.0 3.0	Exponent AK3 2.0 2.0 2.0 2.0 2.0 2.0 2.0	(Diameter  deff,N,m   in mm 40.0 16.0 40.0 70.0 16.0	(Diameter) (deff,N,p)   in mm 40.0 16.0 40.0 40.0 16.0	Constant ad,m for Kd,m 0.15 0.30 0.15 0.20 0.30	Constant ad,p for Kd,p 0.30 0.40 0.30 0.30 0.40	···· ]   	····   ·     	···· 1 1 1
Class   Class   Class   Class	Exponent for Gradient - Influence 0.30 0.30 0.30 0.30 0.30 0.30 0.30	310pe Limit AK2 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0	Exponent AK3 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0	(Diameter  deff,N,m   in mm 	(Diameter) (deff,N,p)   in mm 40.0 16.0 40.0 40.0 16.0 40.0 16.0	Constant   ad,m   for Kd,m  0.15 0.30 0.15 0.20 0.20 0.30 0.25	Constant ad,p for Kd,p 0.30 0.40 0.30 0.40 0.30		····   ·     	···· 1 1 1
Class   Class   Class   1 3 6 11 16 17 20	Exponent for Gradient - Influence 0.30 0.30 0.30 0.30 0.30 0.30 0.30 0.3	310pe Limit AK2 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0	Exponent     AK3   	(Diameter  deff,N,m   in mm   40.0 16.0 40.0 70.0 16.0 16.0 16.0	Diameter (deff,N,p)   in mm 	Constant   ad,m   for Kd,m  0.15 0.30 0.15 0.20 0.30 0.25 0.50	Constant ad,p for Ed,p 0.30 0.40 0.30 0.30 0.40 0.30 0.40 0.30 0.50	     1	1 1 1	···· 1 1 1

### **Stress based Material Generator**

• After initial determination of the strength data, any changes can only be made on a "per line" basis



erial Generator		1	-	
Define Material Parame	ters			
Select Material Class:				
General Structural C	arbon Steels		-	
Material Parameters -				
	Tension	Pressure	Bending	Shear
Ultimate Strength	400.0	400.0	478.8	230.9
Yield Strength	239.6	239.6	303.1	138.3
Pulsating Strength	346.2	0.0	423.1	221.5
Alternating Strength	180.0	180.0	200.9	103.9
Info Also these parameter elongation at rupture hardening exponent r endurance, survival p roughness of specim strength coefficient.	s are define A5, cyclic ha ', slope of S robability, thi en, tempera	d: Young's n rdening coef -N curve, cyc ickness of sp ture of speci	nodulus, ficient K', cycli le limit of becimen, men, fatigue	c
		0	к	Cancel

Parameters can only be changed on a line basis.

Note that pulsating strength for pressure is always set to zero for all material groups



roughness of specimen, temperature of specimen, fatigue

Cancel

OK

strength coefficient

Assign a material class and provide one single value for one single tensile strength value

**MAGNA** 

All strength values edited by the material generator must be confirmed by pressing <Enter>!

Author: FEMFAT SUPPORT

### **Strain based Material Generator**

 Ultimate and/or yield stress as well as four strain S/N curve parameters need to be defined. Endurance cycle limit can be edited by the user.

Material Data			
Manage Materials  1 - Material 1  1 - Material 1	mport New Export Copy Report X Delete	Material Generator Controlling: ○ Stress ◎ Strain Standard: FKM Defect Definition © Gopen	Diagrams

FEMFAT calculates stress based material parameters from strain life parameters.

Import Strai	n Life Par	ameter				
File Format:	MARLIS	Database F	ile	•		
File Name:	_					
Strain Life F	Parameter	Definition				
Select Mater	rial Class:					
Case Ha	rdening S	teels			-	
Static Prope	rties —					
Ultimate :	Strength:					870.0
Yield Stre	ngth:					570.7
Strain Life C	urve —					
Fatigue S	trength C	oefficient S	igma'f:		13	386.01
Fatigue S	trength E	ponent b:			-(	0.0909
Fatigue D	uctility Co	efficient E	psilon'f:		(	0.9086
Fatigue D	ouctility Exp	ponent c:			-(	0.8264
Infinite Life D	Jomain -					
Fatigue E	ndurance	Cycle Limit			20	00000
Calculate P	arameters	s				
			Calculate			
	Cyclic Har	dening Coe	fficient K	140	0.70	
	Cyclic Har	dening Exp	onent n'	0.1	100	
		Tension	Pressure	Bendi	ng	Shea
Ultimate Str	ength	870.0	870.0	1043	.1	502.3
Yield Streng	th	570.7	570.7	675	.7	329.5
	rength	577.8	0.0	686	.4	449.3
Pulsating St	Strength	348.0	348.0	375	.1	200.9
Pulsating St Alternating S						
Pulsating St Alternating S Info ———						
Pulsating St Alternating St Info Also thes elongation hardening specimen	e parame n at ruptur g exponen 1, tempera	ters are def re A5, cyclic it n', slope o ature of spec	ined: Young hardening o f S-N curve, simen.	's modul coefficien thicknes	us, tK',cy sof	clic

MAGNA

### **Conversion of E/N-curves into S/N curves**





### **Conversion of E/N-curves into S/N curves**



Strain equivalence is a necessary condition for comparison of coefficients to obtain the coefficients for description of S/N curve.



# III: How to generate a material in FEMFAT

### **General workflow**





### FAQ's



- What is the minimum requirement to generate a material in FEMFAT?
  - The material class and UTS is needed to generate a complete material card.
- What if I do not know the material class?
  - The material class is defined in the standards. Therefore, it is recommended to search for the standard where the material is defined. Another possibility is to search the datasheet from a supplier. The datasheet includes also the information of the material class.

1.0038 (DIN EN 10025-2 : 2005-04) S235JR Structural steels (EN)

Material description

Material Number:	1.0038 (DIN EN 10025-2 : 2005-04)
Standard:	DIN EN 10025-2 : 2005-04
Replacement:	Supersedes DIN EN 10025 : 1994-03
Standard State:	valid
Origin:	Deutschland
Remark:	The hot rolled, unalloyed quality steel S235JR is applicated for welding constructions up to temperatures of -20°C subject to the load. The steel is not intended for heat treatment. Stress relieving annealing is allowed. Products in the delivery condition +N may be hot formed and/or normalized after delivery. For long products and continuous rolled flats the delivery condition is up to the producer +AR, +N or +M. The delivery condition of four-high rolled sheet is also up to the producer and may be +AR or +N. Both conditions can be ordered. For this steel are available (mat. no 1.0122, S235JRC) grades for folding, roll forming to shape and cold drawing.
Application temperature:	≤ 300.0

Source: WIAM material database IMA Dresden

### FAQ's



- What if I do not know any strength data from my material?
  - This also can be found in the standards. Another possibility is a search in the internet at supplier homepages or material handbooks.

