

Forming simulation at MAHLE by the example of the cooling fin production

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MAHLE



- The Company
- Heat Exchangers
 - Overview of cold formed metal parts
 - Example: Radiator
- Cooling Fins
- Forming Simulation
 - Model set-up
 - Results
- Summary



Employees: 78,000



Around 170 production locations in 32 countries and on five continents



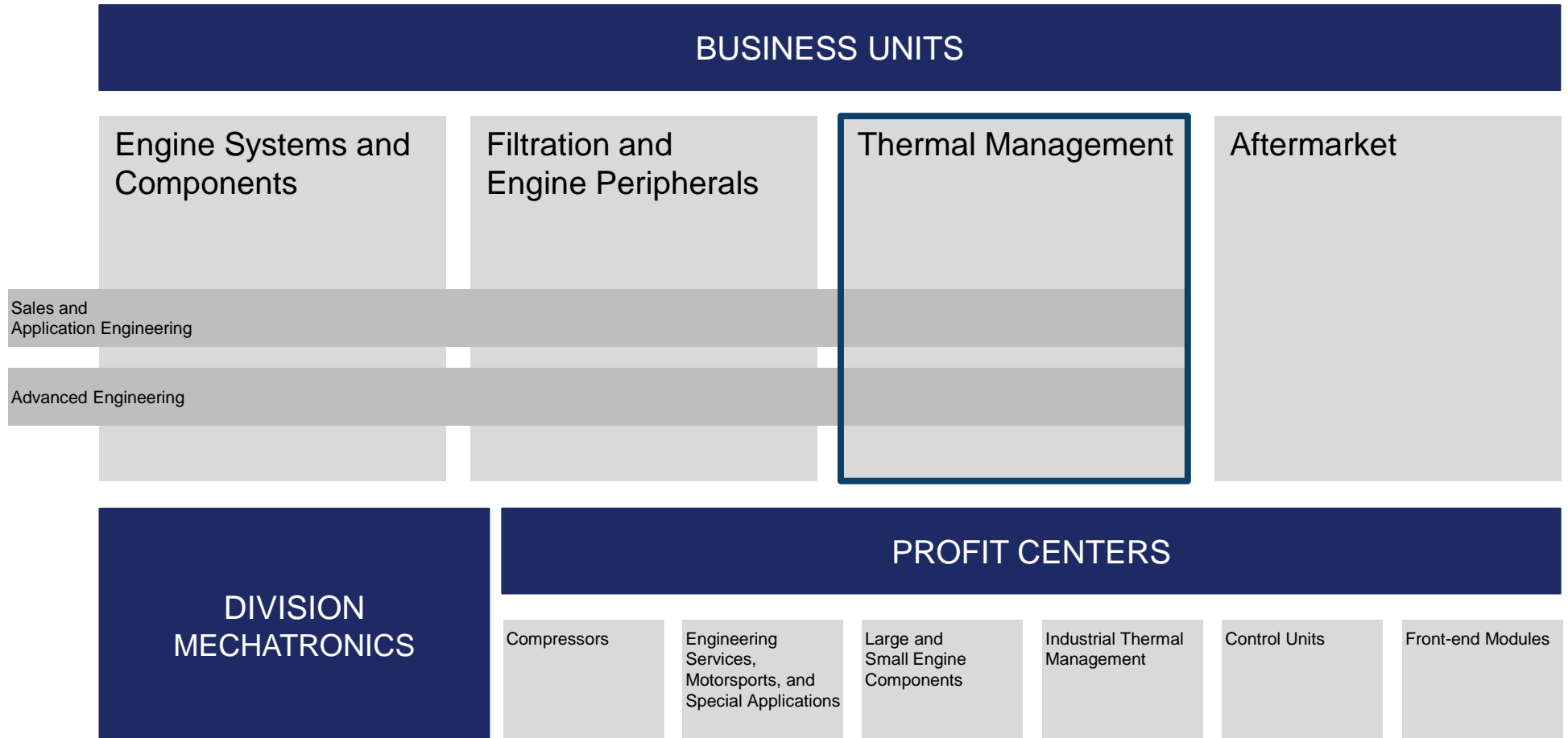
Sales: EUR 12.8 billion (2017)



