# Procedure for the Simulation of sealing systems

IMA-TechSheet #104200 V2

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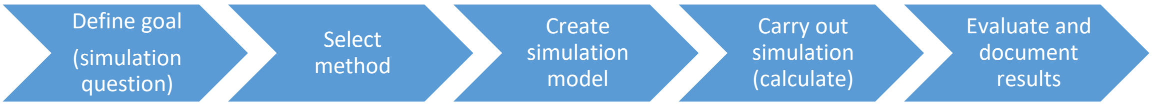
Institute of Machine Components

The implementation of a simulation can be systematically divided into five sections:




## 1. Define the goal (simulation question)

At the beginning of each simulation we define its goal: We formulate the question we want to answer with the help of the simulation. This "simulation question" is usually worked out in a joint discussion involving simulation, sealing technology and application experts. Possible "simulation questions" could be, for example:

- What does the pressure distribution between the sealing edge and shaft/rod look like in pressureless operation or at a certain pressure? Is a return mechanism possible with this?
- With which design variant of the seal environment does the highest/lowest temperature occur in the seal contact? What changes can be made to lower the temperature?
- What is the force required to compress a gasket profile by a certain amount during installation?
- How does the seal cross-section shrink when the seal is cooled to a certain temperature? How does the preload change during this process?
- By how much larger/smaller is the flow rate of a PTFE sleeve with return structures variant A compared to variant B?

## 2. Select a simulation method

Depending on the simulation question, we select a suitable simulation method and the corresponding simulation software from our diversely equipped "simulation toolbox":

- For structural mechanics we use the FEM (Finite Element Method) and the simulation software MSC Marc/Mentat. (see IMA-Techsheet #103010). This also allows wear simulations (IMA-TechSheet #103050).
- For pure flow simulations ("CFD") and coupled heat and flow simulations (CHT) we use ANSYS CFX. (see IMA-Techsheet #103030)
- For questions concerning the flow processes in the sealing gap, our self-developed simulation programme for isoviscous elasto-hydrodynamic lubrication (I-EHL) is used. (see IMA-Techsheet #103040)

If several simulation questions are defined in a project, which cannot be answered with a single simulation method, we perform several simulations with all required simulation methods/tools. If necessary, we use the results of one simulation as input information for other simulations and couple the different partial simulations with it.

## 3. Create simulation model

In modelling, we create the simulation model. This is a simplified representation of the real system and serves to efficiently investigate the simulation question. Only effects that are relevant for answering the simulation question are considered when creating the model. Effects that have virtually no influence on the simulation question are neglected in the modelling.

When modelling, we always work according to the principle of
**"As simple as possible, as complicated as necessary."**

In general, of course, only effects that are known and can be described mathematically can be modelled and examined by means of simulation! For example, the question "How long is a static seal with an O-ring tight under gamma radiation?" cannot be answered without first carrying out corresponding measurements and transferring them into a mathematical model.

The modelling is always carried out in close contact with the client. If questions arise during the modelling, we always consult (with the client) and coordinate the modelling with the application expert. In this way, we ensure that we can precisely answer the simulation question with the simulation model.

**Type of simulation**
If the operating conditions of the sealing system are constant or change only slowly, it is often sufficient to consider the quasi-stationary state of equilibrium in a static simulation. This allows us, for example, to investigate the contact behaviour of sealing rings after assembly.
If operating conditions change significantly in a short period of time, we can use transient simulations to investigate the temporal course of these processes. For example, we can analyse the heating of a sealing system during a start-up process.

**System boundaries and boundary conditions**
We determine the system boundaries and define which boundary conditions should act on these boundaries. We also determine which initial conditions should apply at the start time of the simulation.

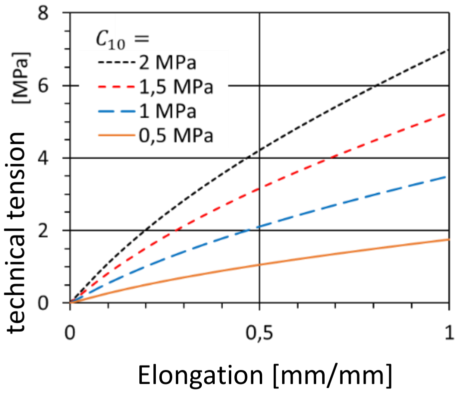
**Geometry description and meshing**
So far, we use symmetries in the model creation and thus reduce the effort for model creation and calculation to a minimum. In addition to 2-dimensional simulation models for plane and rotationally symmetrical questions, we also use partial models with periodic boundary conditions ("pieces of cake"), if possible. Only if no symmetries can be exploited, 3-dimensional modelling is used.


