BERKELEY LAB
Bringing Science Solutions to the World

U.S. DEPARTMENT OF ENERGY
Office of Science

# SVT Disk Cooling System Manifold - Update

Mechanical and Fluid Dynamic Analysis: Structural Verification and Flow Optimization

**Giovanni Rizzo**
**09.23.2025**

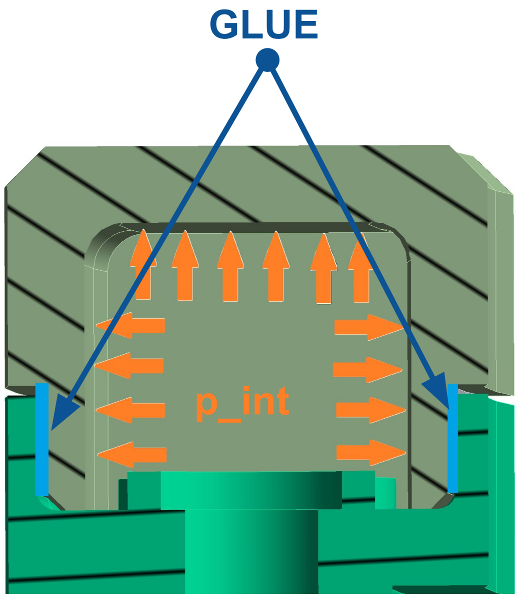
# Mechanical Analysis

The goals of this analysis are:

1. Evaluate the effect of material choice on the system's **maximum pressure capacity**;
2. Assess the static strength of the **adhesive joint**.

# ADHESIVE JOINT ANALYSIS - Model

**Modelling Hypothesis:** $E_\mathrm{a} = 2\,\mathrm{GPa}$ $\sigma_\mathrm{y} = 25\,\mathrm{MPa}$ $fos = 2$

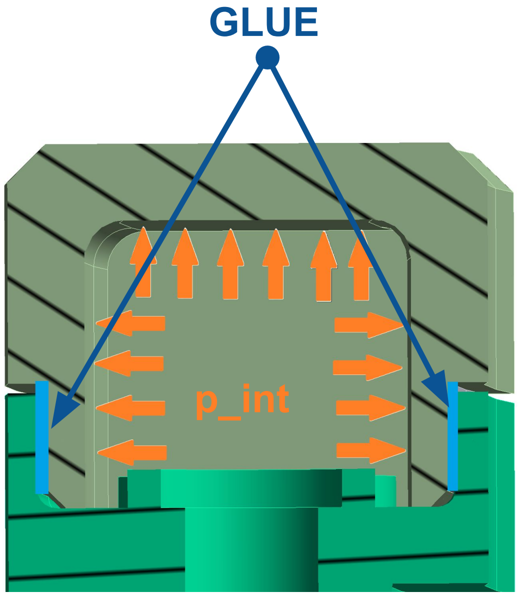



The glue's job is to transfer the load from the upper component to the lower one which is held in place by bolts.

| | |
|---|---|
| $T = p_{int} \cdot \frac{A_{up}}{2}$ | $F = p_{int} \cdot A_l$ |
| ⬇ | ⬇ |
| $\tau = \frac{T}{A_\mathrm{glue}}$ | $\sigma = \frac{F}{A_\mathrm{glue}}$ |

# ADHESIVE JOINT ANALYSIS - Model

**Modelling Hypothesis:** $E_{\mathrm{a}} = 2\,\mathrm{GPa}\ \ \sigma_{\mathrm{y}} = 25\ \mathrm{MPa}\ \ fos = 2$




The glue's job is to transfer the load from the upper component to the lower one which is held in place by bolts.