16 major development locations with around 6,100 development engineers and technicians in Germany, Great Britain, Luxembourg, Slovenia, Spain, the USA, Brazil, Japan, China and India

Group organization

Business units, division Mechatronics, and profit centers



Facts and figures – MAHLE Group

Product portfolio – MAHLE is more than pistons

Passenger car and commercial vehicle applications

MAHLE

Driven by performance

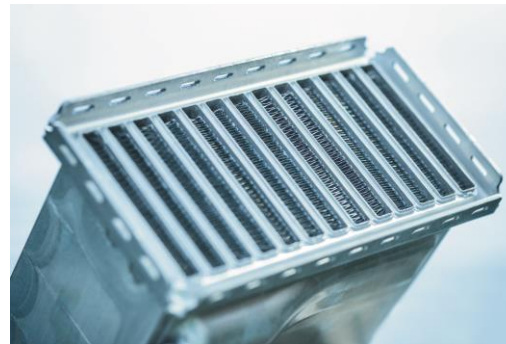


Examples of Heat Exchangers made of **Aluminum** (brazed connections)

Radiators



indirect Charge Air Cooler

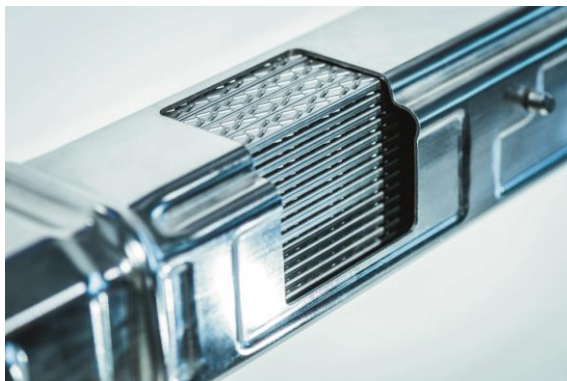


Chiller



Tubes, Turbulators, Cooling (Louvered) fins, Headers, End plates

Stacked Cooling plates



Exhaust Gas Recirculation (EGR)

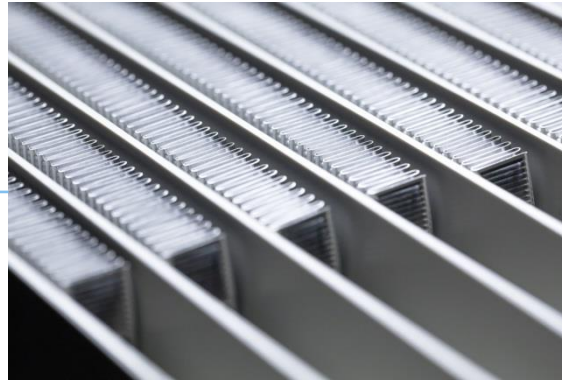
Example of Heat Exchangers made from **Stainless Steel**
(brazed or welded connections)

