VALIMAT

# User Defined Material Cards

4a ENGINEERING GmbH

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# Objective

- Provide an overview of the capabilities of VALIMATs user material card feature
- Show how to use user defined material cards
- Describe the elements of a user defined material card
- Provide some tips for implementing your own user defined material card

# Capabilities of VALIMAT .xml material card format

- Add other material models
- Use standard VALIMAT® Design variable groups
  - Transfer from model to another (Change solver, material card,…)
- Enter user defined variables
- Use implemented curves/tables for hardening, failure,…

| | Name | Start | const... |
|---|---|---|---|
| GroupName: 10_elasticity | | | |
| | e_E | 1000 | ☐ |
| | e_nue | 0.3 | ☑ |
| GroupName: 50_failure | | | |
| | xf_NAHSV | 20 | ☐ |

| | |
|---|---|
| Damage/Failure | Add Erosion DIEM |
| Materialcard ID | 1000000 |
| Density | 1000 |
| Yield behavior | vonMISES |
| ⊟ Function (Hardening, Elastic cur | |
| Curve 1 | 4a model |
| Strain range upto | 4a model |
| Sampling points | 4a model (nue 0.5) |
| Bias factor | 4a model (nue) |
| ⊟ Strain rate dependency | scale curve 1 |
| ⊟ Strain rate dependency curve | Trilinear |
| VP | polymer law |
| 1st strain rate | modified G'Sell |
| 2nd strain rate | Ludwik |
| 3rd strain rate | Bergström |
| | Hollomon |

**Curve 1**

| | |
|---|---|
| ⊟ Strain rate dependency | Table |
| ⊟ Strain rate dependency curve | None |
| VP | Plastic strain |
| 1st strain rate | 0.0001 |
| 2nd strain rate | 0.001 |
| 3rd strain rate | 0.01 |
| 4th strain rate | 0.1 |
| 5th strain rate | 1 |
| 6th strain rate | 10 |
| 7th strain rate | 100 |
| 8th strain rate | 1000 |
| ⊟ Fracture | None |
| ⊞ Ductile Damage Settings | Johnson Cook |
| Shear Damage Settings | Cowper Symond |
| FLC Damage Settings | Kang |
| | Power Law (G'Sell) |

**Strain rate dependency curve**

| | |
|---|---|
| ⊟ Fracture | Damage |
| ⊟ Ductile Damage Settings | Piecewise linear interpolation |
| lower triax value | None |
| upper triax value | plastic equivalent strain |
| step size triax | simple criteria |
| Shear Damage Settings | 4a piecewise linear |
| FLC Damage Settings | Johnson Cook |
| Strainrate Damage Settings | mod Xue-Wierzbicki |
| Postfracture | Xue-Wierzbicki |
| ⊟ Loadcases | Mohr-Coulomb Shell |
| | Piecewise linear interpolation |
| | Mohr-Coulomb |