1.0038 (DIN EN 10025-2 : 2005-04)
S235JR
Structural steels (EN)

Mechanical Properties

Nominal Size [mm]	Temperature [°C]	Tensile Strength [N/mm²]	Yield Strength [N/mm²]
Semi-finished Product: strip, sheet, wide t Condition: normalised or normalising rolled Specimen Direction: longitudinal	flat, section, rod, wire rod		
≤ 1.000	20	360.0 - 510.0	≥ 235.00
1.000 - 1.500	20	360.0 - 510.0	≥ 235.00
1.500 - 2.000	20	360.0 - 510.0	≥ 235.00
2.000 - 2.500	20	360.0 - 510.0	≥ 235.00
2.500 - 3.000	20	360.0 - 510.0	≥ 235.00
3.000 - 16.000	20	360.0 - 510.0	≥ 235.00
16.000 - 40.000	20	360.0 - 510.0	≥ 225.00
40.000 - 63.000	20	360.0 - 510.0	≥ 215.00
63.000 - 80.000	20	360.0 - 510.0	≥ 215.00
80.000 - 100.000	20	360.0 - 510.0	≥ 215.00
100.000 - 150.000	20	350.0 - 500.0	≥ 195.00

	SALZO FLAC	GITTEF CHSTA hmen der Salz Mechanisch	R AHL gitter Gruppe le Eigenschaften <sup>1)</sup>
Werkstoffnummer	1.0038	Nenndicke e	Streckgrenze ReH
gemäß	DIN EN 10025-2	≤16 mm	≥ 235 MPa
Festigkeitsklasse	Α	>16 mm	≥ 225 MPa
S235JI	R	Nenndicke e <3 mm ≥3 mm	Zugfestigkeit R <sub>m</sub> 360 – 510 MPa 360 – 510 MPa
Unlegierte	e Baustähle	Nenndicke e <3 mm 3≤e≤25 mm	Bruchdehnung A <sup>₂</sup> ) (längs/quer) ≥ 21/19 % ≥ 26/24 %

Source: Internet Salzgitter Flachstahl datasheet from supplier

Source: WIAM material database IMA Dresden

### FAQ's



- What if the strength data is given by a range?
  - To be on the safe side use the minimum values to generate the material in FEMFAT.
  - Also possible is to generate 3 materials, a worst case, a best case and a material with the mean values.
     Using the 3 different materials in a FEMFAT analysis will lead to 3 different results.
    - Following conclusions can be derived:
    - 1) Sensitivity of the part due to material deviation
    - 2) Minimum requirement of the static material properties
- What if I just have the Yield strength?
  - Therefore, the material generation is done by directly input the Yield strength. If the material card is new either the UTS or the Yield strength can be used to generate a fully defined material card.
- What if the material class of my material is not available in the material database?
  - If the material class is not available in the FEMFAT material generator a comparable group has to be chosen. The next page shows a conversion table for the most common materials which are not listed in the material generator.

### **Material Classes for Generation of Missing Data**



Material	Class for Material Generator	Remark
Stainless steel	Case hardening steel	
Plastic (not reinforced)	Alu wrought alloy	Switch material class to plastic
Plastic (fibre reinforced)	Alu cast alloy	Switch material class to plastic
Sinter metal	Nodular cast iron	Switch material class to sinter
Magnesium cast	Alu cast alloy	Switch material class to magnesium cast
Titan alloy	Case hardening steel	
Nickel base alloy	Heat treatable steel	Switch material class nickel base alloy
Copper alloy	Alu wrought alloy	
Spring steel	Heat treatable steel	Switch material class spring steel
Tool steel	Case hardening steel	Switch material class tool steel
Deep drawing steels	General structural steel	Switch material class deep drawing steel

• Please switch the material class manually to the corresponding material class if available. As the stress gradient influences and the influence on the inclination of the SN-curve can be different!

### Where to switch the material class



Header Lines	
Material and Specimen Name:	10NiCr5-4 Case Hardening Steel, blind hardened c
Remarks:	Standard No. 1.5805
Data Source:	Source: FKM 2002 & Material Generator MATGEN (
General Data	
Elastic Poisson's Ratio:	0.300
Plastic Poisson's Ratio:	0.00
Specific Mass:	0.000000000 [kg/mm3] (not used for analysis
Coefficient of Thermal Expansion:	0.000000000 [1/°C]
Material Class:	General Structural Carbon Steels
Temperature of Specimen:	General Structural Carbon Steels
Surface Roughness:	Higher Strength Weldable Structural Carbon Steels
Survival Probability of Endurance Data:	Finely Grained Steels Heat Treatable (Tempered) Steels
Linear Static Data	Case Hardening Steels
Young's Modulus X-Direction:	Duaiphase Steels TRIP-Steels
Young's Modulus Y-Direction:	Bake-Hardening Steels Micro Alloy Steels
Young's Modulus Z-Direction:	210000.00 [N/mm2] (not used for analysis)