Tubes, Turbulators, Headers, Housing, Diffusers

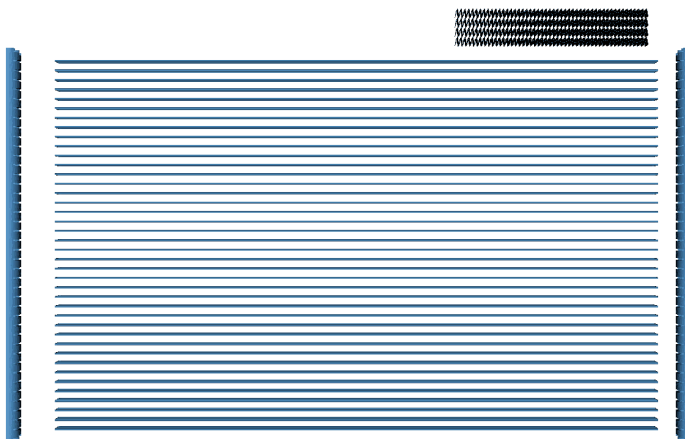
Heat Exchangers

Example: Radiator

- Core of Radiator is made from cold formed Aluminum parts



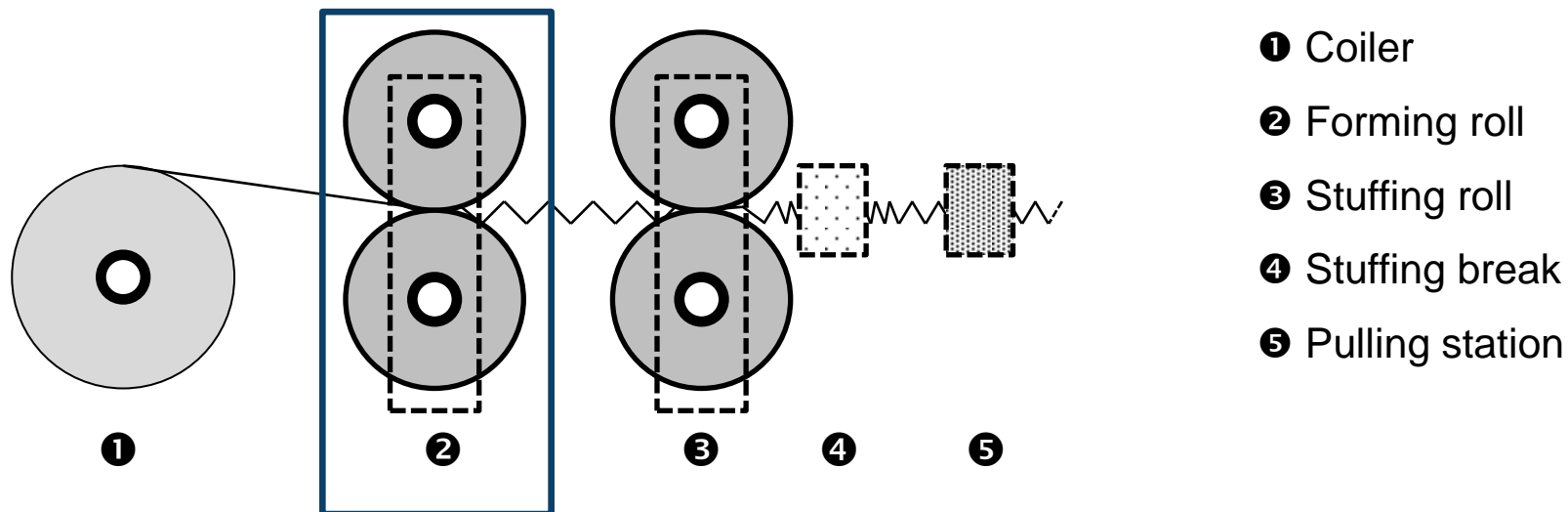
Tubes and louvered Fins



Development assisted by forming simulations:

- Tubes – Sheet thickness ~ 0.30 mm
Roll forming
- Louvered Fins – Sheet thickness ~ 0.10 mm
Roll bending
- Headers – Sheet thickness ~ 1.50 mm
Progressive die process

