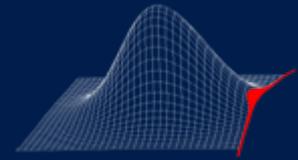




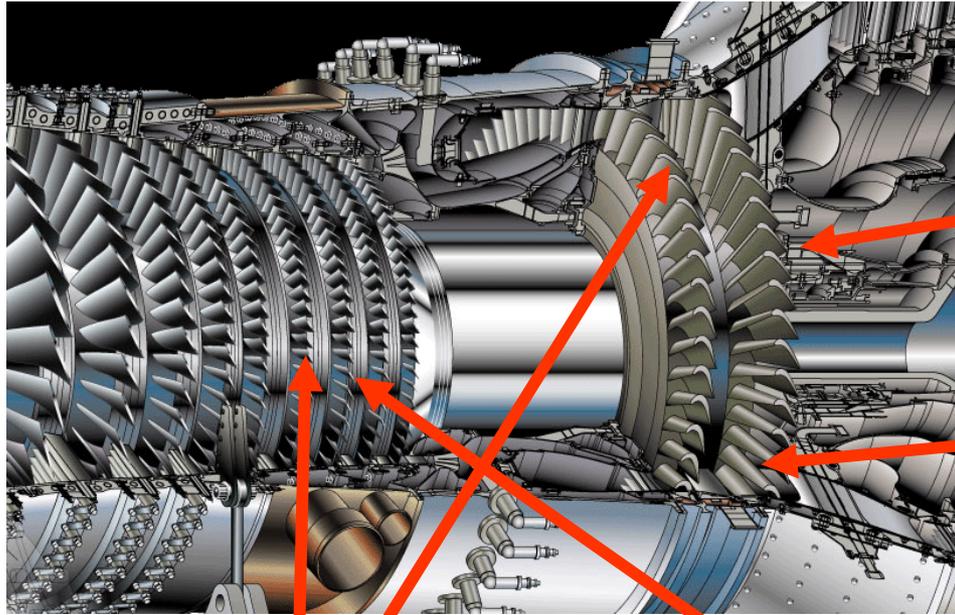
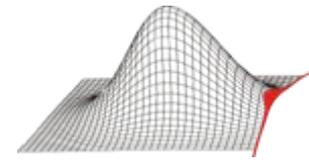
TECHNISCHE
UNIVERSITÄT
DRESDEN



Fakultät Maschinenwesen · Institut für Strömungsmechanik · Professur für Turbomaschinen und Strahlantriebe

Probabilistik im Turbomaschinenbau

Konrad Vogeler



Robustes Design

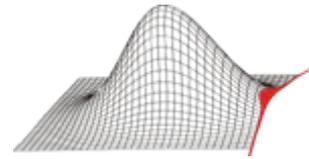
Probabilistische Simulationen eines Sekundärluftsystems einer Gasturbine

Probabilistische Lebensdauer-Untersuchungen von gekühlten Turbinenschaufeln

Untersuchung des Einflusses von Geometriestreuerungen auf den Verdichterwirkungsgrad und auf HCF Verhalten bei Verdichterschaufeln (Produktion und Betrieb)

Aerodynamik und Kühlung

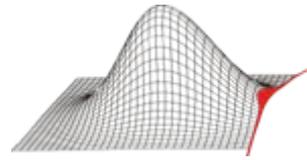
Aerodynamische Optimierung und Verlustuntersuchungen für Turbinen und Verdichter
Filmkühlung auf Seitenwänden



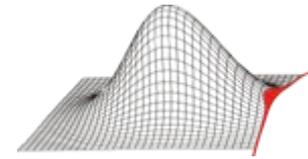
Zwei Turbinenschaufeln aus der gleichen Maschine



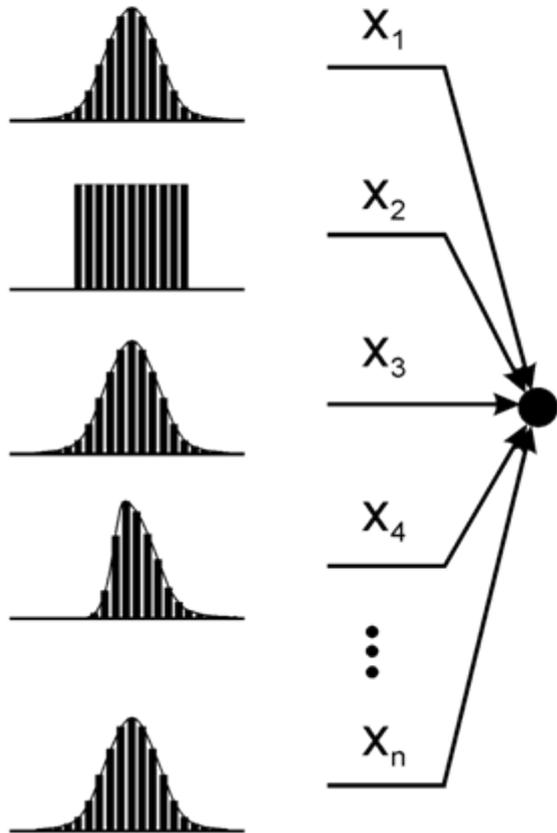
Quelle: Massachusetts Institute of Technology, Prof. David L. Darmofal



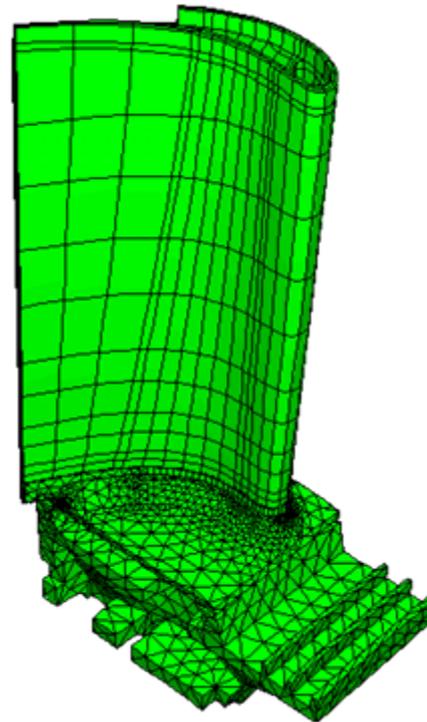
- Produktionsstreuungen (Geometrie)
- Produktionsstreuungen (Material)
- Randbedingungen (Temperatur, Drehzahl, Inzidenz...)