### Material generation based on the UTS



Example

### <u>A) Material card based on UTS</u>

Material name: 10NiCr5 UTS= 800N/mm<sup>2</sup>

Define Material Paramete Select Material Class: Case Hardening Steels Material Parameters Ultimate Strength Yield Strength Pulsating Strength Alternating Strength	Tension 900.0 620.0 590.0	Pressure 900.0 620.0 0.0	<ul> <li>Bending</li> <li>1079.0</li> <li>734.0</li> <li>701.0</li> </ul>	Shear 520.0 358.0
Select Material Class: Case Hardening Steel: Material Parameters Ultimate Strength Yield Strength Pulsating Strength Alternating Strength	s Tension 900.0 620.0 590.0	Pressure 900.0 620.0 0.0	Bending 1079.0 734.0	Shear 520.0 358.0
Case Hardening Steels Material Parameters Ultimate Strength Yield Strength Pulsating Strength Alternating Strength	s Tension 900.0 620.0 590.0	Pressure 900.0 620.0 0.0	Bending 1079.0 734.0	Shear 520.0 358.0
Material Parameters Ultimate Strength Yield Strength Pulsating Strength Alternating Strength	Tension 900.0 620.0 590.0	Pressure 900.0 620.0 0.0	Bending 1079.0 734.0	Shear 520.0 358.0
Ultimate Strength Yield Strength Pulsating Strength Alternating Strength	Tension 900.0 620.0 590.0	Pressure 900.0 620.0 0.0	Bending 1079.0 734.0	Shear 520.0 358.0
Ultimate Strength Yield Strength Pulsating Strength Alternating Strength	900.0 620.0 590.0	900.0 620.0 0.0	1079.0 734.0	520.0 358.0
Yield Strength Pulsating Strength Alternating Strength	620.0 590.0	620.0 0.0	734.0	358.0
Pulsating Strength Alternating Strength	590.0	0.0	701.0	
Alternating Strength			701.0	459.0
	360.0	360.0	385.0	210.0
Info				
Also these parameters elongation at rupture A5 hardening exponent n', endurance, survival pro roughness of specimer	are define 5, cyclic ha slope of S bability, th n, tempera	d: Young's m rdening coef -N curve, cyc ickness of sp ture of speci	nodulus, ficient K', cycli le limit of becimen, men.	с
		OI	<	Cancel

### Steps for this example:

- 1. Available material from database: 10NiCr5-4\_FKM2002.ffd
- 2. Type in the UTS

Select Material Class:				
Case Hardening Stee	ls		-	
Material Parameters —				
_	Tension	Pressure	Bending	Shea
Ultimate Strength	800 0	800.0	959.2	461.9
Yield Strength	503.1	503.1	595.7	290.5
Pulsating Strength	542.4	0.0	644.4	421.8
Alternating Strength	320.0	320.0	346.4	184.8
Also these parameters elongation at rupture A hardening exponent n endurance, survival pr roughness of specime	s are define A5, cyclic ha ', slope of S obability, th en, tempera	ed: Young's n Irdening coef I-N curve, cyc Ickness of sp Iture of speci	nodulus, ficient K*, cycli le limit of becimen, men.	c
		OI	K	Cancel

### Material generation based on the Yield strength

### B) Material card based on YIELD

Material name: 10NiCr5 YIELD= 400N/mm<sup>2</sup>

Define Material Parame	ters			
Case Hardening Stee	els		-	
Material Parameters —				
	Tension	Pressure	Bending	Shear
Ultimate Strength	900.0	900.0	1079.0	520.0
Yield Strength	620.0	620.0	734.0	358.0
Pulsating Strength	590.0	0.0	701.0	459.0
Alternating Strength	360.0	360.0	385.0	210.0
Also these parameter elongation at rupture / hardening exponent n endurance, survival pi roughness of specim	's are define A5, cyclic ha I', slope of S robability, th en, tempera	ed: Young's m irdening coef I-N curve, cyc ickness of sp iture of speci	nodulus, ficient K', cycli le limit of becimen, men.	ic
		OI	<	Cancel
Imported star	idard i	materia	al from	

Steps for this example:

### Example

**MAGNA** 

- 1. Available material from database: 10NiCr5-4\_FKM2002.ffd
- 2. Type in the UTS such that the YIELD is matching. Also possible is to generate a new material card using the same material class and type in the YIELD directly

Material Parameters       Tension       Pressure       Bending       Shear         Ultimate Strength       694,0       694.0       832.1       400.7         Yield Strength       400.6       400.6       474.3       231.3         Pulsating Strength       485.8       0.0       577.1       377.8         Alternating Strength       277.6       277.6       302.7       160.3         Info       Also these parameters are defined: Young's modulus, elongation at rupture A5, cyclic hardening coefficient K', cyclic hardening exponent n', slope of S-N curve, cycle limit of endurance, survival probability, thickness of specimen, roughness of specimen, temperature of specimen.       OK       Cancel	Case Hardening Ste	els		<b>.</b>	
Tension       Pressure       Bending       Shear         Uttimate Strength       694,0       694,0       832.1       400.7         Yield Strength       400.6       400.6       474.3       231.3         Pulsating Strength       485.8       0.0       577.1       377.8         Alternating Strength       277.6       277.6       302.7       160.3         Info	Material Parameters –				
Ultimate Strength 694,0 694,0 832.1 400.7 Yield Strength 400.6 400.6 474.3 231.3 Pulsating Strength 485.8 0.0 577.1 377.8 Alternating Strength 277.6 277.6 302.7 160.3 Info Also these parameters are defined: Young's modulus, elongation at rupture A5, cyclic hardening coefficient K', cyclic hardening exponent n', slope of S-N curve, cycle limit of endurance, survival probability, thickness of specimen, roughness of specimen, temperature of specimen. OK Cancel		Tension	Pressure	Bending	Shear
Yield Strength       400.6       400.6       474.3       231.3         Pulsating Strength       485.8       0.0       577.1       377.8         Alternating Strength       277.6       277.6       302.7       160.3         Info	Ultimate Strength	6940	694.0	832.1	400.7
Pulsating Strength       485.8       0.0       577.1       377.8         Alternating Strength       277.6       277.6       302.7       160.3         Info	Yield Strength	400.6	400.6	474.3	231.3
Alternating Strength 277.6 277.6 302.7 160.3 Info Also these parameters are defined: Young's modulus, elongation at rupture A5, cyclic hardening coefficient K', cyclic hardening exponent n', slope of S-N curve, cycle limit of endurance, survival probability, thickness of specimen, roughness of specimen, temperature of specimen. OK Cancel	Pulsating Strength	485.8	0.0	577.1	377.8
Info Also these parameters are defined: Young's modulus, elongation at rupture A5, cyclic hardening coefficient K', cyclic hardening exponent n', slope of S-N curve, cycle limit of endurance, survival probability, thickness of specimen, roughness of specimen, temperature of specimen. OK Cancel	Alternating Strength	277.6	277.6	302.7	160.3
OK Cancel	Also these paramete	A5 cvclic har	dening coef	ficient K', cycli	с
	elongation at rupture hardening exponent endurance, survival ¢ roughness of specin	n', slope of S- probability, thi nen, temperat	N curve, cyc ckness of sp ure of speci	le limit of becimen, men.	