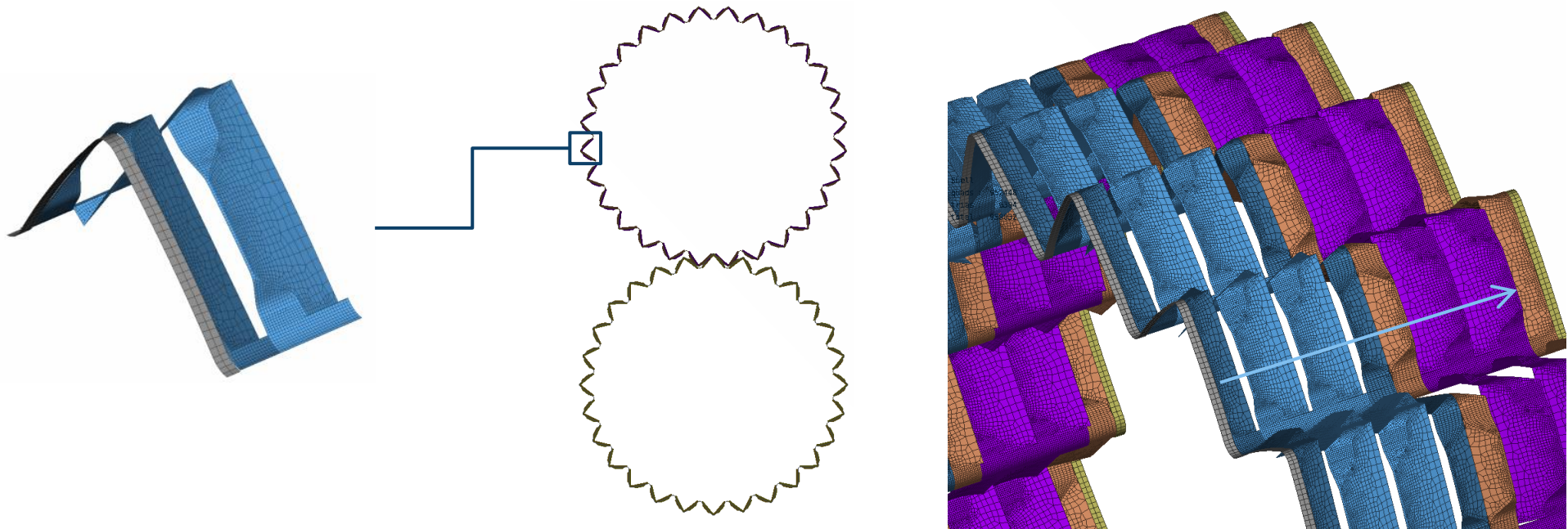
- Strong influence on performance of heat exchanger
 - big surface, geometry determines turbulence behavior of fluid flow (gas or liquid)
 - coefficient of heat transfer
- Production process (schematic)



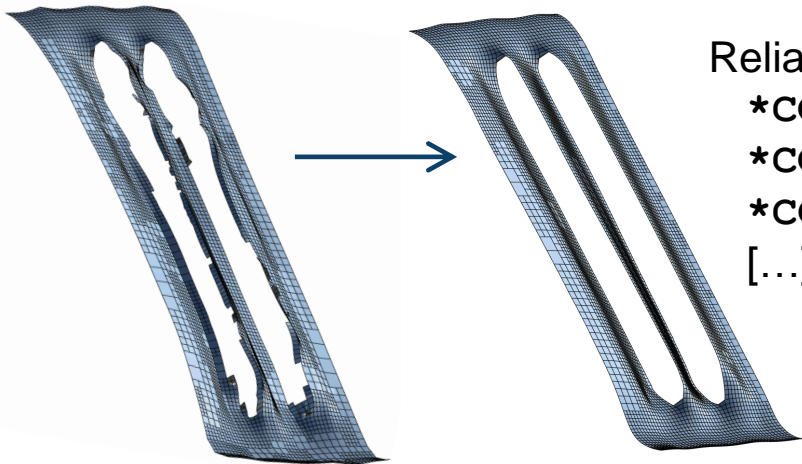
Presentation focuses on simulation of forming roll

■ Forming rolls

- Assumed to be rigid → ***MAT_RIGID**
- Mesh density depends on local curvature and function (cutting edge)
- Meshing one tooth for each type of forming roll
- Identical mesh on all teeth → synchronizing mesh to similar parts