probabilistische Eingangsgrößen

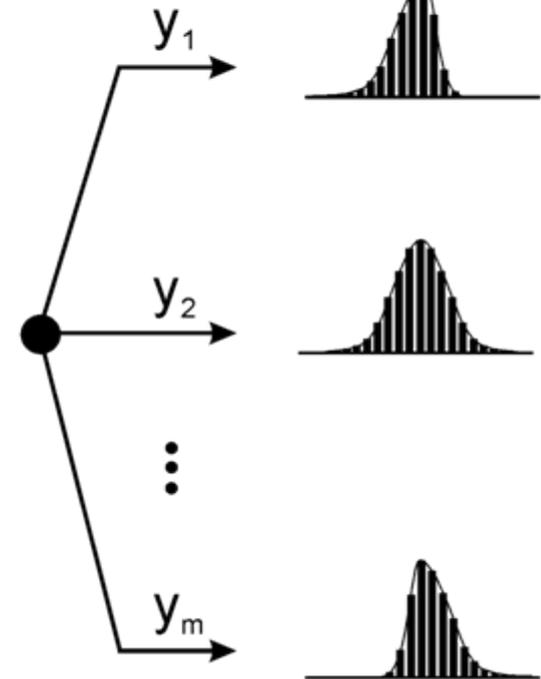


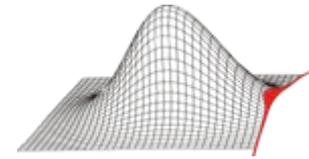
Strukturanalyse



deterministisches
Modell

Streuung der Ergebnisgrößen





2D Mittelschnitt einer HPT Schaufel

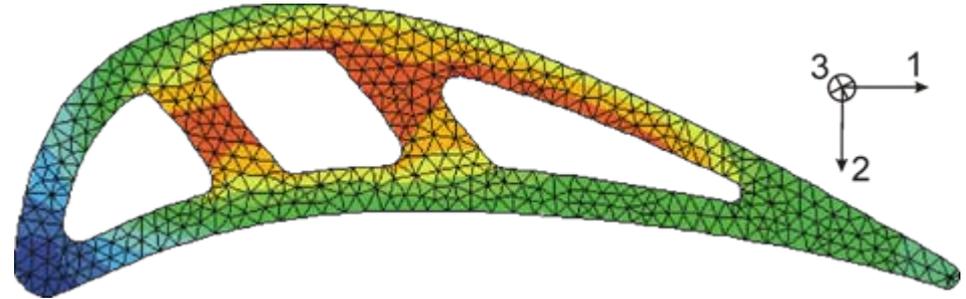
1500 Elemente

3000 Knoten

ABAQUS (v6.3)

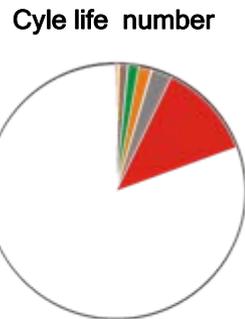
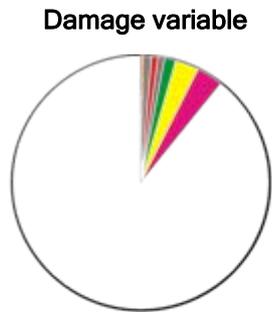
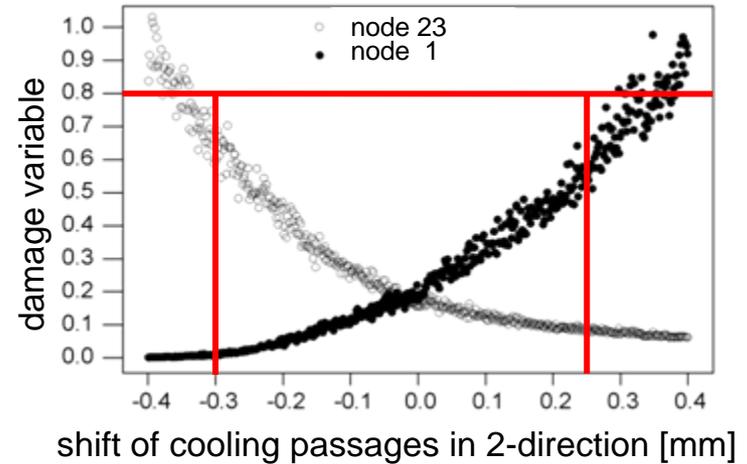
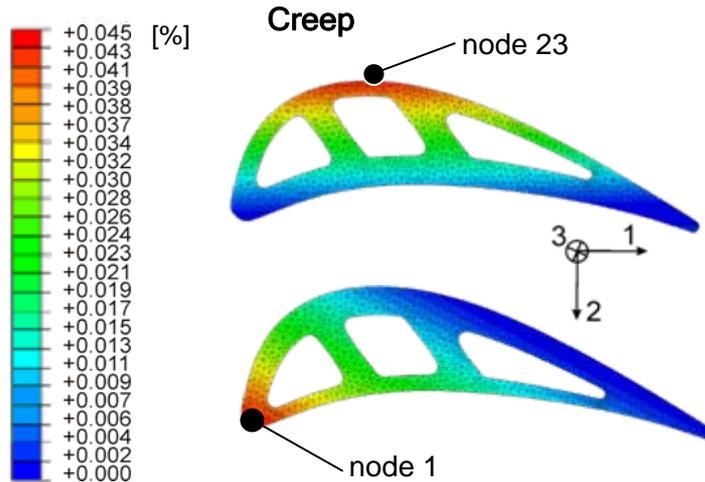
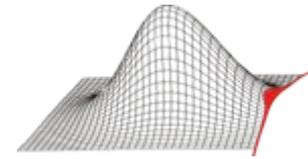
Mechanische Lasten wg. Rotation

Thermische Lasten wg. Temperaturdifferenzen (statisch)

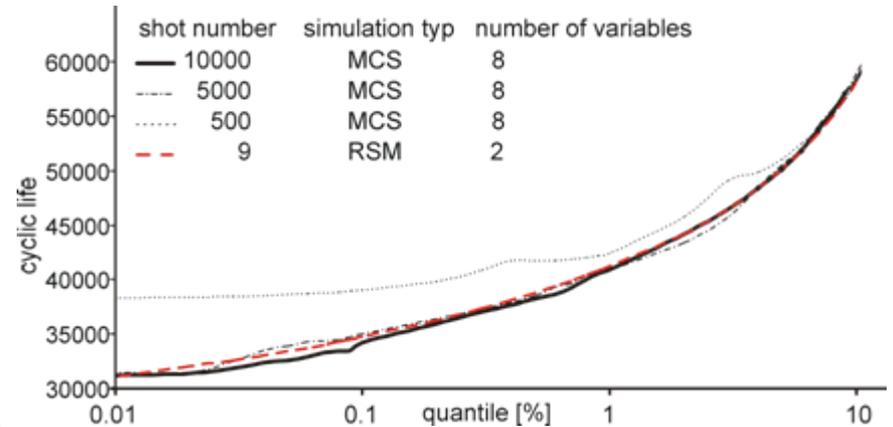


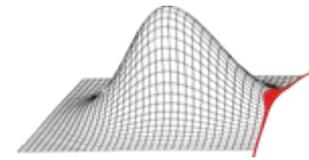
Input:

Kernbewegung beim Gießen, Young's Modulus, Wärmeleitfähigkeit, Ausdehnungskoeffizient, spez. Wärmekapazität, Materialdaten (LCF / creep), Zentrifugalkraft ...