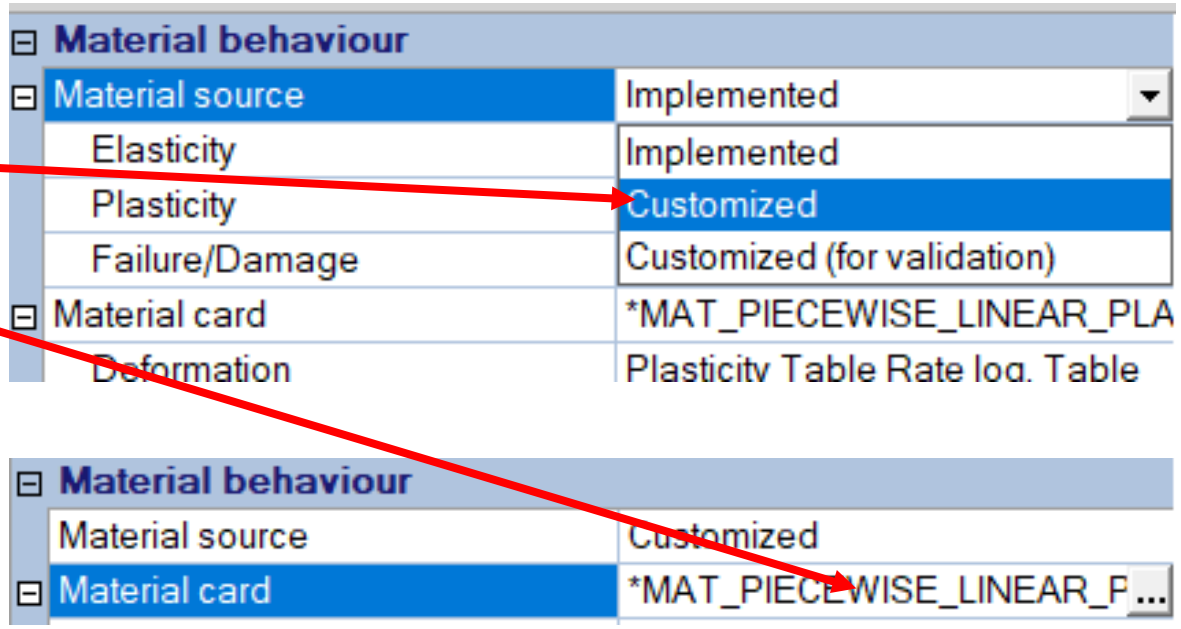
**Ductile Damage Settings**

# How to use .xml material cards

In Material behavior:

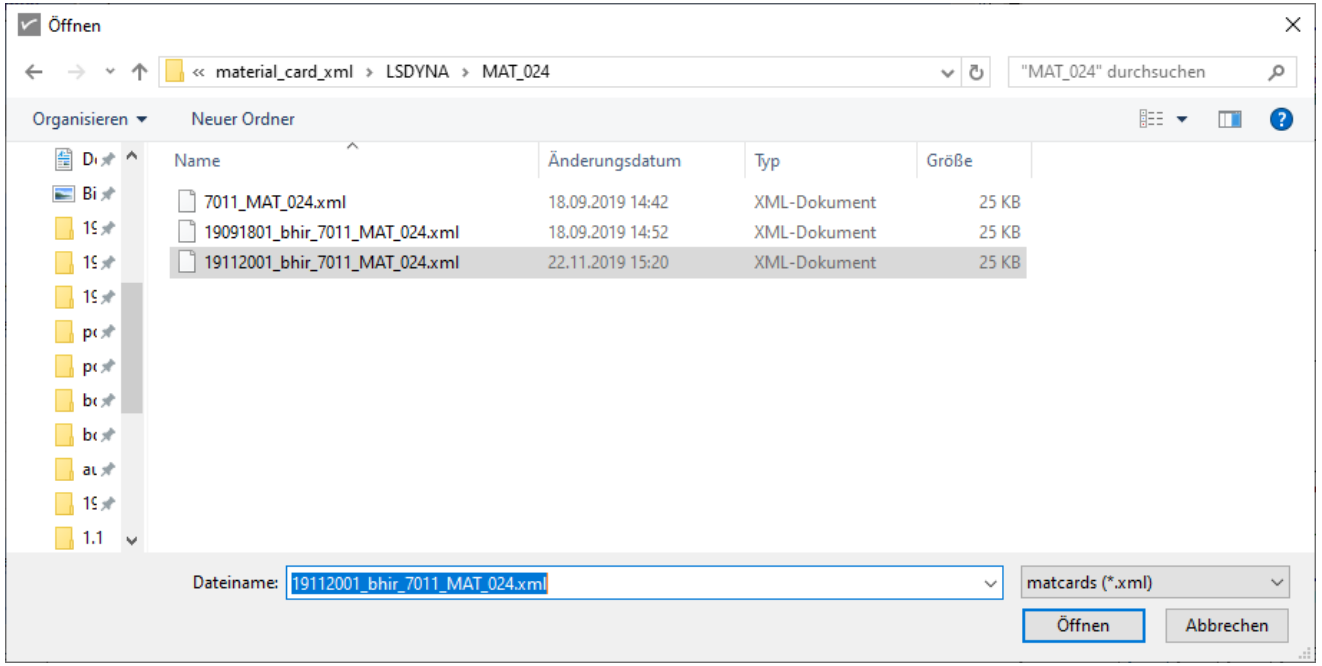
1.) Set Material source to customized

2.) next click on Material card field



# How to use .xml material cards

3.) select the .xml material card file



# How to use .xml material cards (tips for switching)

4.) Set the correct settings for user defined material card (**<u>old settings are unfortunately lost</u>**)