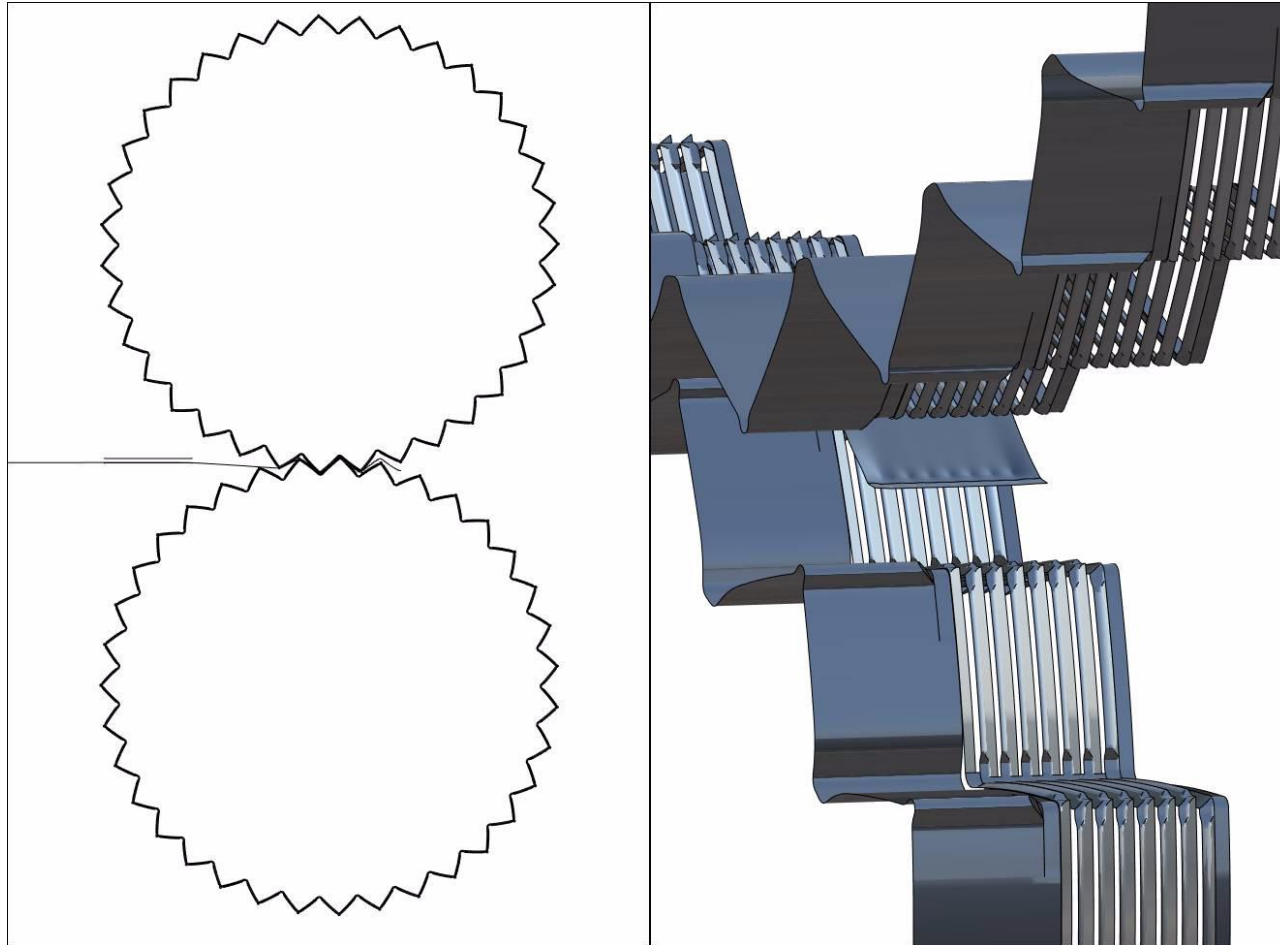
- Process
 - Endless process at high rotational velocity
 - Simulation comprises initialization and forming process at constant velocity
- Aluminum Sheet
 - Shell elements (QUAD4) type **ELFORM = 16**
 - Adaptive remeshing (***CONTROL_ADAPTIVE** and ***DEFINE_ADAPTIVE_BOX**)
 - ***MAT_PIECEWISE_LINEAR_PLASTICITY** with specific **FAIL** value



Reliable louver cuts requires adjustments of solver settings for:

```
*CONTACT_<OPTION>  
*CONTROL_CONTACT  
*CONTROL_ADAPTIVE  
[...]
```