### Material generation based on UTS and Yield strength

### <u>C) Material card based on UTS & YIELD</u>

Material name: 10NiCr5 UTS= 850N/mm<sup>2</sup> YIELD= 600N/mm<sup>2</sup>

Define Material Parame	tore			
	1010			
Select Material Class:				
Case Hardening Stee	els		-	
Material Parameters —				
	Tension	Pressure	Bending	Shear
Ultimate Strength	900.0	900.0	1079.0	520.0
Yield Strength	620.0	620.0	734.0	358.0
Pulsating Strength	590.0	0.0	701.0	459.0
Alternating Strength	360.0	360.0	385.0	210.0
Also these parameter elongation at rupture hardening exponent n endurance, survival pi roughness of specim	s are define A5, cyclic ha ', slope of S robability, th en, tempera	d: Young's m rdening coef -N curve, cyc ickness of sp ture of speci	nodulus, ficient K', cycli le limit of becimen, men.	с
		O	K	Cancel
mported s	tanda	ard ma	aterial	from

Steps for this example:

- 1. Available material from database: 10NiCr5-4\_FKM2002.ffd
- 2. Type in the UTS
- 3. Modify the YIELD strength

aterial Generator	00	-	de la	×
Define Material Paramete	ers			
Select Material Class:				
Case Hardening Steel	s		-	
Material Parameters —				
_	Tension	Pressure	Bending	Shear
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	551.4	551.4	652.9	318.4
Pulsating Strength	567.8	0.0	674.5	441.5
Alternating Strength	340.0	340.0	366.9	196.3
Info				
Also these parameters elongation at rupture A hardening exponent n', endurance, survival pro roughness of specime	are define 5, cyclic ha slope of S bability, th n, tempera	ed: Young's m indening coef i-N curve, cyc ickness of sp iture of speci	nodulus, ficient K', cycli le limit of becimen, men.	ic
		Oł	<	Cancel
<ul> <li>Modify the second second</li></ul>	ne U⁻	TS to	850 N	J/mm²

	ters			
Select Material Class:				
Case Hardening Stee	els		-	
Material Parameters —				
	Tension	Pressure	Bending	Shea
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	600.0	600.0	710.4	346.4
Pulsating Strength	567.8	0.0	674.5	441.5
Alternating Strength	340.0	340.0	366.9	196.3
Info Also these parameter elongation at rupture / hardening exponent n	's are define A5, cyclic ha I', slope of S robability, thi	d: Young's m rdening coef -N curve, cyc ickness of sp	nodulus, ficient K', cycli le limit of becimen,	ic

- Modify the YIELD to 600 N/mm<sup>2</sup>
- Save the new material card

**MAGNA** 

# Material generation based on the UTS, Yield and alternating tensile strength

D) Material card based on UTS & YIELD & ATS (1/2)



Material name: 10NiCr5

Alt tensile str =  $400 \text{ N/mm}^2$ 

Tension

850.0

600.0

567.8

340.0

Pressure

850.0

600.0

340.0

0.0

UTS= 850Nmm<sup>2</sup>

Material Generator

Define Material Parameters Select Material Class: Case Hardening Steels Material Parameters

Ultimate Strength

Alternating Strength

Yield Strength Pulsating Strength

 $YIELD = 600 N/mm^2$ 

Also these parameters are defined: Young's modulus, elongation at rupture A5, cyclic hardening coefficient K; cyclic hardening exponent n', slope of S-N curve, cycle limit of endurance, survival probability, thickness of specimen, roughness of specimen, temperature of specimen.

OK Cancel

Bending

1019.2

710.4

674.5

366.9

Shear

346.4

441.5

196.3

# Material modified due to UTS and YIELD

Steps for this example:

- 1. Calculate the mean stress sensitivity
- 2. Type in the ATS
- Modify the pulsating strength with the calculated mean stress sensitivity

$$M = 2\frac{\sigma_{alt}}{\sigma_{puls}} - 1 \Longrightarrow \sigma_{puls} = 2\frac{\sigma_{alt}}{M+1}$$
$$M = 2\frac{340}{567.8} - 1 = 0.1976$$

 Calculate the mean stress sensitivity

Case Hardening Ste	els		-	
Material Parameters -				
	Tension	Pressure	Bending	Shear
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	600.0	600.0	710.4	346.4
Pulsating Strength	567.8	0.0	674.5	441.5
Alternating Strength	400.0	400.0	431.6	230.9
Also these paramete elongation at rupture hardening exponent r endurance, survival p	rs are define A5, cyclic ha n', slope of S robability, thi ien, tempera	d: Young's m rdening coef -N curve, cyc ickness of sp ture of speci	nodulus, ficient K', cycli le limit of becimen, men.	ic
roughness of specim				

### 36



Example

# Material generation based on the UTS, Yield and alternating tensile strength



<u>Material name: 10NiCr5</u> UTS= 850N/mm<sup>2</sup> YIELD= 600N/mm<sup>2</sup> Alt. tensile str. = 400 N/mm<sup>2</sup>

lact Material Clase:				
Oses Herdesias Ota	-1-			
Case Hardening Ste	eis		· · ·	
aterial Parameters —				
	Tension	Pressure	Bending	Shear
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	600.0	600.0	710.4	346.4
Pulsating Strength	567.8	0.0	674.5	441.5
Alternating Strength	40010	400.0	431.6	230.9
		400.0	101.0	
fo	rs are define	d: Young's n	nodulus,	
fo Also these paramete elongation at rupture	rs are define A5, cyclic ha	d: Young's n	nodulus, ficient K', cycli	c
fo Also these parameter elongation at rupture hardening exponent r endurance, survival p	rs are define A5, cyclic ha 1', slope of S robability, th	d: Young's n rdening coef -N curve, cyc ickness of st	nodulus, ficient K', cycli le limit of pecimen.	c
fo Also these paramete elongation at rupture hardening exponent r endurance, survival p roughness of specim	rs are define A5, cyclic ha 1', slope of S robability, th ien, tempera	d: Young's n rdening coef -N curve, cyc ickness of sp ture of speci	nodulus, ficient K', cycl le limit of pecimen, men.	c
fo Also these paramete elongation at rupture hardening exponent r endurance, survival p roughness of specim	rs are define A5, cyclic ha 1', slope of S robability, th ien, tempera	d: Young's n rdening coef -N curve, cyc ickness of sp ture of speci	nodulus, ficient K', cycl le limit of pecimen, men.	c
fo Also these paramete elongation at rupture hardening exponent r endurance, survival p roughness of specim	rs are define A5, cyclic ha I', slope of S robability, th ien, tempera	d: Young's n rdening coef -N curve, cyc ickness of sp ture of speci	nodulus, ficient K', cycl le limit of becimen, men.	c Cancel