Do the following:

1. Set Deformation
2. Set Damage/Failure
3. Then paste old Design variables

| | |
|---|---|
| Material card | C:\Users\bhir\Documents\181128( |
| Deformation | Plasticity Table Rate log. Table |
| Damage/Failure | Add Erosion DIEM |

Parameter model* | Model database

200217_039 | Material | Designvariables | Layers

| Name | Start | const... | from | to | Variance |
|---|---|---|---|---|---|
| GroupName: 10_elasticity | | | | | |
| e_E | 1000 | ☐ | 20% | 20% | 10% |
| e_nue | 0.3 | ☑ | (NULL) | (NULL) | (NULL) |
| GroupName: 20_yield | | | | | |
| y_0 | 90 | ☐ | 5 | 150 | 50 |
| GroupName: 21_hardening | | | | | |
| h_nuep | 0.5 | ☐ | 0 | 0.5 | (NULL) |
| h_y | 90 | ☐ | 5 | 150 | 50 |
| h_y2 | 90 | ☐ | 0 | 150 | (NULL) |

# xml schema

```
1   <?xml version="1.0" encoding="UTF-8"?>
2   <!--
3   Material: MAT1
4   Author: Bernhard Jilka
5   Date: 03.08.2016
6   Version:1
7   -->
8   <matcard xmlns="urn:4a:impetus:matcard"
9    xmlns:xsi="http://www.w3.org/2001/XMLSc
10   xsi:schemaLocation="urn:4a:impetus:matc
11   name="*MAT_ELASTIC (*MAT_001)" A_MAT_TY
12  <matcard cases>
15  <matcard output>
21  <damage cases>
24  <damage output>
26  </matcard>
```

Encoding information

Comments

XML Schema Definition

Variables for the whole material card

case specific variables

what is written into the material.inp file

failure case specific variables

what is written into the material.inp file

# Impetus vs ls_opt formula

**impetus_formula** are used to create the **static** part of a material card (no changes in the optimization runs)

- Use **only** VALIMAT database variables
- Examples:

```
<impetus_formula formula="db_mattyp"/>
<impetus_formula formula="ID_MAT" format="0D8S"/>
<impetus_formula formula="db_rho" format="3D10S"/>
```

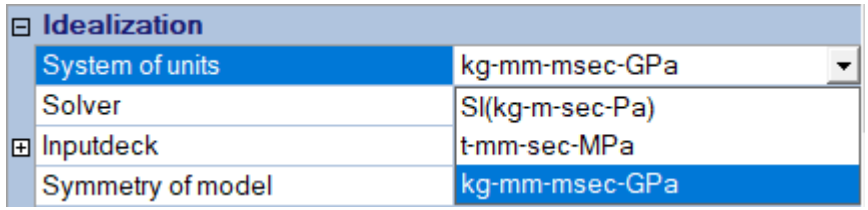
**ls_opt formula** create the **dynamic** part of a material card (lsopt replaceable code, dependant from design variables)

- Use **only** **LS-Opt variables**
- Examples:

```
<ls_opt formula="e_E*US_stress" format="0D10S"/>
<ls_opt formula="e_nue" format="0D10S"/>
```

# unit systems

- In VALIMAT we support 3 types of unit systems (Variables are declared in t-mm-sec-MPa):




- db_vars are always converted to current unit system!

