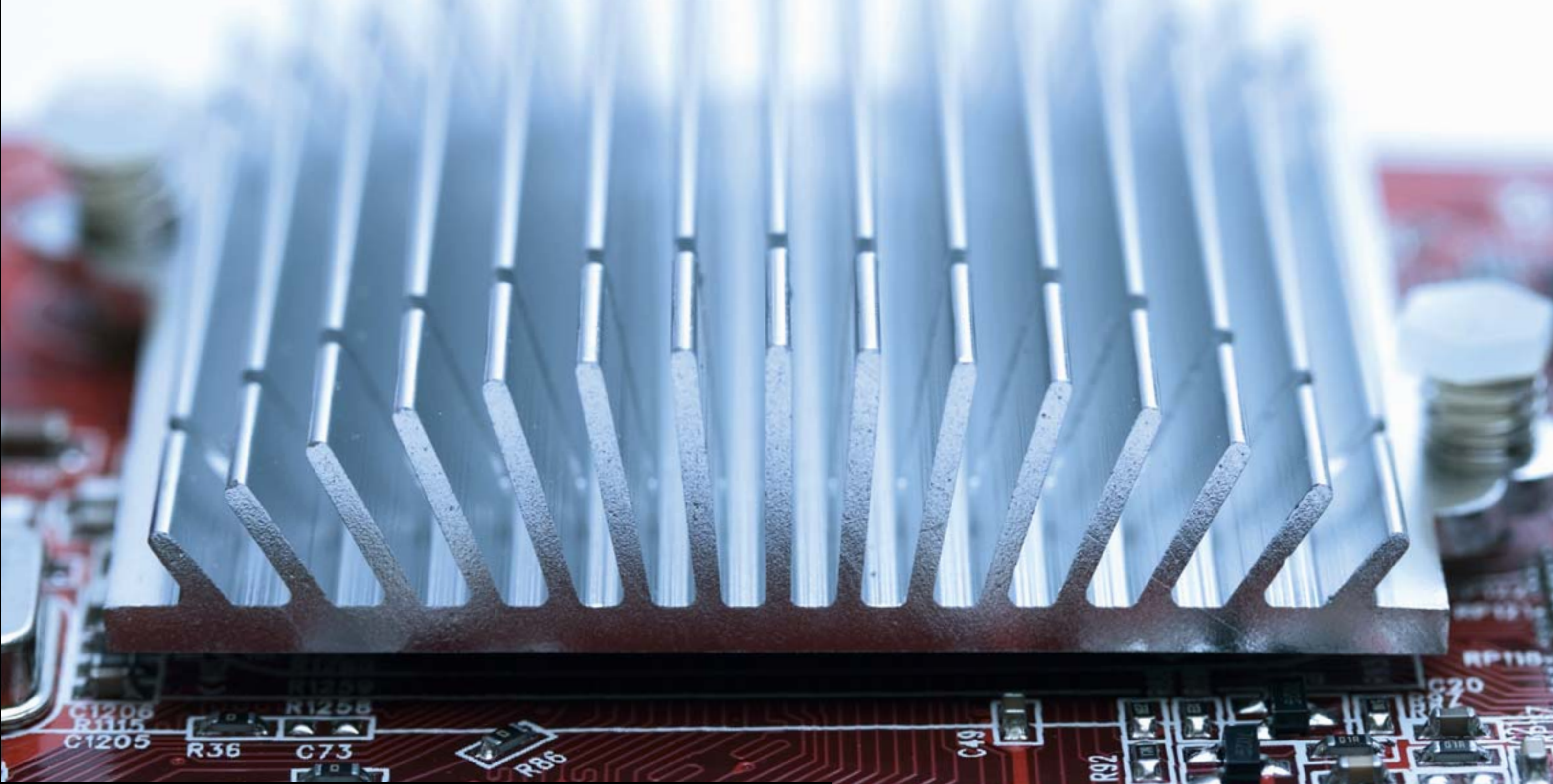

METHODS FOR OPTIMIZATION OF AIR COOLED SURFACE TOPOLOGIES

optiSLang is used at Robert Bosch GmbH for optimizing the surface topology of heat sink geometries to enhance their convective heat transfer to the ambient air flow.

Motivation

The thermal performance requirements of air cooled electronic control units (ECUs) increase continuously due to the growing extent of implemented functionality and thus higher power loss density and the trend of miniaturization. To meet these targets, it is mandatory to enhance the convective heat transfer to the ambient air flow by means of optimizing the surface topology of heat sink geometries.