Steps for this example:

- 1. Calculate the mean stress sensitivity
- 2. Type in the ATS
- Modify the pulsating strength with the calculated mean stress sensitivity

$$M = 2\frac{\sigma_{alt}}{\sigma_{puls}} - 1 \Longrightarrow \sigma_{puls} = 2\frac{\sigma_{alt}}{M+1}$$
$$\sigma_{puls} = 2\frac{400}{0.1976+1} = 668\frac{N}{mm^2}$$

 Calculate the new pulsating strength with the mean stress sensitivity 0.1976

Soloct Material Class:				
Select Material Class.				
Case Hardening Ste	els		<b>_</b>	
Material Parameters —				
	Tension	Pressure	Bending	Shea
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	600.0	600.0	710.4	346.4
Pulsating Strength	668.0	0.0	793.6	519.4
Alternating Strength	400.0	400.0	431.6	230.9
Also these parameter	rs are define A5, cyclic ha	d: Young's m rdening coef -N curve, cvc	nodulus, ficient K', cycli le limit of	ic

- Modify the PST to 668 N/mm<sup>2</sup>
- Save the new material card



Example

### FAQ

- **MAGNA**
- Why is it necessary to modify the pulsating strength according the mean stress sensitivity?
  - For each material class a different value of the mean stress sensitivity (MSS) is calculated.
  - If the MSS is not known, it is better to use the standard values from the material generator.



# Material generation based based on the UTS, Yield and alternating bending strength



Example

### E) Material card based on UTS & YIELD & ABS (1/2)

<u>Material name: 10NiCr5</u> UTS= 850N/mm<sup>2</sup> YIELD= 600N/mm<sup>2</sup> Alt. bending str. = 480 N/mm<sup>2</sup>

-Define Material Parame Select Material Class:	ters			
Case Hardening Stee	els		~	
Material Parameters —				
	Tension	Pressure	Bending	Shear
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	600.0	600.0	710.4	346.4
Pulsating Strength	567.8	0.0	674.5	352.4
Alternating Strength	340.0	340.0	366.9	196.3
Info Also these parameter	s are define	d: Young's m	nodulus, elon	gation at
rupture A5, cyclic hard n', slope of S-N curve, thickness of specime specimen, fatigue stre	ening coeffi cycle limit c n, roughnes ength coeffic	cient K', cycli of endurance, s of specime cient.	c hardening e survival prot en, temperatu	exponent ability, re of
rupture A5, cyclic hard n', slope of S-N curve, thickness of specime specimen, fatigue stre	ening coeffi cycle limit c n, roughnes ength coeffic	cient K', cycli of endurance, s of specime cient. O	c hardening e survival prob en, temperatu K	exponent vability, re of Cancel

Steps for this example:

- Calculate the mean stress sensitivity
- 2. Type in the ATS so that the ABS is matching
- 3. Modify the pulsating strength with the calculated mean stress sensitivity

$$M = 2\frac{\sigma_{alt}}{\sigma_{puls}} - 1 \Longrightarrow \sigma_{puls} = 2\frac{\sigma_{alt}}{M+1}$$
$$M = 2\frac{340}{567.8} - 1 = 0.1976$$

Calculate the mean stress sensitivity

Select Material Class:				
Case Hardening Ste	ele			
Material Parameters —	010			
	Tension	Pressure	Bending	Shear
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	600.0	600.0	710.4	346.4
Pulsating Strength	567.8	0.0	674.5	352.4
Alternating Strength	445 0	445.0	480.2	256.9
Info Also these parameter rupture A5, cyclic harc n', slope of S-N curve, thickness of specime specimen, fatigue str	rs are define lening coeffi , cycle limit c n, roughnes ength coeffic	d: Young's n cient K', cycli of endurance s of specime cient.	nodulus, elon c hardening e , survival prob en, temperatu	gation at exponent ability, re of

Modify the ATS to 445 N/mm<sup>2</sup> so that the ABS is matching 480 N/mm<sup>2</sup>

# Material generation based on the UTS, Yield and alternating bending strength



### E) Material card based on UTS & YIELD & ABS (2/2)

Material name: 10NiCr5 UTS= 850N/mm<sup>2</sup> YIELD= 600N/mm<sup>2</sup> Alt. bending str. = 480 N/mm<sup>2</sup>

Case Hardening St	eels		~	
laterial Parameters -				
	Tension	Pressure	Bending	Shear
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	600.0	600.0	710.4	346.4
Pulsating Strength	567.8	0.0	674.5	352.4
Alternating Strength	4450	445.0	480.2	256.9
Also these parameter rupture A5, cyclic har n', slope of S-N curv thickness of specim specimen, fatigue st	ers are define rdening coeffi e, cycle limit o en, roughnes trength coeffic	d: Young's m cient K', cycli f endurance, s of specime cient.	nodulus, elon c hardening e , survival prob en, temperatu	gation at xponent ability, re of

Steps for this example:

- 1. Calculate the mean stress sensitivity
- 2. Type in the ATS so that the ABS is matching
- 3. Modify the pulsating strength with the calculated mean stress sensitivity

$$M = 2\frac{\sigma_{alt}}{\sigma_{puls}} - 1 \Longrightarrow \sigma_{puls} = 2\frac{\sigma_{alt}}{M+1}$$
$$\sigma_{puls} = 2\frac{445}{0.1976+1} = 743\frac{N}{mm^2}$$

 Calculate the new pulsating strength with the mean stress sensitivity 0.1976

elect Material Class:				
Case Hardening Ste	els		~	
laterial Parameters -				
	Tension	Pressure	Bending	Shear
Ultimate Strength	850.0	850.0	1019.2	490.8
Yield Strength	600.0	600.0	710.4	346.4
Pulsating Strength	743 0	0.0	882.7	461.1
Alternating Strength	445.0	445.0	480.2	256.9
Also these paramete rupture A5, cyclic har n', slope of S-N curve	ers are define dening coeffi e, cycle limit o en, roughnes	d: Young's m cient K', cycli f endurance, s of specime	nodulus, elon c hardening e survival prot en, temperatu	gation at exponent bability, ire of

- Modify the PS to 743 N/mm<sup>2</sup>
- Save the new material card

Example



# Calibration of Material Data ... Based on Test Results

Author: FEMFAT SUPPORT

### **Overview**



- Specimen tests of one material for:
  - Static tensile test or cyclic stabilized tensile test
  - SN curves for different tensile load condition (R=-1, R=0, R=0.5, ....)
  - SN curves for different notched specimens
  - SN curves for different load types (tension, bending, torsion/shear)