- The variables are dependent from the unit system and the time scaling.

| conversion factors | |
|---|---|
| US_length | US_stiffness |
| US_time | US_force |
| US_density | US_energy |
| US_strainrate | US_stress |
| US_velocity | |

- Example: Young's modulus conversion:

```
<ls_opt formula="e_E*US_stress" format="0D10S"/>
```

# user variable feature

Add user variable to the LS-Opt variables

- Define in matcard_vars
  - case:
  - name: variable name (naming convention xm_(matcard) or xf_ (failure))
  - description: Description
  - group: GroupName
  - position: unique position for ordering
  - static:constant either ”true” or “false”
  - startvalue: Start
  - lowerbound: from
  - upperbound: to
  - optimizationwindow: Variance
  - boundary_condition: Condition
- Use in ls_opt formula by name

```
<ls_opt formula="xm_da" format="0D10S"/>
```

| Material card | C:\Users\bhir\Documents\18112801_Dateie |
|---|---|
| Deformation | MAT_001 |
| Damage/Failure | MAT_001 |
| Materialcard ID | MAT_001+damping |

```
<matcard_vars>
<designvar case="2" name="xm_da" de
<designvar case="2" name="xm_db" de
</matcard_vars>
<matcard_output>
```

| Name | Start | const... | from | to | Variance | Condition | Description |
|---|---|---|---|---|---|---|---|
| GroupName: 10_elasticity | | | | | | | |
| GroupName: 90_damping | | | | | | | |
| xm_da | 0.0 | ✓ | (NULL) | (NULL) | (NULL) | | axial damping factor |
| xm_db | 0.0 | ✓ | (NULL) | (NULL) | (NULL) | | Bending damping factor |

Click here to add a new row

# table input (arrays)

- epp (equivalent plastic/total strain)
  - strain range upto defines the endpoint of the curve
  - Sampling points defines number of points in the curve
  - Bias factor defines a bias to the front end of the curve
    - Bas factor=1: equally distributed points
- triax (stress triaxiality)
  - lower triax value to upper triax value with step size triax
  - typical values: plane stress state [-2/3;2/3;1/9]
- strain rate dependency:
  - db_epspkt1➔db_epspkt8
  - typical values: (LS-DYNA/PAMCRASH [0.001;1000;0;…]; ABAQUS [0.0;0.001;1000;…])

| | |
|---|---|
| Yield behavior | vonMISES |
| ⊟ Function (Hardening, Elastic curv | |
| Curve 1 | Bilinear |
| Strain range upto | 2.5 |
| Sampling points | 50 |
| Bias factor | 10 |

| | |
|---|---|
| ⊟ Fracture | Damage |
| ⊟ Ductile Damage Settings | Mohr-Coulomb |
| lower triax value | -0.66 |
| upper triax value | 0.66 |
| step size triax | 0.11 |

| | |
|---|---|
| ⊟ Strain rate dependency | Table |
| ⊟ Strain rate dependency curve | None |
| VP | Plastic strain |
| 1st strain rate | 0.0001 |
| 2nd strain rate | 0.001 |
| 3rd strain rate | 0.01 |
| 4th strain rate | 0.1 |
| 5th strain rate | 1 |
| 6th strain rate | 10 |
| 7th strain rate | 100 |
| 8th strain rate | 1000 |

# curve definition (arrays)

- hardening curve: sig; s2g; s3g ← result of Curve 1;2;3 (epp)
  - number of curves: “A_MAT_TYPE_PLASTIC_enum”=
    - 0: “none_0”
    - 1: “vonMises_11”; “vonMises_12”; ”Hillr2D_51”; ”HillR3D_52”; “Hill3D_53”; “Hill2D_54”; “RaghavaHill2D_55”
    - 2: “DruckerPrager_21”; “Raghava_22”
    - 3: “GenYLD3_31”; ”GenYLD5_32”

| | |
|---|---|
| Material card | C:\Users\bhir\Documents\181128( |
| Deformation | basic plasticity |
| Damage/Failure | None |
| Materialcard ID | 1000000 |
| Density | 1000 |
| Yield behavior | vonMISES |
| Function (Hardening, Elastic curv | |
| Curve 1 | Bilinear |
| Strain range upto | 2.5 |
| Sampling points | 50 |
| Bias factor | 10 |

- ductile damage: fail_ductile ← Ductile Damage Settings (triax)
  - availability depends on “A_MAT_FRAC_DIEM_DUCTILE”

| | |
|---|---|
| Fracture | Damage |
| Ductile Damage Settings | Mohr-Coulomb |
| lower triax value | -0.66 |
| upper triax value | 0.66 |
| step size triax | 0.11 |

*See “matcard.xsd” for available options and “dv_and_curve_def.xml” for VALIMAT names, variables and function definitions.