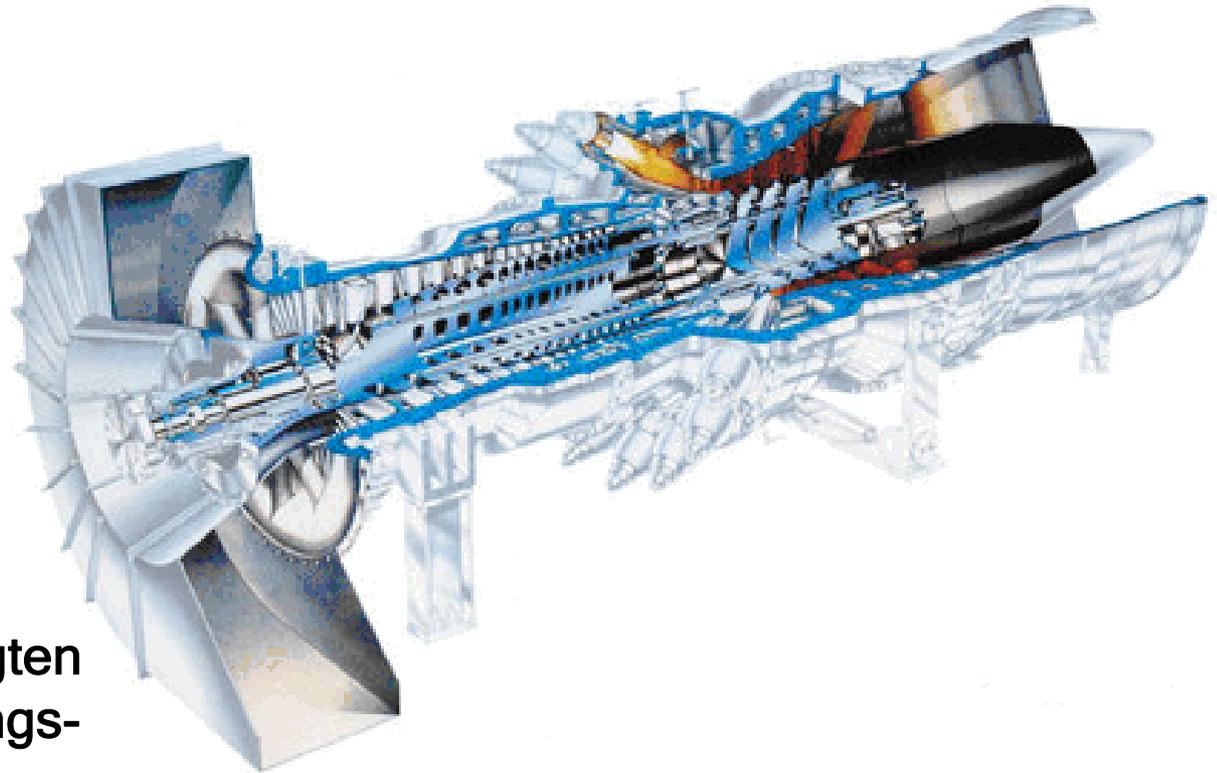


- base metal conductivity
- TMF material data
- specific heat capacity
- shift of cooling cores in direction 1
- coefficient of expansion
- Young's modulus
- centrifugal force
- shift of cooling cores in direction 2

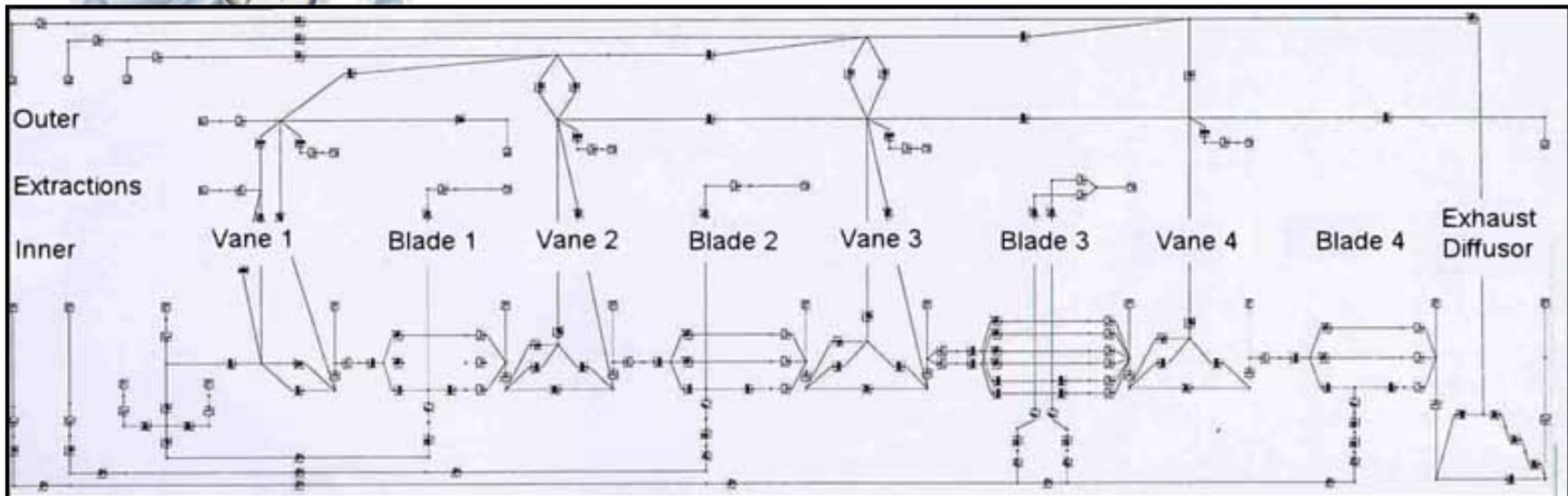
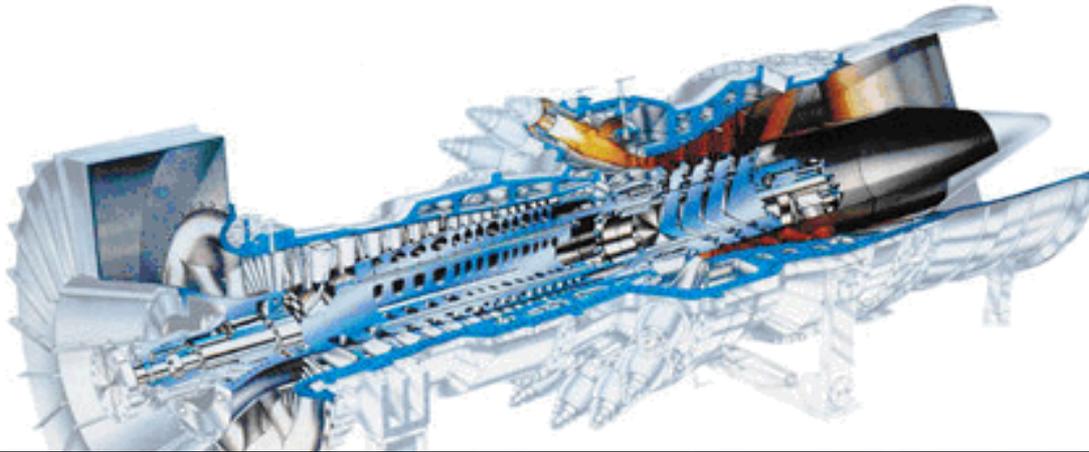
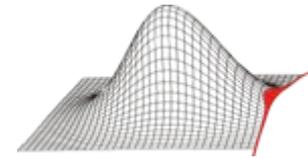