**MAXIMUM SHEAR STRESS THEORY**

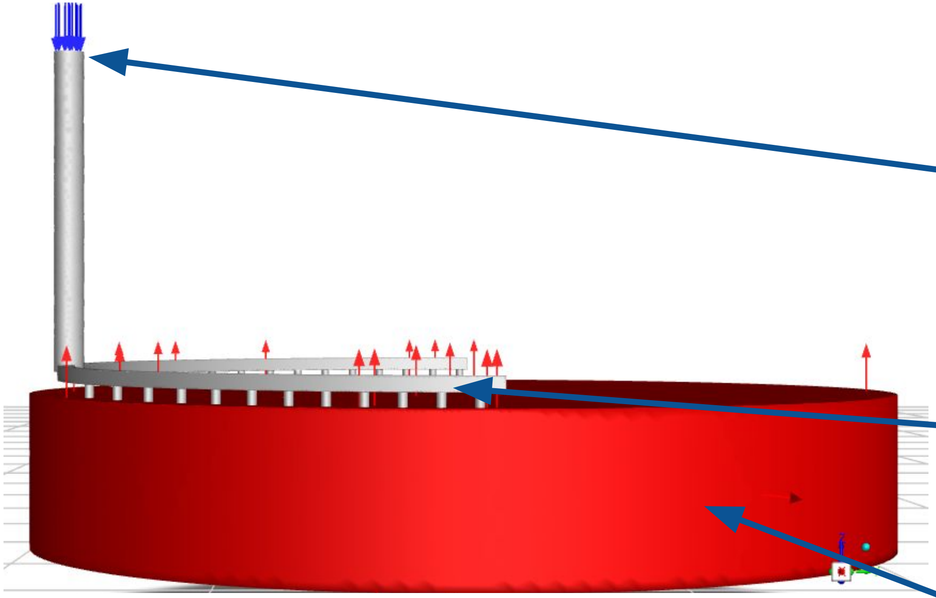
$$p\_int\_max := \frac{\dfrac{\sigma y}{fos}}{\sqrt[2]{\left(\dfrac{A\_l}{A\_glue}\right)^2 + 4\cdot\left(\dfrac{\dfrac{A\_up}{2}}{A\_glue}\right)^2}} = 42.446\ bar$$

# Fluid Dynamic Analysis

The goals of this analysis are:

1. To develop a **model** that accurately describes the physical phenomena
2. To **optimize the manifold design** to achieve a uniform mass flow rate through each orifice.
3. Experimental validation

# CFD MODEL SET UP



**PHYSICAL MODEL:**

- ➔ **Fluid:** Air as an **ideal gas**, at 278.15 K
- ➔ **Turbulence Model:** SST
- ➔ **Analysis type:** Steady - state

## INLET:

- ➔ **Type:** Mass Flow Inlet
- ➔ **Value:** 0.037 kg/s
- ➔ **Note:** Extended pipe to ensure fully developed flow prior to impingement on the manifold wall.

## WALL:

- ➔ **Type:** No-slip wall
- ➔ **Roughness Height:** 0.005 mm

## OUTLET:

- ➔ **Type:** Pressure Outlet
- ➔ **Value:** 0 (Gauge pressure) - *Baseline assumption*
- ➔ **Note:** An external plenum (red cylinder) is modeled to avoid imposing artificial back-pressure on the outlets.

# OPTIMIZATION

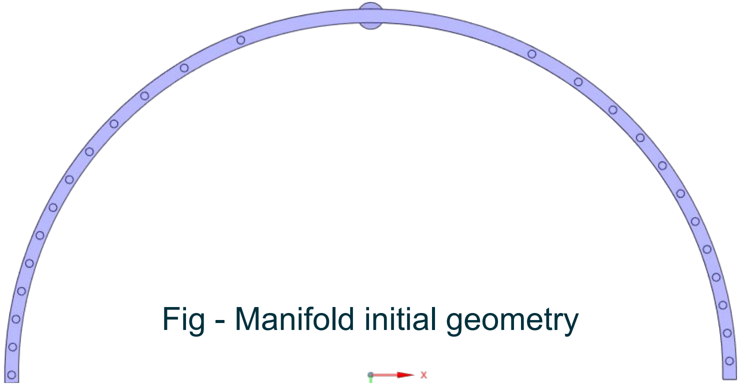
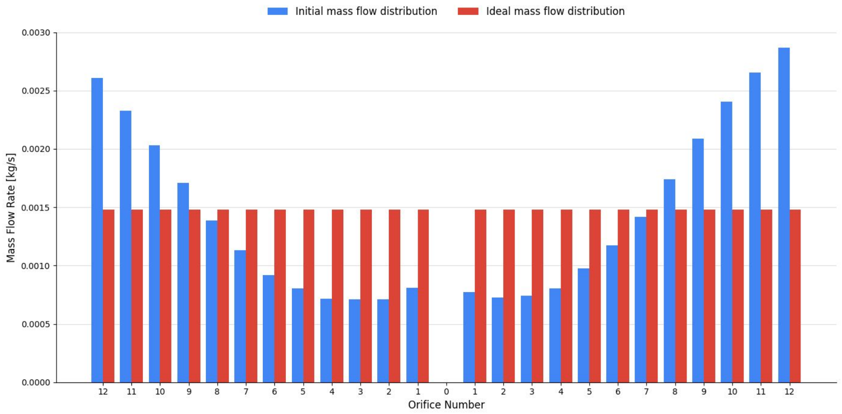


Fig - Manifold initial geometry




➔ **Methodology - Parametric Optimization**

- **Design Variables:** The diameters of each orifice ($d_i$).
- **Output Response**: The mass flow rate through each individual orifice ($\dot{m}_i$)