# impetus_material curve feature

impetus_material curve definitions allow the creation of curves

xVal: arithmetical expression with an array

yVal: arithmeticel expression with an array

```
<impetus_materialcurve xVal="epp" yVal="sig" format="10D20S"/>
```

| Function (Hardening, Elastic curv | |
|---|---|
| Curve 1 | Bilinear |
| Strain range upto | 2.5 |
| Sampling points | 50 |
| Bias factor | 10 |

```
*DEFINE_CURVE
$#     lcid      sidr       sfa       sfo      offa      offo    dattyp
   1000001         0         1         1         0         0
$#                al                  ol
<<(0)*1+0:20>><<((h y+h ET*0)*(1+1/v p*log(max(0.0001,v epspkt)/v epspkt)))*1+0:20>>
```

# impetus_material curve feature

- Example: MAT_SAMP-1

```
name="*MAT_SAMP-1 (*MAT_187) log Table R9.3+" A_MAT_TYPE_ELASTIC="linearElastic_0" A_MOD_IDEALIZATION="all_2" A_SOLVER="LSDYN
<matcard_cases>
<case id="1" name="vonMises (non associated)" A_MAT_ELASTIC_CURVE="linearElastic_1" A_MAT_TYPE_PLASTIC="vonMises_11" A_MAT_TYP
<case id="2" name="Pressure dependent (Drucker-Prager)" A_MAT_ELASTIC_CURVE="linearElastic_1" A_MAT_TYPE_PLASTIC="Raghava_22"
<case id="3" name="Parabolic yield surface (Shear given)" A_MAT_ELASTIC_CURVE="linearElastic_1" A_MAT_TYPE_PLASTIC="GenYLD3_31
<case id="5" name="Parabolic yield surface (Biax-tension given)" A_MAT_ELASTIC_CURVE="linearElastic_1" A_MAT_TYPE_PLASTIC="Ger
<case id="4" name="General yield surface" A_MAT_ELASTIC_CURVE="linearElastic_1" A_MAT_TYPE_PLASTIC="GenYLD5_32" A_MAT_TYPE_VIS
</matcard_cases>
```

**activates**

| | |
|---|---|
| Material card | *MAT_SAMP-1 (*MAT_187) log Table R9.3 |
| Deformation | Pressure dependent (Drucker-Prager) |
| Damage/Failure | vonMises (non associated) |
| Materialcard ID | Pressure dependent (Drucker-Prager) |
| Density | Parabolic yield surface (Shear given) |
| Yield behavior | Parabolic yield surface (Biax-tension given) |
| Function (Hardening, Elastic curve fo | General yield surface |
| Curve 1 | Bilinear |
| Curve 2 | scale curve 1 |

```
<impetus_materialtable/>
<XMLIF mcase="2-4">
*DEFINE_CURVE
$#     lcid      sidr       sfa       sfo      offa      offo    dattyp
<impetus_formula formula="ID_FUNC10" format="0D10S"/>          0       1.0       1.0       0.0       0.0         0
$#                 a1                  o1
<impetus_materialcurve xVal="epp" yVal="s2g" format="10D20S"/>
</XMLIF>
```

**adds this curve to card**

# impetus_materialtable feature

material table definitions allows for fast viscoplasticity definition

It creates a table definition with strain rates and hardening curve ids

The curves are a combination of the first material curve and the strain rate dependency model

Example: Bilinear hardening and Johnson Cook strain rate dependency

```
<impetus_materialtable/>
```

| | |
|---|---|
| ⊟ Function (Hardening, Elastic curv | |
| Curve 1 | Bilinear |
| Strain range upto | 2.5 |
| Sampling points | 50 |
| Bias factor | 10 |
| ⊟ Strain rate dependency | Table |
| ⊟ Strain rate dependency curve | Johnson Cook |
| VP | Plastic strain |
| 1st strain rate | 0.0001 |
| 2nd strain rate | 1000 |
| 3rd strain rate | 0 |