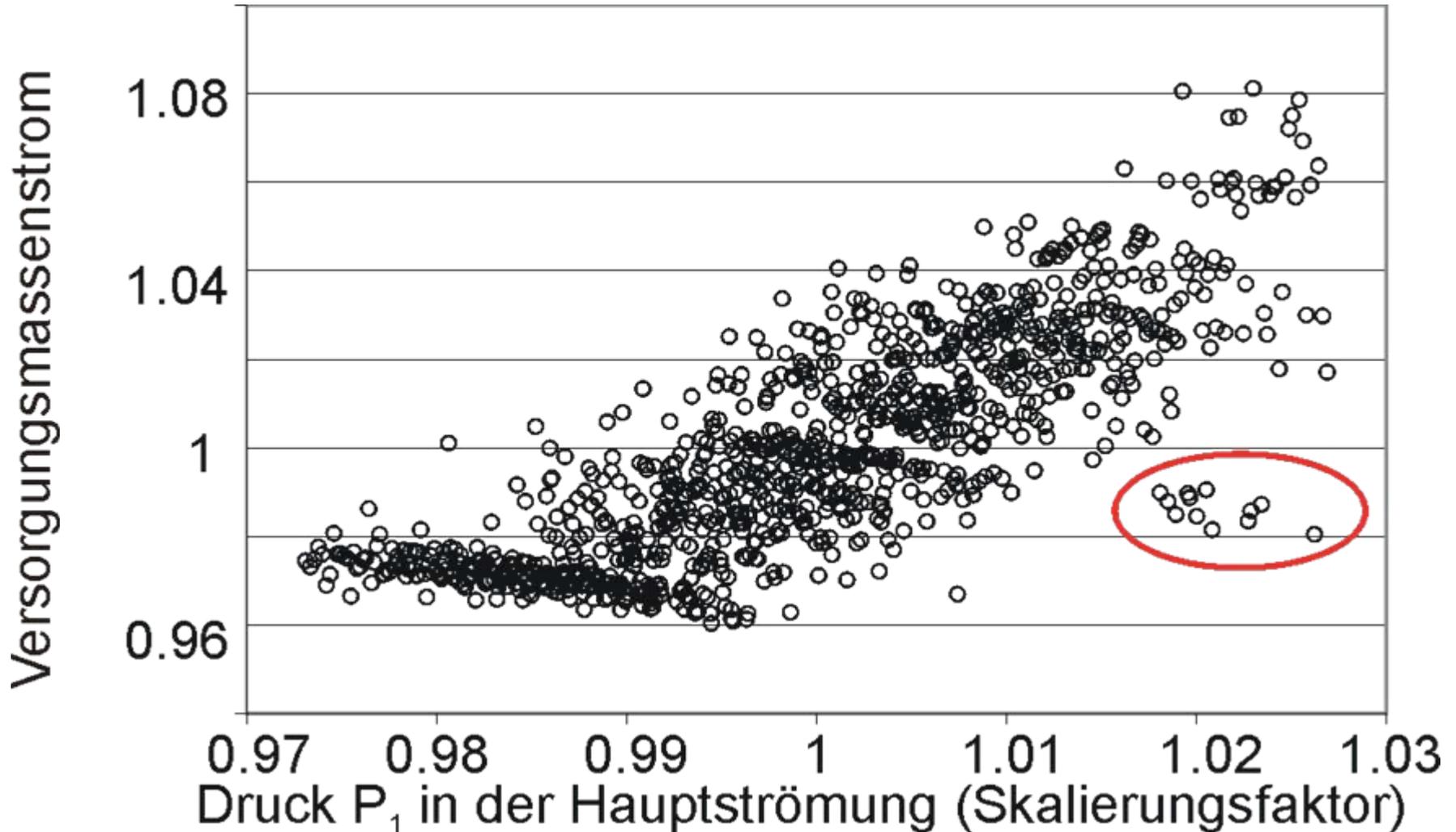
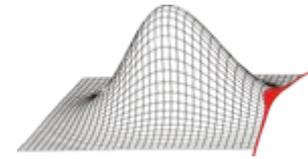


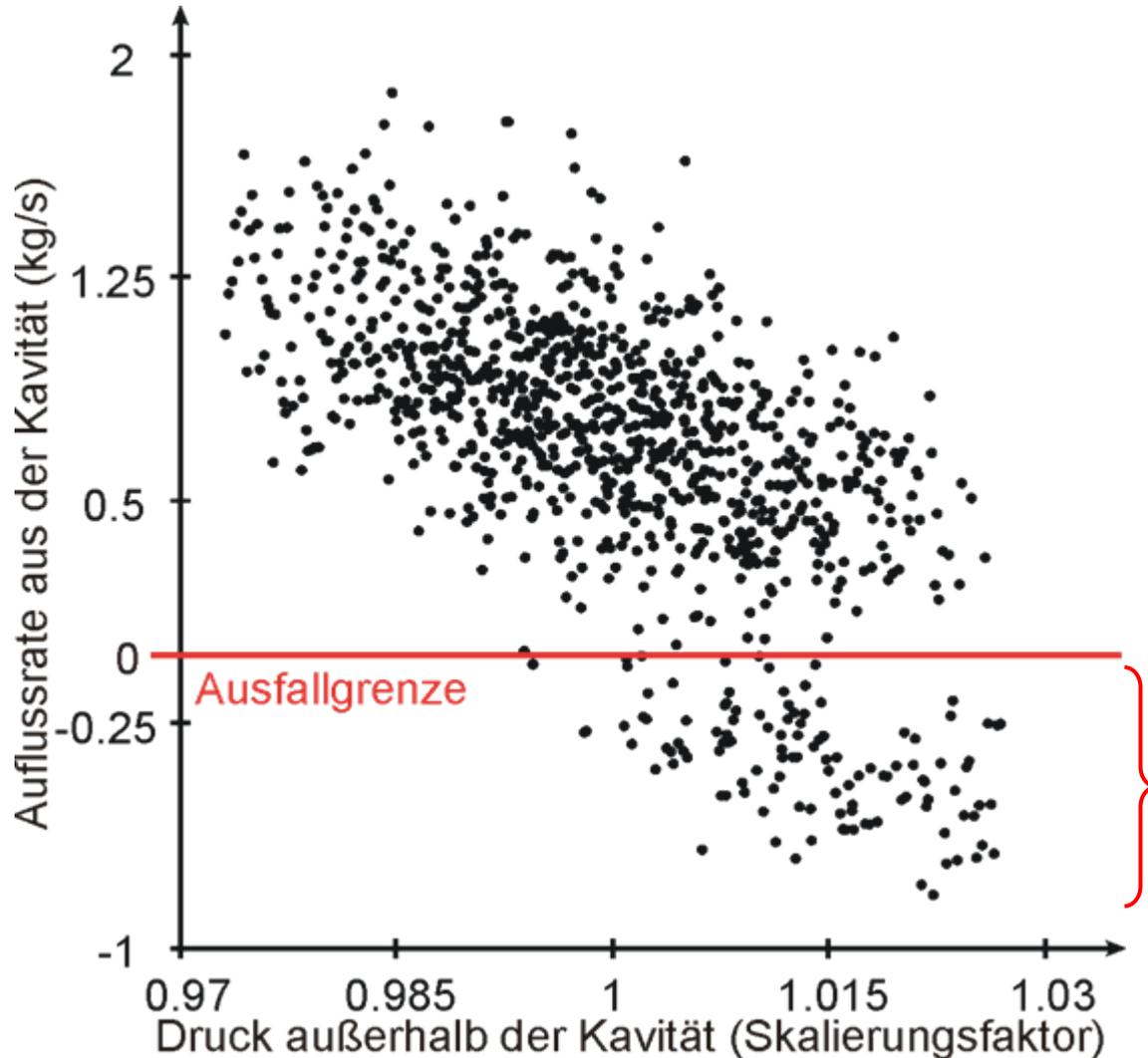
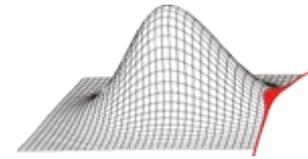
Ermitteln des Einflusses von Streuungen auf Durchflussraten und Leckagen des Sekundärluftsystems.



Anzahl der berücksichtigten probabilistischen Eingangsgrößen: bis zu 263

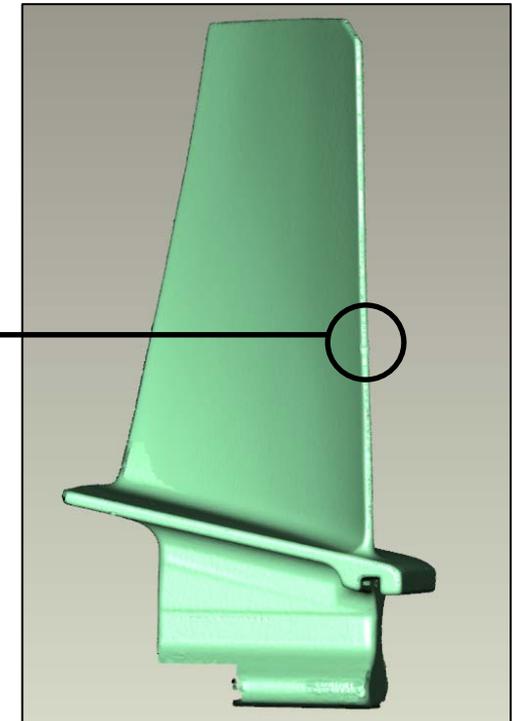
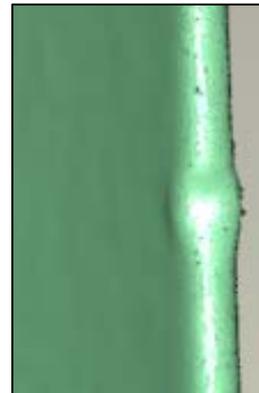
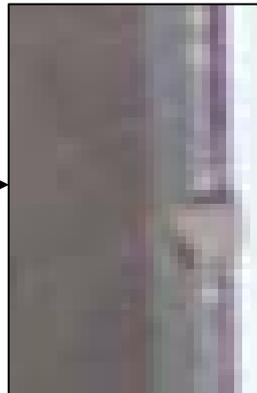
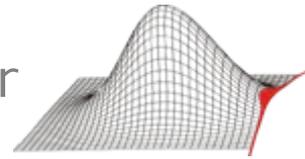