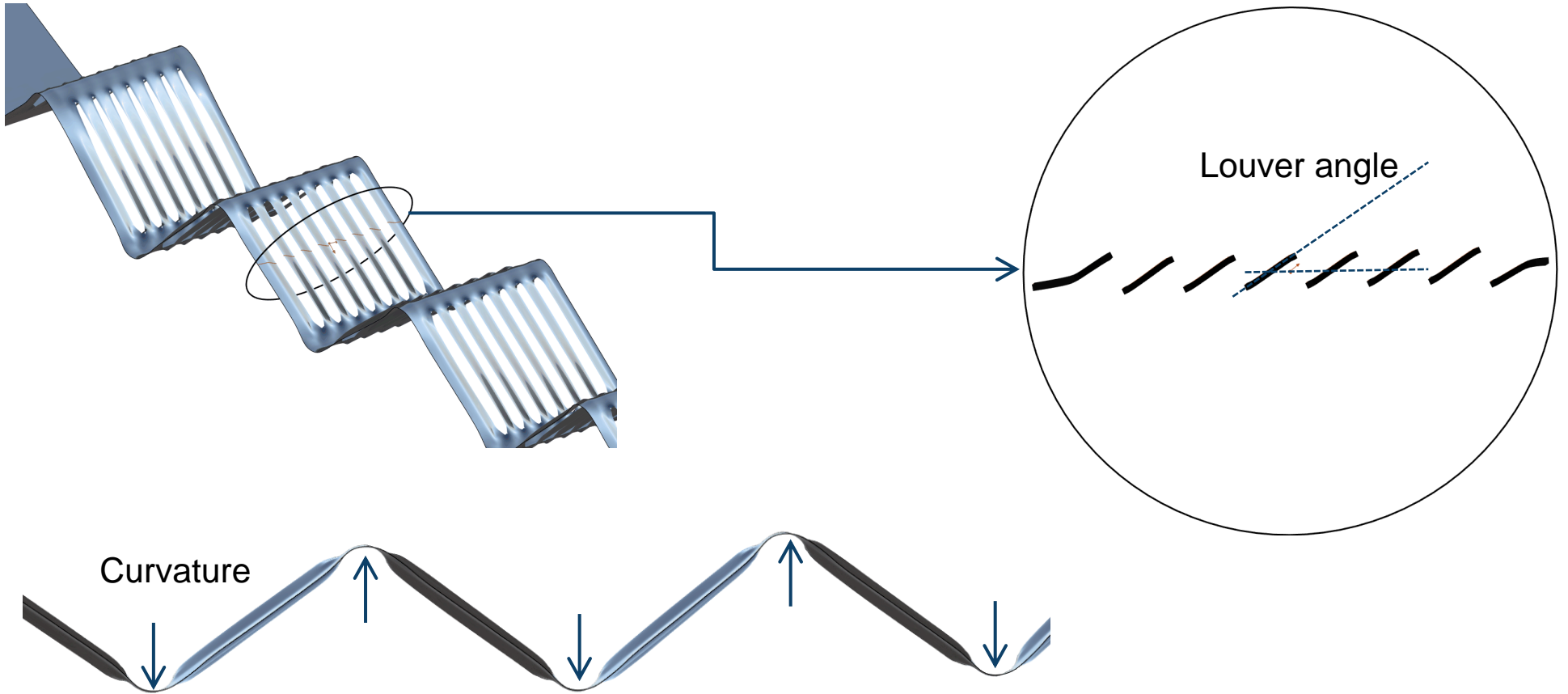
- Example: Louvered fin with 14 louvers → 7 Forming rolls in model due to symmetry



Evaluation of results with respect to:

- Feasibility
- Geometry of Louver
- Curvature of bending area

- Evaluation of geometry of louvers and curvature of bending area



The most important components of the cooling circuit are heat exchangers, which are usually made of different formed aluminum sheet parts. The product and process development of these parts is assisted by forming simulations at MAHLE. This presentations shows

- the forming simulation of cooling fins
- the model set-up
- selected results

At MAHLE, forming simulation contributes to an accelerated product and process development.

Thank you for your attention!