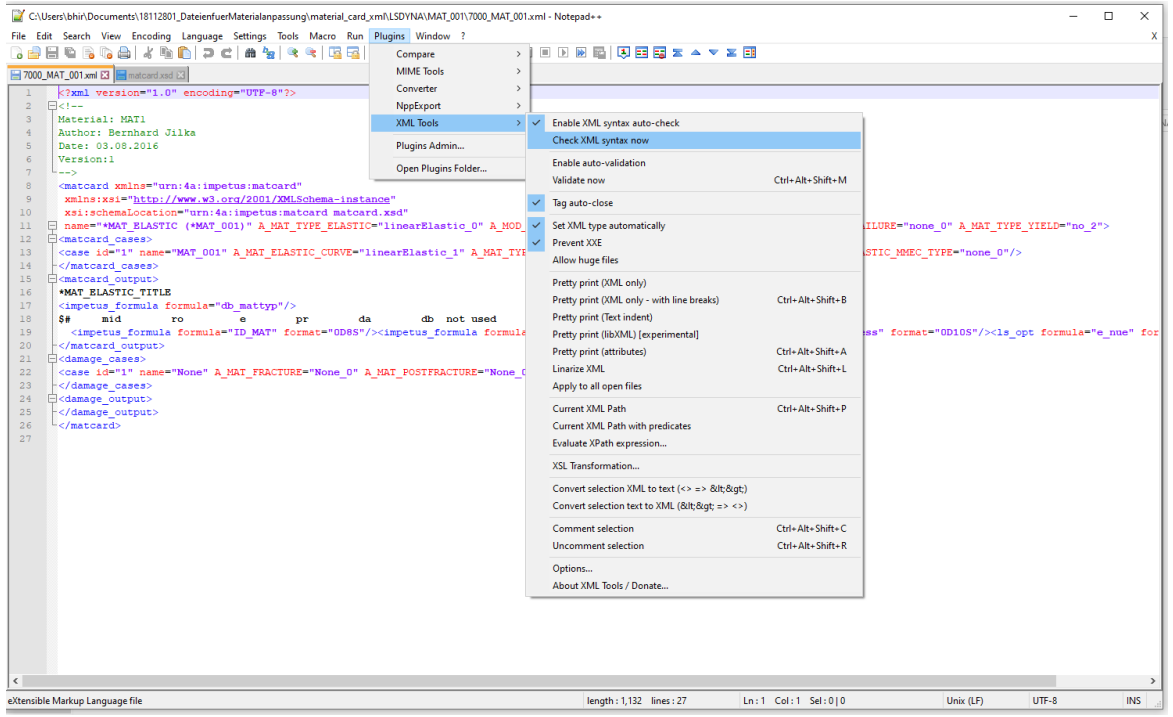
```
*DEFINE_TABLE
$#     tbid
   1000000
$#                value       lcid
<<log(0.0001*1/US_time):20>>   1000001
<<log(1000*1/US_time):20>>   1000002
*DEFINE_CURVE
$#     lcid      sidr       sfa       sfo      offa      offo    dattyp
   1000001         0         1         1         0         0
$#                 a1                  o1
<<(0)*1+0:20>><<((h_y+h_ET*0)*(1+1/v_p*log(max(0.0001,v_epspkt)/v_epspkt)))*1+0:20>>
```

# Tips for implementing a new material card for VALIMAT®

- For the text editor we use Notepad++, which has the plugin “XML tools” that allows to check the file for compliance with the schema file (Have a copy of “matcard.xsd” in the working directory).
- Doesn’t detect all problems!
- Variable definitions are in the dv_and_curve_def.xml