### **BASIS: Tensile Test for Unnotched Specimen**



Static test σ-ε Curve 500 400 o [Nmm2] 300 ŝ Sal 200 100 0 0.01 0.02 0.03 Strain ɛ [-] 1 - AMaSi1 F32 Ultimate Strength: 310.0 [N/mm2] Yield Strength 260.0 [N/mm2] Young's Modulus: 72000.0 [N/n Elongation at Rupture A5: 10.0 [%] Ultimate Tensile Strength (UTS)

**Yield Strength** 

# SN curve for R=-1



### Parameter of SN Curve

- Endurance Limit  $\sigma_{end}$
- Slope k
- Cycle Limit N<sub>C</sub>

### Date: June 21 / Author: ECS St. Valentin

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### **SN Curve Tests for different Stress Ratios R**

• Calibration for R=0, R=0.5.... => Haigh Diagram



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### Calibration of inclination of S/N curve for Mean Stress

Inclination of S/N curve for a given mean stress is calculated from Haigh Diagram



- Determine the original S/N curve of the base material
- 2 Map the ultimate tensile stress on the line B1-B2
- **3** Determine the inclination of the modified S/N curve  $k_{C,\sigma m}$

N<u>с,м</u> log  $\sigma IITS.\sigma_m$ k<sub>C,σm</sub>  $\sigma_{\sigma UTS}(\sigma_m$ log  $\sigma_{ALT,\sigma m}$ 

### **Bending Test and Notched Specimen Test**



• Calibration of stress gradient influence:



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### **Design of experiments for a standard steel**



 Awareness of the influences that are taken into account by material properties helps designing test plans.

Material property	Following influences are concerned
Endurance stress limit tension/compression R=-1	Component S/N curve endurance limit Mean stress influence (Haigh-Diagram) Notch influence (stress gradient) Equivalent stress computation (cutting plane stress)
Endurance stress limit tension R=0 (pulsating)	Mean stress influence (Haigh-diagram)
Endurance stress limit bending R=-1	Notch influence (stress gradient)
Notch sensitivity exponent $\boldsymbol{\nu}$	Notch influence (stress gradient), derived from component S/N curve
Endurance stress limit shear R=-1	Equivalent cutting plane stress
Slope of S/N curve R=-1	Slope of component S/N curve
Yield stress in tension	Mean stress influence in Haigh-diagram
Cyclic stress-strain curve	Consideration of local plastification
Yield stress shear	Mean stress influence (mean stress)
Ultimate stress tension	Mean stress influence (Haigh-diagram)
Yield stress compression	Mean stress influence (Haigh-diagram)
Ultimate stress compression	Mean stress influence (Haigh-diagram)
Cycle limit of S/N curve R=-1	Cycle limit of component S/N curve
Modulus of elasticity E	Plasticity law (mean stress changes)
Elongation at rupture	Property ratio tension/shear (ductility)

Date: December 2020

Author: FEMFAT SUPPORT

### **Overview Material Database (FEMFAT 5.4, 2019)**

Material Class	Number of Materials
Steel	157
Cast Iron	82
Aluminum Wrought Alloys	89
Aluminum Casting Alloys	208
Magnesium Casting Alloys	4
Copper and Nickel Base Alloys	4
Epoxy Adhesive	1
Plastics without Reinforcement	2
Plastics with Short Fibers	15
Plastics with Continuous Fibers	1

5 Natural Rubber Materials in FEMFAT 5.4.2

**MAGNA** 

564 materials

Sources:

- 398 FKM-Guideline
- 17 WIAM-Database
- Other sources
   (datasheets, books, papers, google, etc.)



# **Plastic Materials** Material generation for non reinforced and short fiber reinforced plastic materials

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Two possible ways:

- Usage of FEMFAT material generator
- Modification of an existing similar material (\*.ffd file)

### **Plastic material generation: Material Generator**

### Non-reinforced Material

Define Material Parameters						
Select Material Class:						
Aluminium Wrought	Alloys		~			
Material Parameters —						
	Tension	Pressure	Bending	Shear		
Ultimate Strength	100,0	100.0	119.3	57.7		
Yield Strength	45.4	45.4	54.4	26.2		
Pulsating Strength	56.6	0.0	60.0	33.4		
Alternating Strength	30.0	30.0	40.5	17.3		

# Specimen Halgh Diagram

### **Reinforced Material**

Define Material Parame	eters			
Select Material Class:				
Aluminium Casting A	Alloys		$\sim$	
Material Parameters —				
	Tension	Pressure	Bending	Shear
Ultimate Strength	1000	150.0	120.0	75.0
Yield Strength	64.1	96.1	77.1	48.1
Pulsating Strength	46.2	0.0	61.0	36.8
Alternating Strength	30.0	30.0	46.2	22.5



### <u>Non-reinforced plastic material</u> Material class **Aluminum Wrought Alloy**.

**M MAGNA** 

<u>Reinforced plastic material</u> Material class **Aluminum Cast Alloy.** 

Change the material class to ,Plastic' after generation

The aim of this procedure is to get a FEMFAT material that identifies highly stressed areas. The damage value itself is still to be evaluated by the engineer.

### **Plastic material generation: Material Generator**

### **Reinforced Material**





Relations:



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- Stress gradient: (Attention to the specimen thickness)  $\sigma_{alt Bending} / \sigma_{alt TC} = 46.2 / 30.0 = 1.54$
- Mean stress influence: ( $\sigma_{alt TC}$  \*2/  $\sigma_{pulsating TC}$ ) -1= (30.0\*2/46.2)-1 = 0.30

Attention: In the case of the pulsating strength, the upper stress is entered in the table.