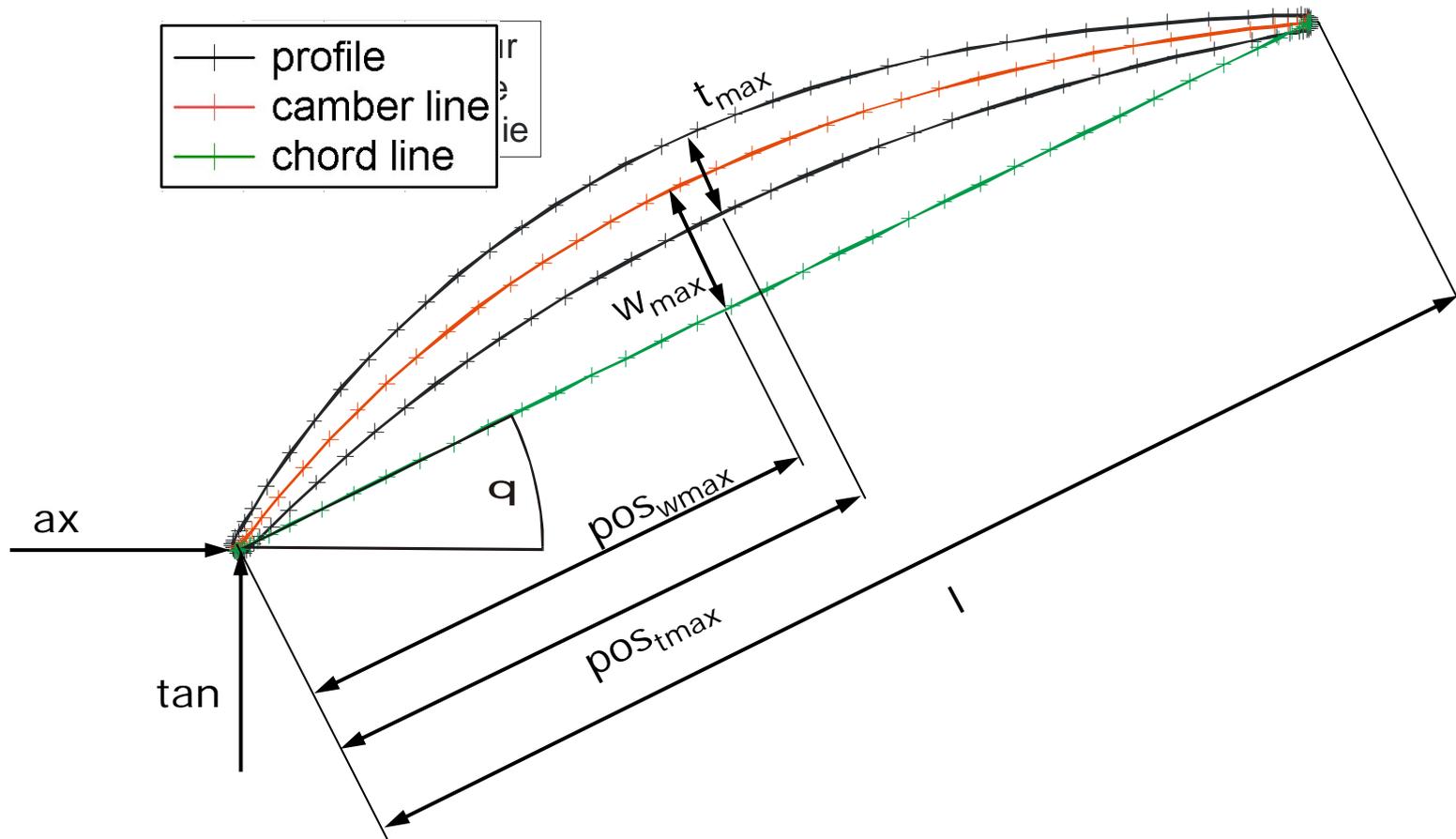
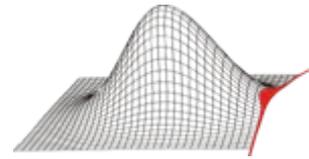


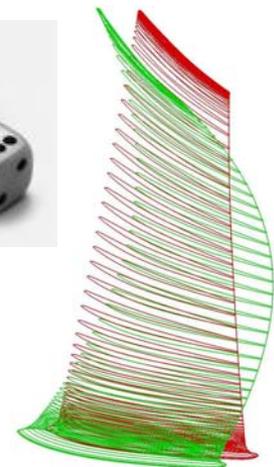
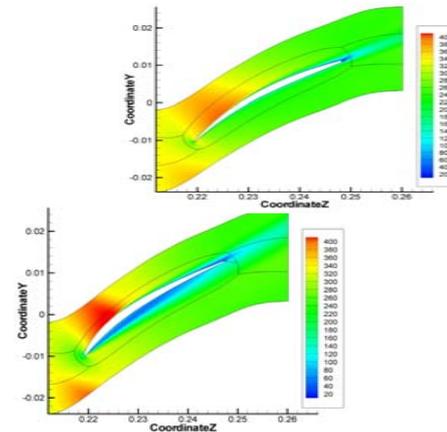
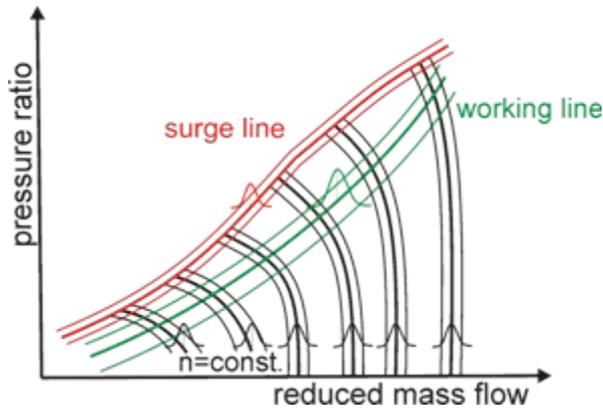
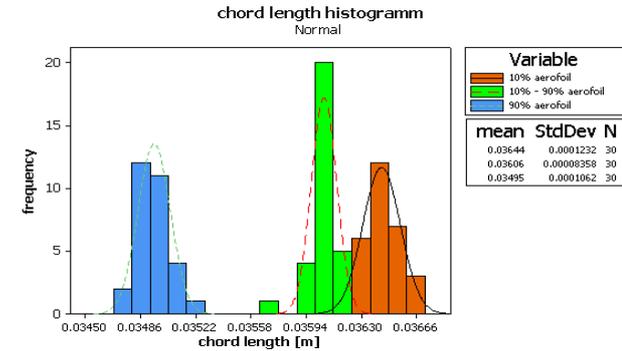
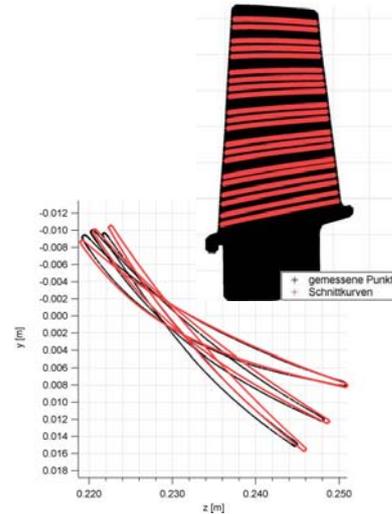
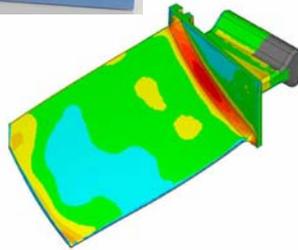
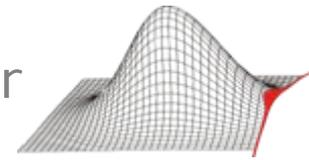