dv_and_curve_def.xml

matcard.xsd



# Variable Descriptions

# material card

- name
- A_MAT_TYPE_ELASTIC
- A_MOD_IDEALIZATION
- A_SOLVER
- A_MAT_TYPE_FAILURE
- A_MAT_TYPE_YIELD

# material card options

- A_MAT_TYPE_ELASTIC
- A_MOD_IDEALIZATION
- A_SOLVER
- A_MAT_TYPE_FAILURE
- A_MAT_TYPE_YIELD

# matcard_cases options

- A_MAT_ELASTIC_CURVE
- A_MAT_TYPE_PLASTIC
- A_MAT_TYPE_VISKO
- A_MAT_ELASTIC_MMEC_TYPE

# damage_cases options

- A_MAT_FRACTURE
- A_MAT_POSTFRACTURE

# test database variables

| mdb entry | variable | mdb entry | variable |
|---|---|---|---|
| T_EVAL_FILTER: | db_filter | T_RES_VELOCITY0: | db_v_0 |
| T_ID: | db_id | T_SPECIMEN: | db_pkz |
| T_LOADING_CASE: | db_test | T_SPECIMEN_LENGTH: | db_l |
| T_LOADING_CASE_long: | db_test_long | T_SPECIMEN_MOISTURE: | db_mos |
| T_LOADING_CASE_short: | db_test_short | T_SPECIMEN_ORIENTATION: | db_orient |
| T_LOADING_CONTACTANGLE: | db_alpha | T_SPECIMEN_T_THICKNESS: | db_h_T |
| T_LOADING_FORCE: | db_lf | T_SPECIMEN_T_WIDTH: | db_b_T |
| T_LOADING_GAUGE: | db_lw | T_SPECIMEN_TENSION_WIDTH: | db_b_Ten |
| T_LOADING_MASS: | db_mp | T_SPECIMEN_TENSION_LENGTH: | db_l_Ten |
| T_LOADING_FORCE_RADIUS: | db_r_f | T_SPECIMEN_TEMPERATUR: | db_T |
| T_LOADING_GAUGE_RADIUS: | db_r_g | T_SPECIMEN_THICKNESS: | db_h |
| T_LOADING_MASSARM: | db_mh | T_SPECIMEN_WIDTH: | db_b |
| T_LOADING_MASSFIN: | db_mf | T_TEST_PENDULUMARM: | db_lp |
| T_LOADING_VELOCITY: | db_va | T_SPECIMEN_PUNCTURE_DIAMETER: | db_punc_dia |
| T_MATERIALTYPE: | db_material | T_TEST_TYPE: | db_pm |
| T_RES_ENERGY_LOST: | db_el | T_TEST_TYPE_long: | db_pm_long |
| T_RES_MODUL: | db_mod | T_TEST_TYPE_short: | db_pm_short |

# model database variables

| mdb entry | variable | mdb entry | variable |
|---|---|---|---|
| A_MAT_FRICTION: | db_fr | A_SOLVER: | db_solver |
| A_MAT_POISSON: | db_nue | A_MAT_VISKO_EPSPKT1: | db_epspkt1 |
| A_MAT_STRAIN_FAILURE: | db_plstrainfailure | A_MAT_VISKO_EPSPKT2: | db_epspkt2 |
| A_MATERIALTYPE: | db_mattyp | A_MAT_VISKO_EPSPKT3: | db_epspkt3 |
| A_MOD_CONTACT_DENSITY: | db_contdensity | A_MAT_VISKO_EPSPKT4: | db_epspkt4 |
| A_MOD_CONTACT_MODULUS: | db_contmodulus | A_MAT_VISKO_EPSPKT5: | db_epspkt5 |
| A_MOD_CONTACT_THICKNESS: | db_contth | A_MAT_VISKO_EPSPKT6: | db_epspkt6 |
| A_MOD_ELEMENTSIZE: | db_elsize | A_MAT_VISKO_EPSPKT7: | db_epspkt7 |
| A_MOD_EXPLIMPL: | db_timescale | A_MAT_VISKO_EPSPKT8: | db_epspkt8 |
| A_MOD_ELEMENT_TYPE: | db_elform | A_MAT_DENSITY: | db_rho |
| A_MOD_IDEALIZATION: | db_eltyp | A_MOD_WRITEPART: | db_writepart |
| A_MOD_LAYER: | db_ellayer | A_CASE_ADDITIONAL_NUMBER_RESULTS: | db_nr_udef_vars |
| A_MOD_SYMMETRY: | db_elmodell | A_COMMENT: | db_comment_modell |
| A_MOD_UNITS: | db_unitsystem | A_MATERIALFILELINK: | db_mat_file |
| A_MOD_USERDEF: | db_par | A_MAT_ID: | db_mat_id |
| A_MOD_SHELL_THINNING: | db_shell_thickness_update | A_ID: | db_modell_id |
| A_MOD_VP: | db_VP | | |