- For equivalent stress:  $\sigma_{\text{Yield, shear}} / \sigma_{\text{Yield, T/C}} = 48.1 / 64.1 = 0.75$   $\sigma_E = \sqrt{\sigma_n^2 + k^2 \tau^2} \quad k = \frac{\sigma_A}{\tau_A}$
- Static relations:

 $\sigma_{alt\ TC}$  /  $\sigma_{UTS\ T/C}$  = 30 / 100 = 0.30

### **Plastic material generation: Further Settings**

What else must be done:

- Change material class from 'aluminum wrought' or '-cast' to 'plastic'.
- S/N Curve:
  - Change cycle Limit from 1.0E7 -> 1.0E6
  - Change slope from 11.0 -> 12.0
- Settings for Gradient influence: Exponent v=0.6, AK2=5.0, AK3=0.55 (not necessary as of version 5.4.1, because of modified userdefparam.dbs)
- Check survival probability. If test data are used -> Ps=50%.
- Change specimen thickness from 7.5mm to 3.85mm : Reference material for gradient influence: Aluminum cast alloy gradient influence: 1.80 for specimen thickness 2.0mm 1.54 for specimen thickness 3.85mm (corresponds to 2.19 for thickness 2.0mm) 1.54 for specimen thickness 3.85mm (corresponds to 1.80 for thickness 2.0mm)
- Miner Modified Parameter in material: A=1 B=0 (Miner Elementary is automatically calculated for this material even if the calculation parameter is set to Miner Modified. So one can treat steel and plastic part in one analysis.)

### FEMFAT material generation: Modification of a existing similar material (\*.ffd file)

- The entries in the FEMFAT \*.ffd file are changed, e.g. starting from an already existing plastic material. The stress gradient, the mean stress sensitivity ... must be taken into account as described in the previous point.
- This is also the procedure for anisotropic plastic material.

1							
-1							
201							
SIEIR-FILE	2.0		508 -h			c	
EMS GRILON T	SG 50/4, CO	naitionea,	50% short	glass II.	bers, PA66+	6 semicr	ystalline
EMS GRILON T	SG 50/4, co	nditioned					
Confidental							
Last modific	ation: 21.7	.2015 by A	. Mösenbac	her			
-1							
-1							
218							
EMS GRILON T	SG 50/4, co	nditioned,	50% short	glass fi	bers, PA66+	6 semicr	ystalline
21.7.2015 by	A. Mösenba	cher, Lehr	stuhl für	Allgemein	en Maschine	nbau, Mor	ntanuni
MUL AMB, EMS	-Grivory						
0.3300E+000.	1550E-050.1	.500E-04	0	91	23.00	0.00	50.000000
0.1165E+050.	0000E+000.0	000E+000.2	621E+030.2	100E+000.	0000E+000.3	870E+010	.0000E+00
0.0000E+000.	0000E+000.0	000E+00					
0.0000E+000.	0000E+000.0	000E+000.0	000E+000.0	000E+000.	0000E+00		
262.1200	0.2100	0.0000	0.0000	0.0000	0.0000	0.5000	0.00000
0.0000	0.0000	0.0000					
0.1551E+030.	9990E+020.€	450E+020.4	610E+020.2	000E+01			
0.2125E+030.	1369E+030.0	000E+000.4	610E+020.2	000E+01			
0.2543E+030.	1638E+030.0	000E+000.9	060E+020.2	000E+01			
0.1097E+030.	7070E+020.0	000E+000.3	260E+020.0	000E+00			
-1							
-1							
223							
Grilon TSG 5	0/4, condit	ioned, 50%	short gla	ss fibers	, PA66+6 se	micrystal	lline
konditionier	te Biax und	l trockene	- Kurzprüfkö	rper aus	Platte und	UB-Versu	che
EMS-Grivory	und Lehrstv	ahl für All	gemeinen M	aschinenb	au der MUL		
basierend au	f Modelle f	ür den tro	- ckenen Wer	kstoff mi	t TG-Versch	iebung	
1	1	-1.00	1.00	0.00	2.00	0.00	23.00
13.80	1000000	46.10	0	0.00	0.00	0.00	50.000000
0.00	0						
-1	-						



Anisotropic material (SFRP with fiber orientation) can be assessed with following **FEMFAT** modules:

	BASIC/BREAK	ChannelMAX	TransMAX	Spectral
FEMFAT 5.3a	no	yes	yes	no
FEMFAT 5.4a	no	yes	yes	no
FEMFAT 5.4.1	no	yes	yes	yes
FEMFAT 5.4.2	no	yes	yes	yes

## **FEMFAT Settings**

Date: January 2021

- The analysis target should be set to MINER Elementary, because plastics have no fatigue strength (can also be set in \*.ffd and then this material is calculated with Miner Elementary despite Miner Modified setting).
- For anisotropic material the fiber orientation has to be entered under *Node Characteristics*. Under *General Factors* the "Fiber Orientation" influence has to be checked.
- Easy consideration of the lower fatigue properties of weld lines:
  - Export weld lines from Moldex3D when mapping (node list).
  - Map with DIGIMAT -> nodes are mapped to elements. -> generate node list (ANSA)
  - Read weld line nodes into FEMFAT and reduce strength with a factor 0.5 using "General Surface Treatment Factor" under *Node Characteristics* (the factor 0.5 is not based on tests, just an idea!).

Author: FEMFAT Support



Temperature Process Influence WELD Local Material P	roperties
Microstructure Parameter	
<ul> <li>Secondary Dendrite Arm Spacing SDAS</li> </ul>	
<ul> <li>Solidification Time</li> </ul>	
O Cooling Rate	
Fiber Orientation	
MOLDFLOW XML	0.000
Eff MOLDFLOW XML	
DIGIMAT DOF	
Surface Treatment	
None ~	
General Surface Treatment Factor: 0.000	
Forge Influence Factor: 1.000	
Fiber Orientation	Logarithmic interpolation
Local Material Properties	Linear interpolation
Rotating Principal Stresses Influence	Loganomic interpolation

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# Material Data for Elastomers ....ffd-files for natural rubber for different Shore hardness

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### **Fatigue assessment of Elastomers**

- Different material behavior hyper elastic (Mullins effect).
- 2) Fatigue analysis can be done stress based.
- 3) Haigh diagrams can be used.
- The maximum upper stress is responsible for the crack (between R=-∞ and R=0).
- 5) Influence of stress gradient is not known and assessed at the moment.

<u>Source</u>: M. Flamm: Ein Beitrag zur Betriebsfestigkeitsvorhersage mehraxial belasteter Elastomerbauteile. VDI Verlag, 2003

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### **Standard Haigh-Diagram for Elastomers**





- Elastomers behaves like brittle material.
  - Construction of Hiagh Diagram analogous to Gray Cast Iron.
- Mean stress sensitivity
   M ≥ 1 is possible.

