# FEBioHeat Plugin

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# 1 Introduction

The FEBioHeat plugin adds the ability to FEBio to solve heat transfer problems, which are defined by the heat transfer equation.

$$\rho C \frac{\partial T}{\partial t} + \nabla \cdot \mathbf{q} = Q \tag{1}$$

Here, $\rho$ is the density, *C* is the specific heat, **q** is the heat flux, and Q is the heat generation per volume.

The FEBioHeat plugin currently supports steady-state (where the first term in the left-hand side of equation 1 is ignore), and transient linear heat transfer analysis.

This document describes the format of the FEBio input file for a heat-transfer analysis.

This manual assumes the 2.5 FEBio format specification.

# 2 Heat Module

The module type must be set to “heat” for solving a heat-transfer problem with this plugin.

```
<Module type="heat"/>
```

# 3 Heat transfer constitutive model

Currently, only one constitutive model is supported for heat-transfer analysis, namely the “isotropic Fourier”, which defines the heat flux $\mathbf{q}$ as follows.

$$\mathbf{q} = -k \nabla T \tag{2}$$

Here, $T$ is the temperature and $k$ the thermal conductivity.

This material has three parameters as shown in the following table.

| parameter | description | units (SI) |
|---|---|---|
| `density` | The material density | $kg/m^3$ |
| `k` | The thermal conductivity | W/m.K |
| `c` | The specific heat | J/kg.K |

The units are just given as an example of a consistent set of units for these variables. Users can use their preferred unit system instead.

Note that density and specific heat are only used for transient analysis.

An example of material definition follows below.

```
<material id="1" name="myMaterial1" type="isotropic Fourier">
	<density>1.0</density>
	<k>0.4</k>
	<c>1.0</c>
</material>
```

# 4 Heat Transfer Boundary Conditions

## 4.1 Fixed and prescribed temperature

A prescribed or fixed temperature boundary condition is defined using "T" as the name of the degree of freedom. Aside from that it is defined similarly to any other prescribed or fixed boundary condition in FEBio and must be defined in the *Boundary* section of the FEBio input file. For example,

```
<prescribe bc="T" node_set="PrescribedBC1">
      <scale lc="1">1.0</scale>
      <relative>0</relative>
</prescribe>
```

## 4.2 Heat flux

The heat flux surface load prescribes the heat flux on a surface of the mesh. It is defined as a *surface_load* with the type attribute set to "heatflux". It takes a single parameter, namely "flux", which specifies the value of the heat flux.

```
<surface_load type="heatflux" surface="Surface01">
      <flux lc="1">2.5</flux>
</surface_load>
```

## 4.3 Convective heat flux

A convective heat flux applies a flux boundary condition where the flux is proportional to the difference between the surface temperature $T$ and the ambient temperature $T_a$.

$$q_c = h_c\left(T - T_a\right) \tag{3}$$

This boundary load is defined as a *surface_load* with the type attribute set to "convective_heatflux" and requires two parameters.

| parameter | description | units (SI) |
|---|---|---|
| hc | The proportionality constant $h_c$ | W/m$^2$.K |
| Ta | The ambient temperature | K |

An example is given below.

```
<surface_load type="convective_heatflux" surface="Surface01">
      <hc>60.0</hc>
      <Ta lc="1">25</Ta>
</surface_load>
```

# 5 Heat source

A heat source can be added by defining a *body_load* with the type set to "heat_source". Only one parameter is required, "Q", to define the heat source value.

| parameter | description | units (SI) |
|---|---|---|
| Q | The constant heat source value | W/m$^3$ |

```
<body_load type="heat_source">
      <Q lc="1">13.5</Q>
</body_load>
```

# 6 Output variables

The heat transfer plugin adds several output variables to both the plot file and the log file.

## 6.1 Plot file variables

The following table shows a list of all new variables defined by the plugin.

| variable | description |
|---|---|
| temperature | The nodal temperature at the mesh nodes |
| heat flux | The average heat flux over each element. |

## 6.2 Log file variables

The following table shows a list a log file variables.

| variable | description | class |
|---|---|---|
| T | nodal temperature | node_data |