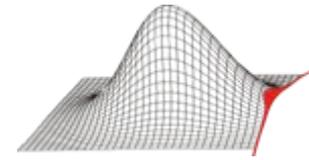
Heißgaseinbruch
→ Systemausfall

In diesem Beispiel:
 $P_f = 11.8\%$



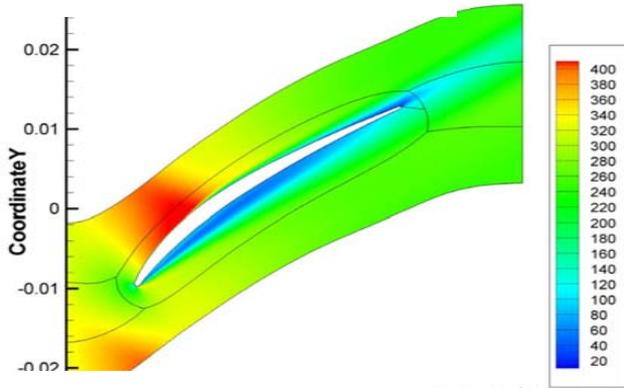




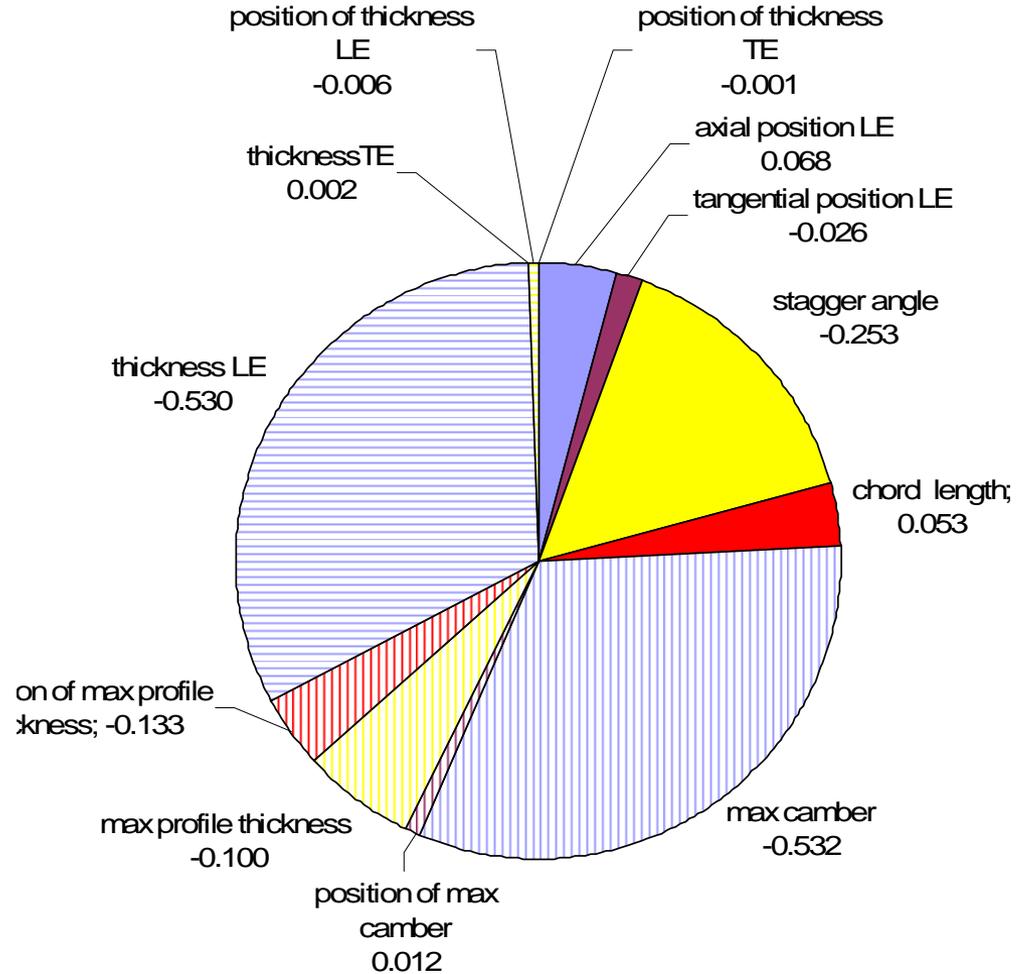
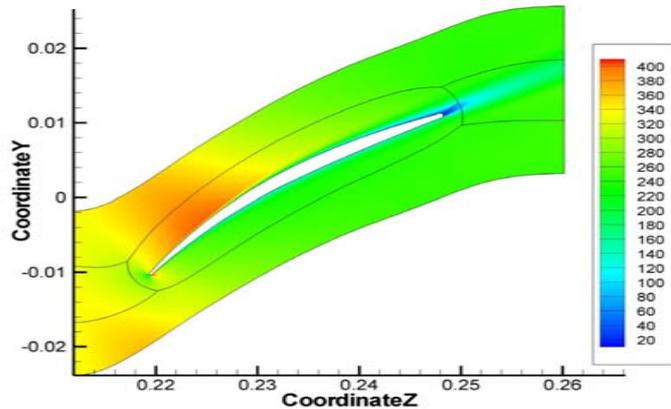


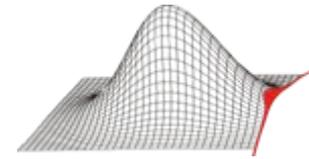
Ergebnis MCS: Einfluß der Parameter auf den Wirkungsgrad

Simulation 1:

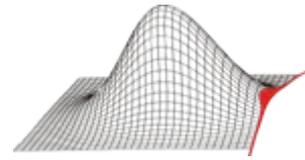


Simulation 2:

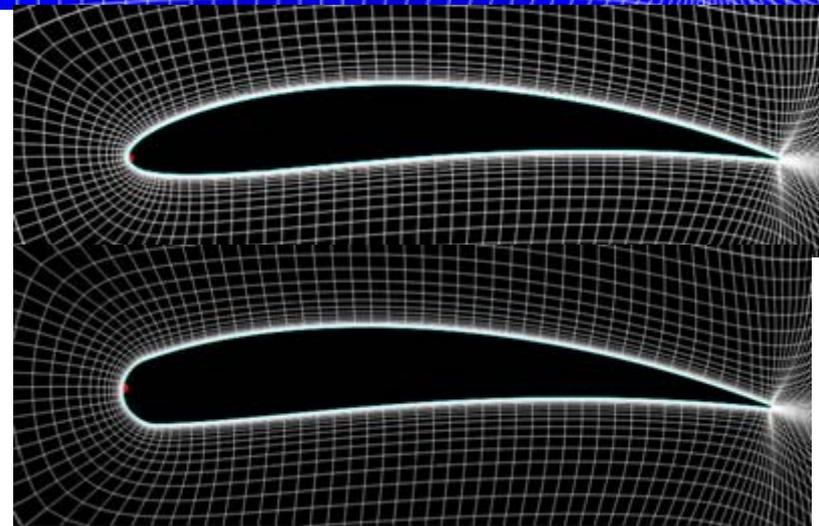
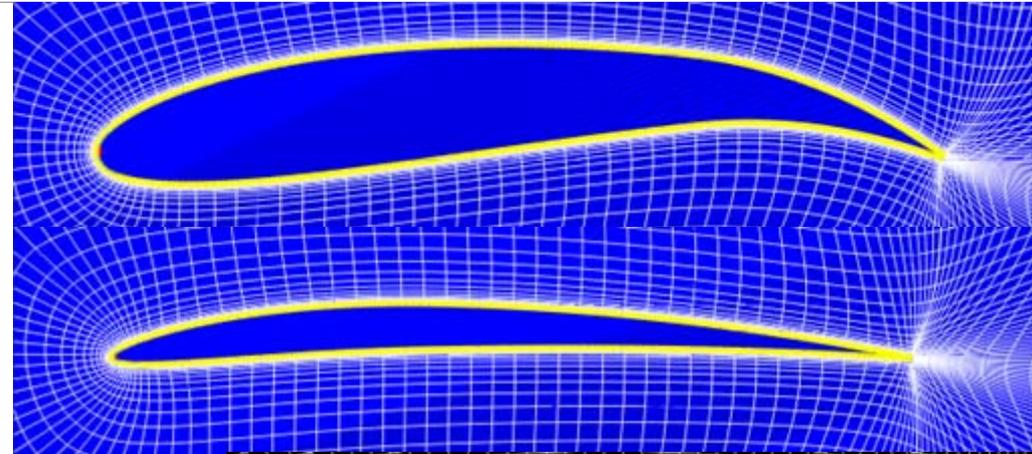


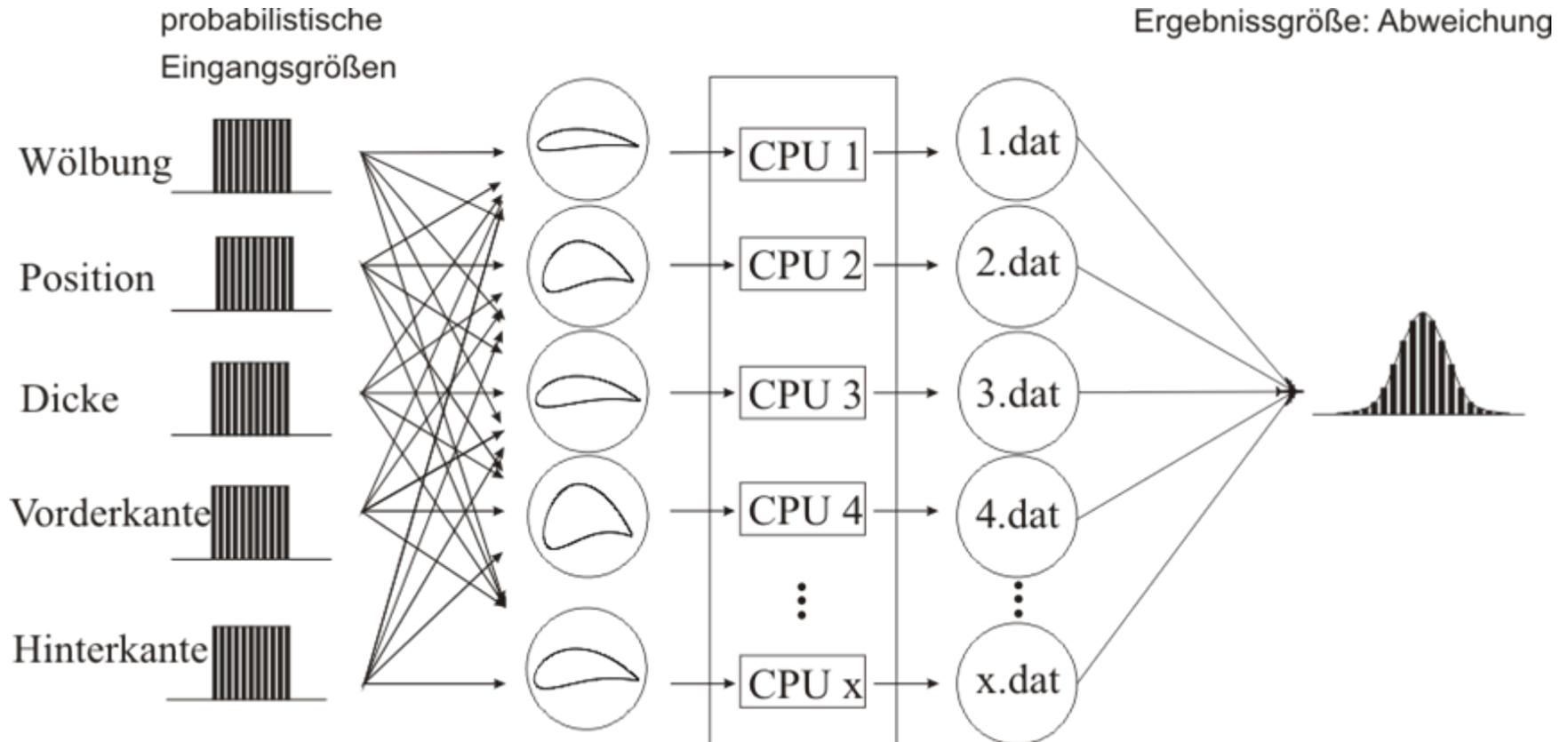
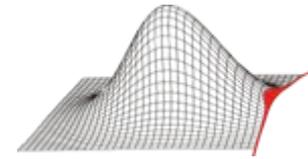