- Released in **FEMFAT 5.4.2**
- New Material class "301 Elastomers (NR)"
- 5 new material datasets for natural rubber:
  - Elastomer\_NR\_40ShA\_Sig1p1\_ECS.ffd
  - Elastomer\_NR\_45ShA\_Sig1p25\_ECS.ffd
  - Elastomer\_NR\_50ShA\_Sig1p4\_ECS.ffd
  - Elastomer\_NR\_55ShA\_Sig1p5\_ECS.ffd
  - Elastomer\_NR\_60ShA\_Sig1p7\_ECS.ffd

Natural Rubber

Tension/Compression alternating strength

### **Gradient Influence and PLAST deactivated**

 Material Files has been generated in way, that the gradient influence and PLAST was deactivated:

Gradient Influence on fatigue limit

$$\sigma_{alt Bending} = \sigma_{altTC}$$
  
 $\nu = 0$ 

**MAGNA** 

### Gradient Influence on slope

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## **FEMFAT Analysis Settings**

- Elastomers behaves like brittle material. => "Normal Stress in Critical Plane" ( $\sigma_{an}$ ,  $\sigma_{mn}$ ) shall be used.
- Miner elementary option
- R = const. Option
- Template for Elastomere analysis



Analysis Parameters Analysis Target  Damage Endurance Safety Factor Static Safety Factor Stress/Strain Comparison STRAIN Comp Degree of Multiaxiality  Global Parameters Analysis Filter Cutting Plane Parameters Stress Selection Normal Stress in Critical Plane 90.000000 [%] Rainflow Counting Number of Rainflow Classes: 64 Rainflow Counting Method: FEMFAT 5.1 Amplitude Limit for Class Filter: 0.0 [Norma2]				·u	- a
Analysis Target  Damage  Endurance Safety Factor Static Safety Factor BREAK FEMFAT 5.0 Cycles: 0.0e+00 Cycles:	Analysis Parameters				
Damage MINER Elementary R = const. Cycles: 0.00+00 Static Safety Factor BREAK FEMFAT 5.0 Criterion: Utimate Strength O Degree of Multiaxiality Global Parameters Analysis Filter Cutting Plane Parameters Stress Selection Stress Selection Interface Selection 90.0000000 [%] Rainflow Counting Number of Rainflow Classes: 64 Rainflow Counting Method: FEMFAT 5.1 0.0 [N/mm2] High Parameter: 0.0 [N/mm2]	Analysis Target				
Endurance Safety Factor       R = const.       Cycles:       0.0e+00         Static Safety Factor       BREAK       FEMFAT 5.0       Criterion:       Ultimate Strength         Stress/Strain Comparison       STRAIN Comp         Degree of Multiaxiality         Global Parameters       Analysis Filter       Cutting Plane Parameters         Stress Selection         Vormal Stress in Critical Plane       y         Survival Probability       90.0000000 [%]         Rainflow Counting       64         Rainflow Classes:       64         Rainflow Counting Method:       FEMFAT 5.1         Amplitude Limit for Class Filter:       0.0 [N/mm2]	Damage	MINER Elementary	~		
Static Safety Factor       BREAK       FEMFAT 5.0       Criterion:       Uttimate Strength         Stress/Strain Comparison       STRAIN Comp         Degree of Multiaxiality         Global Parameters       Analysis Filter       Cutting Plane Parameters         Stress Selection         Normal Stress in Critical Plane         90.000000       [%]         Rainflow Counting       90.000000       [%]         Rainflow Counting Method:       FEMFAT 5.1       64         Amplitude Limit for Class Filter:       0.0       [N/mm2]	Endurance Safety Factor	R = const.	✓ Cycles:	0.0e+00	
Stress/Strain Comparison       STRAIN Comp         Degree of Multiaxiality         Global Parameters         Analysis Filter       Cutting Plane Parameters         Stress Selection         Normal Stress in Critical Plane         90.000000         [%]         Rainflow Counting         Number of Rainflow Classes:         64         Rainflow Counting Method:         FEMFAT 5.1         Amplitude Limit for Class Filter:         0.0         [N/mm2]	Static Safety Factor BREAK	FEMFAT 5.0	✓ Criterion:	Ultimate Strength	~
Degree of Multiaxiality  Global Parameters Analysis Filter Cutting Plane Parameters  Stress Selection  Normal Stress in Critical Plane  90.000000 [%]  Rainflow Counting  Number of Rainflow Classes: 64  Rainflow Counting Method: FEMFAT 5.1 Amplitude Limit for Class Filter: 0.0 [N/mm2] Hith Besolution	O Stress/Strain Comparison STRAIN	Comp			
Global Parameters Analysis Filter Cutting Plane Parameters Stress Selection Normal Stress in Critical Plane 90.0000000 [%] Rainflow Counting Number of Rainflow Classes: 64 Rainflow Counting Method: FEMFAT 5.1 Amplitude Limit for Class Filter: 0.0 [N/mm2] Hith Besolution	<ul> <li>Degree of Multiaxiality</li> </ul>				
Survival Probability 90.000000 [%] Rainflow Counting Number of Rainflow Classes: Rainflow Counting Method: Amplitude Limit for Class Filter: 0.0 [N/mm2] High Besolution	Stress Selection		~		
90.000000       [%]         Rainflow Counting       64         Rainflow Counting Method:       FEMFAT 5.1         Amplitude Limit for Class Filter:       0.0         Image: Second s	Survival Probability				
Rainflow Counting          Number of Rainflow Classes:       64         Rainflow Counting Method:       FEMFAT 5.1 ~         Amplitude Limit for Class Filter:       0.0 [N/mm2]         High Resolution		90.000000 [%]			
Number of Rainflow Classes:     64       Rainflow Counting Method:     FEMFAT 5.1       Amplitude Limit for Class Filter:     0.0       High Resolution	Rainflow Counting				
Rainflow Counting Method: FEMFAT 5.1 ~ Amplitude Limit for Class Filter: 0.0 [N/mm2]	Number of Rainflow Classes:		6	4	
Amplitude Limit for Class Filter: 0.0 [N/mm2]	Rainflow Counting Method: FEMP	AT 5.1	~		
High Resolution	Amplitude Limit for Class Filter:	0.0 [N/mm2]			
	High Resolution				



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### Summary

- Extensive material database is provided with FEMFAT.
- Material generator for the most important material classes can be used to estimate the cyclic material data.
- User has many flexible options for incorporating test results into FEMFAT material data.
- Data for non-metallic materials can be generated.
- Future Development of Material Generators for:
  - Microalloyed steels
  - Stainless and forged steels
  - Elastomers

Date: June 21 / Author: ECS St. Valentin

# DRIVING EXCELLENCE. INSPIRING INNOVATION.

Date: June 21 / Author: ECS St. Valentin