Introduction

In order to quantify the cooler performance for a given power loss P_v and air flow, either the cooler temperature or the derived scalar quantity Thermal Resistance "R_{th}" is usually chosen as a primary output variable:

$$R_{th} = \frac{T_{surf} - T_{amb}}{P_v}$$

with the heater surface temperature T_{surf} and the constant ambient temperature T_{amb}. Furthermore, the objective material volume of the heat sink as an indirect estimation for the manufacturing costs is of relevance and used as secondary output variable. It is not unusual that optimal cooler design and low cooler mass are in conflict with each other, therefore, a multi-objective optimization has to be performed in order to compromise for a design.

Realization

In order to tackle this task, several different approaches were implemented in both, optiSLang and optiSLang inside ANSYS Workbench utilizing different computational fluid dynamics programs (CFD), namely scStream (Cradle), FloEFD (Mentor Graphics) and CFX (ANSYS) as it can be seen in Fig. 1 (see next page). These procedures all have their own benefits and draw backs. In standalone optiSLang for example any scriptable software can be used as shown in Fig. 1a) - c) (see next page). The method shown in Fig. 1b) (see next page) even relies on implementing Excel with its powerful Visual Basic utilities in order to control calculations, simulations and several batch scriptable programs. In this case, VBA, VBS, windows batch, scStream, ANSYS APDL and Python was used.