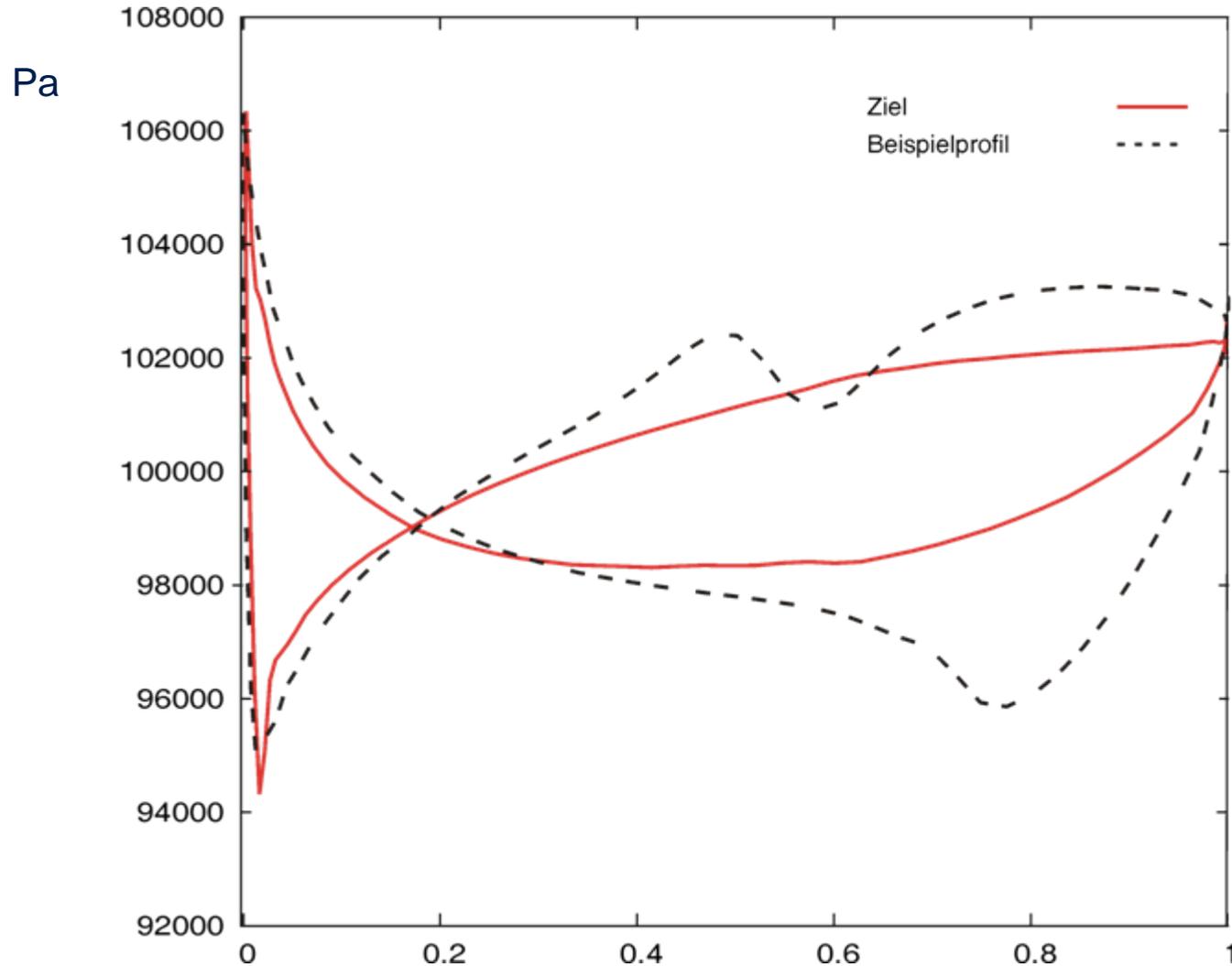
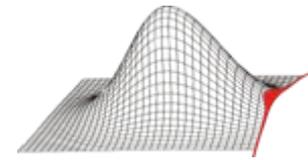
- Ausgang: Druckverteilung eines parametrisierten Verdichterprofils (NACA 6512)
- Ziel: Suchstrategie, um von einem beliebigen Ausgangsprofil das NACA 6512 wiederzufinden
- Ansatz: Zusätzliche Parameterisierung des CFD Netzes
- Abhängigkeit: Morphing mit Hypermesh in von den Profilparametern
- Suchstrategie: Korrelation zwischen der Druckverteilung und den Profilparametern

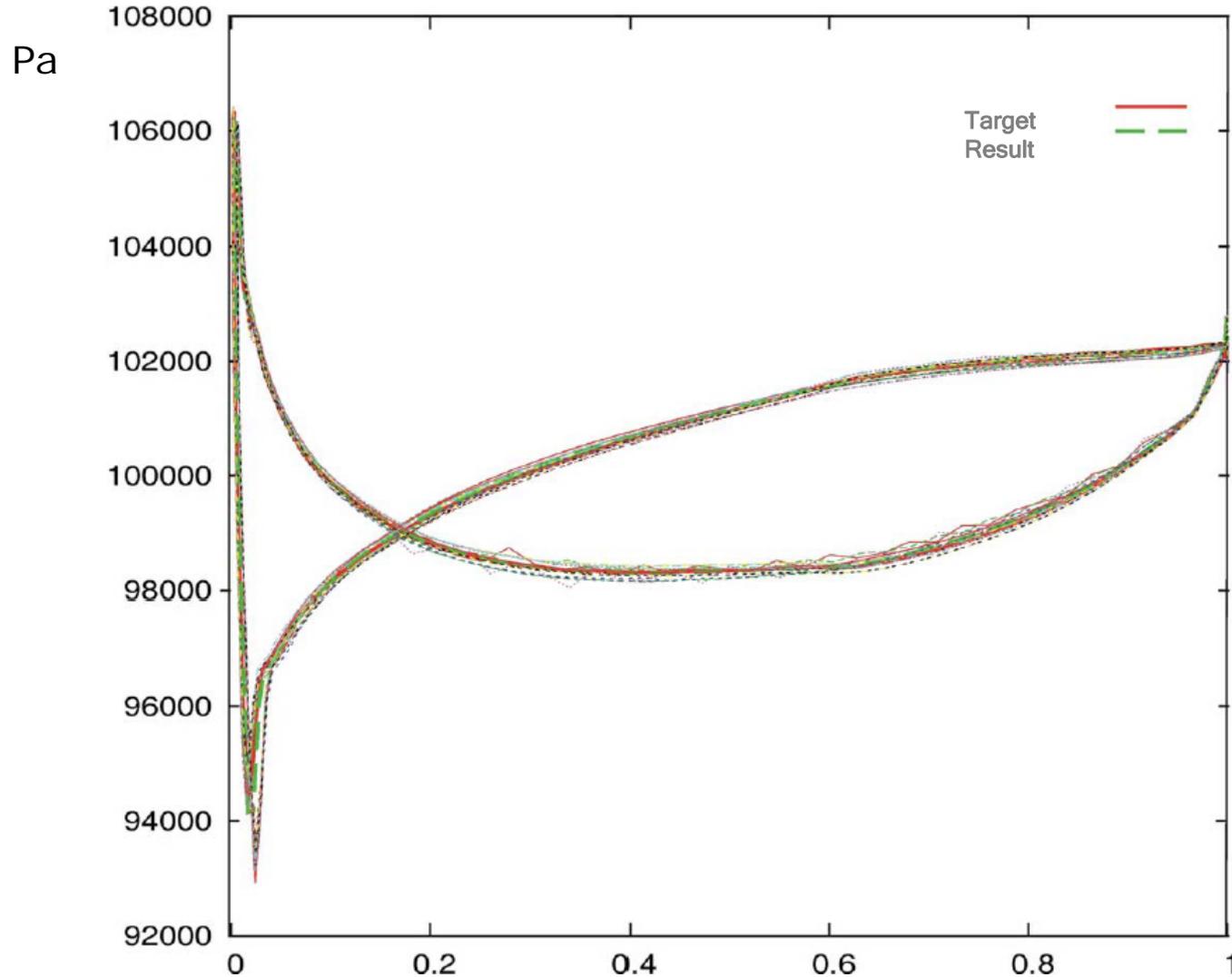
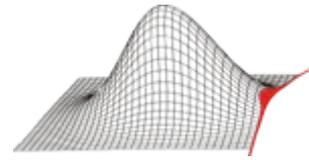


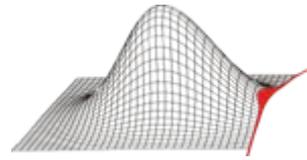
- Profilgenerator
- C-Programm mit Input:
- NACA 4-Digit Definition
NACA 6512
 - Wölbung (4-9)
 - Wölbungsrücklage (4-7)
 - Dicke (06-14)











Kühlluftverteilung in kritischen Komponenten

Sekundärluftsystem mit gekühlten Komponenten

Einfluss der Fertigungstoleranzen auf Aerodynamik und Lebensdauer

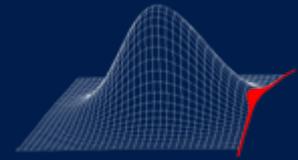
Lebensdauer Rotorscheiben

Leistungsrechnung, wesentliche Einflußparameter

Verfügbarkeit; Einzelkomponente, Gesamtanlage

Wartungsstrategie / Ersatzteil Logistik

Evolutionäre Optimierung / Inverses Design



Probabilistik im Turbomaschinenbau

Konrad Vogeler