We can import the geometry of the sealing element and the surrounding components into the simulation software in various ways, depending on availability:

- Import from CAD data set (e.g. STEP format)
- Micrograph using resin casting of the sealing element (see IMA-Techsheet #104030)
- Simulation carried out (e.g. geometry of a sealing element after assembly for subsequent coupled heat and flow simulation)

Depending on the requirements, the geometry of the sealing element and the surrounding components is simplified. In doing so, we remove details (such as injection burrs on the sealing element) that have (almost) no influence on the simulation result and would therefore unnecessarily increase the effort for modelling and calculation.

In the so-called "discretisation", the geometry is divided into a large number of small elements that form the so-called "calculation mesh". For each element, the underlying physical equations are solved approximately in the later calculation. When meshing, we make sure that we create a fine and high-quality calculation mesh, especially in "important" areas (such as e.g. density ranges). In a so-called mesh refinement study, we refine the calculation mesh until the simulation result does not change any more and we are sure that it is mesh-independent.




**Material modelling**

Elastomers or PTFE compounds are often used as sealing materials, and their mechanical behaviour differs significantly from that of other material groups such as metal alloys. Elastomers show a highly pronounced non-linear stress-strain behaviour. In addition, the stress-strain behaviour is strongly dependent on time and temperature due to the so-called visco-elasticity. In the case of PTFE compounds, there are also plastic effects ("flow").

To accurately represent the material behaviour of elastomers, we use hyperelastic material models (e.g. Neo-Hooke or Mooney-Rivlin model). The viscoelasticity is represented by means of a Prony series and a temperature shift with the so-called WLF equation. For PTFE compounds, we use elastic-plastic material models that represent the so-called equilibrium flow curve.

For sealing materials we can determine the required material parameters in different ways (see IMA-TechSheet #103020):

- Rough calculation from Shore A hardness (fastest method)
- Tensile test on universal testing machine (see IMA-TechSheet #102120)
- Pure shear test on universal testing machine
- Inflation test for biaxial stress state (see IMA-TechSheet #102130)
- DMA (Dynamic Mechanical Analysis)

If the temperature-viscosity behaviour of oils is required for a flow simulation, we determine this on our rheometer (IMA-TechSheet #102170).

**Operating conditions**

Frequently, several operating points with different operating conditions are to be analysed and compared by means of simulation. For this purpose we parameterise the simulation model. This allows us to vary one or more parameters in a parameter study. This allows us to determine critical operating points, for example (see IMA-TechSheet #103060).

## 4. Carry out simulation (calculation)

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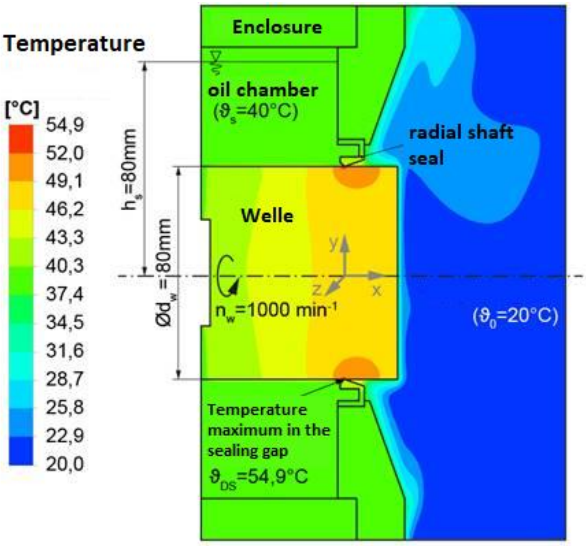
For the computation of the simulations at the IMA, we use modern, high-performance workstations. For very computationally intensive simulations, we have access to the clusters of the High-Performance Computing Centre Stuttgart (HLRS, www.hlrs.de), which is affiliated with the University of Stuttgart.

We have a large number of permanent licences of established simulation software packages for teaching and publicly funded research. If required, we can obtain licences for commercial purposes on a short-term rental basis and use them to work on customer-specific projects with industrial companies.

## 5. Evaluate and document results




During the evaluation we critically question all simulation results and continuously check them for plausibility. We prepare the simulation results in such a way that they are also understandable for "simulation laymen" and clearly answer the question defined at the beginning. For an efficient evaluation of the results, we use self-programmed evaluation routines that automatically determine technical parameters.

In addition to the pure presentation of the results, there is always an evaluation of the sealing technology, which is supplemented by recommendations for action. The results are presented and documented in consultation with the client. It can, for example, take the form of an overview, keyword-like short report in presentation form or a detailed written report with a comprehensive presentation of the entire simulation process. Presentations of results are made via a web meeting or during a personal visit (to the client or to the IMA).