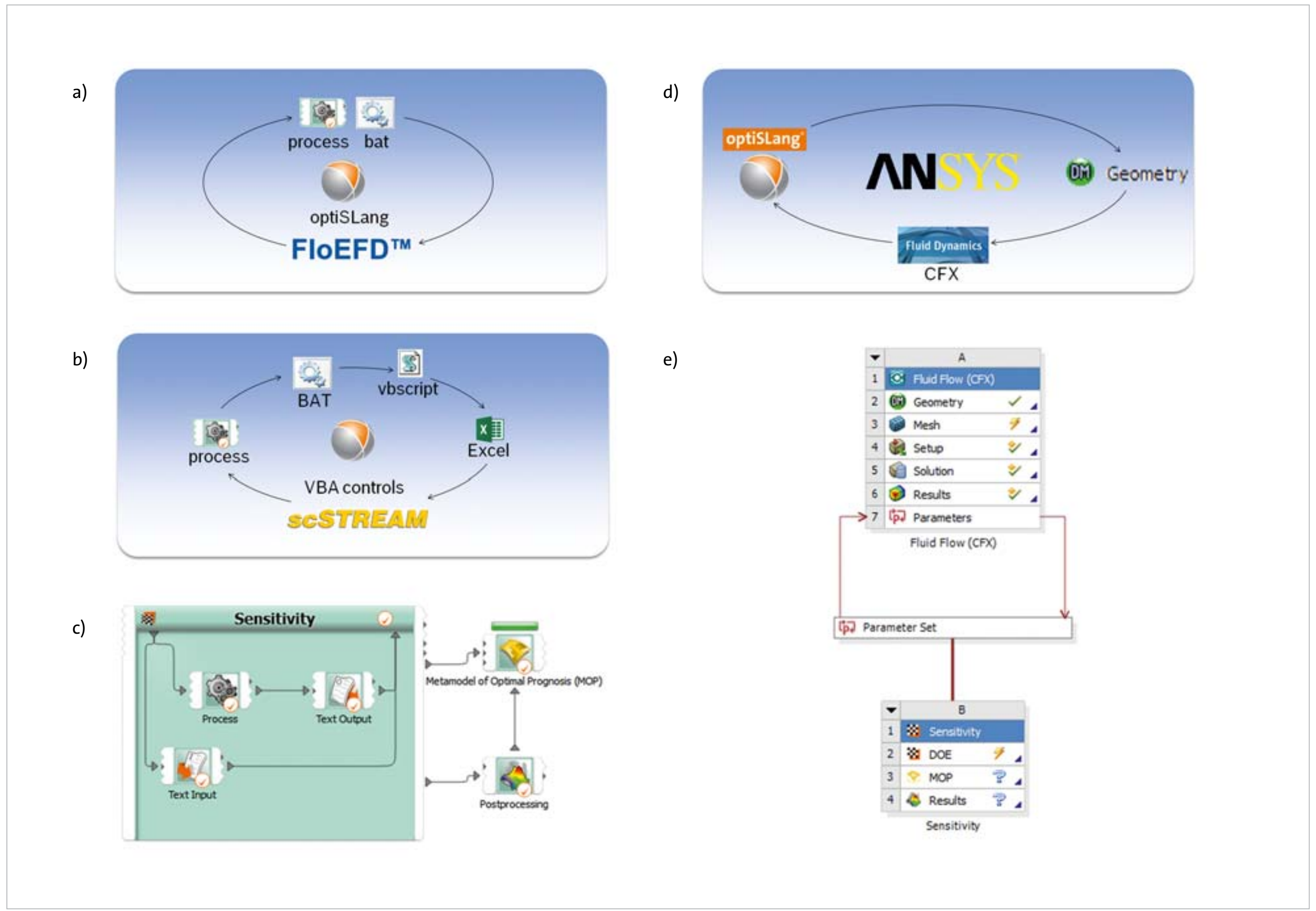

Figure 1: Implementation of workflows. a) - c) standalone optiSLang, d), e) optiSLang inside ANSYS Workbench.

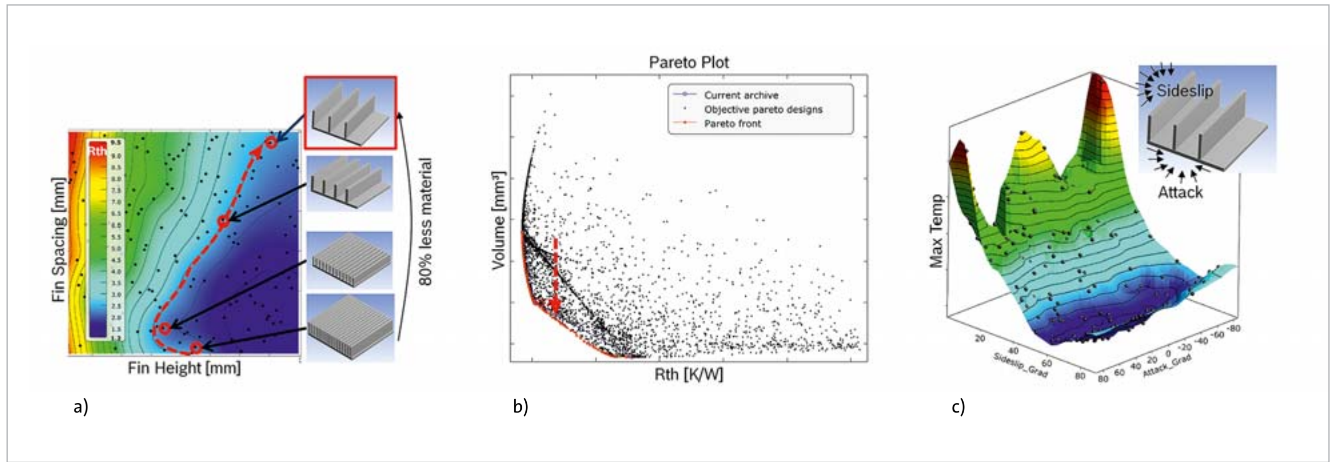

Figure 2: a) Rth value of cooler with fins depending on geometry with indicated isoline, b) Pareto plot depending on cooler volume and c) sensitivity analysis of air flow vector depending on maximum cooler temperature

This approach is functional, but includes the handling of several interfaces introducing a high level of complexity. In Fig. 1d) – e) ANSYS Design Modeler and CFX was used in order to generate and calculate parametrized geometries controlled by optiSLang inside ANSYS Workbench. The benefit of this approach is that geometry generation, calculation and result evaluation is done in one framework. With this solution however, the user is obliged to use CFD solutions implemented into ANSYS.

Results

The examined geometry in the following results is a simple solid metal fin-heatsink structure with a heating boundary condition at the base. In Fig. 2 the sensitivity analysis of the cooler R_{th} is shown for fin height, fin spacing and air flow directions, all varied according to an Advanced Latin Hypercube algorithm. In Fig. 2a) the R_{th} is plotted as a function of fin height vs. fin spacing for a fixed air flow direction. It is evident, that the R_{th} gradually improves with increasing fin height. Several designs are displayed near an isoline of the R_{th} revealing that the mass of the cooler can be reduced by 80% while maintaining the same thermal performance. This is achieved by increasing the fin height and fin spacing. In Fig. 2b) the corresponding Pareto front is shown giving insight in the multi objective optimization.

In Fig. 2c) the geometry was fixed and the air flow angle was varied. In this analysis the maximum temperature of the cooler is evaluated. Local and global minima are present depending on alignment of the air flow. Based on these sensitivity analyses, a subsequent optimization based on a Metamodel of Optimal Prognosis (MOP) can be performed without the need of additional CFD simulations.

Summary

The presented workflows and results serve as a proof of concept study. It has to be verified that this approach is also suitable for complex geometries.

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