➔ **Target Function - Minimize RMSD**

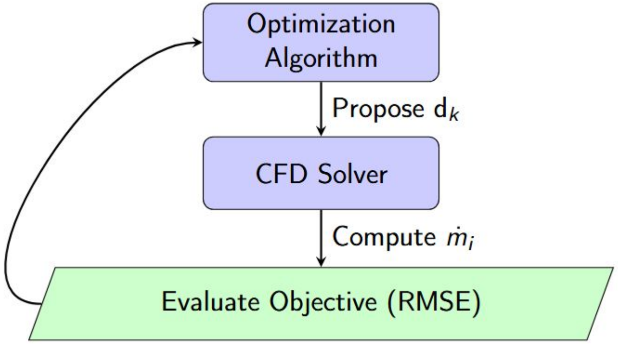
$$\mathrm{RMSD} = \sqrt{\frac{\sum_{i=1}^{N}(\dot{m}_i - \dot{m}_{\mathrm{target}})^2}{N}}$$

$$\dot{m}_{\mathrm{target}} = \frac{\dot{m}_{\mathrm{tot}}}{\#\mathrm{orifices}} = 0.00148\ \frac{\mathrm{kg}}{\mathrm{s}}$$

# OPTIMIZATION - Method [2]

**Problem:** Very high computational cost of CFD simulation

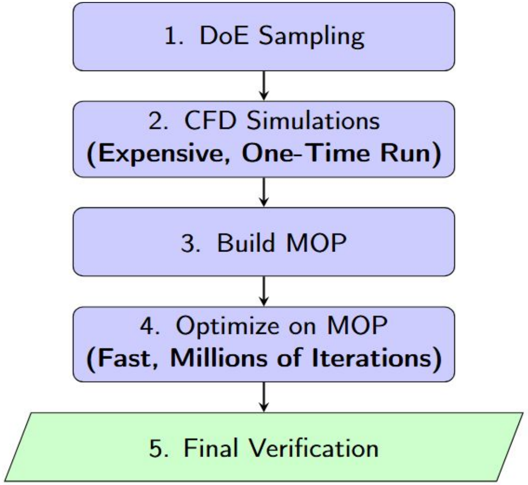
## Direct optimization process




**X Very slow**

**X High Risk of Local minimum**

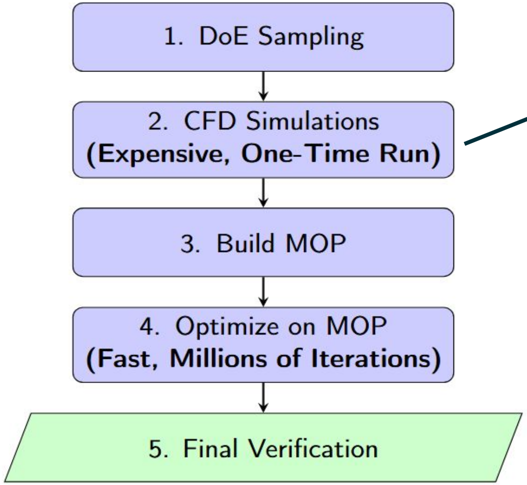
## Metamodel-based Optimization



# OPTIMIZATION - Method

**Problem:** Very high computational cost of CFD simulation

## Metamodel-based Optimization [3]




Train a metamodel using CFD simulations to achieve a high **Coefficient of Prediction**.

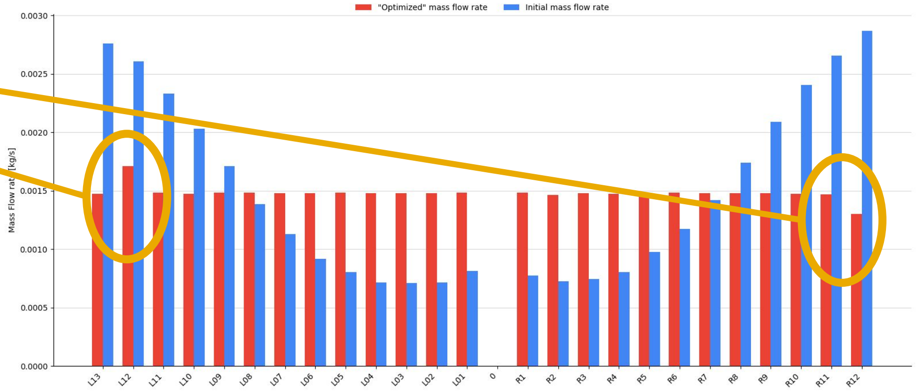
X Complex geometry needs many points to create a MOP with high CoP

Attempt 1: **model without plenum:**

- **50 Samples**
- **CoP = 0.9**
- **10000 iteration**

# OPTIMIZATION - Results 1

**Mass flow rate**



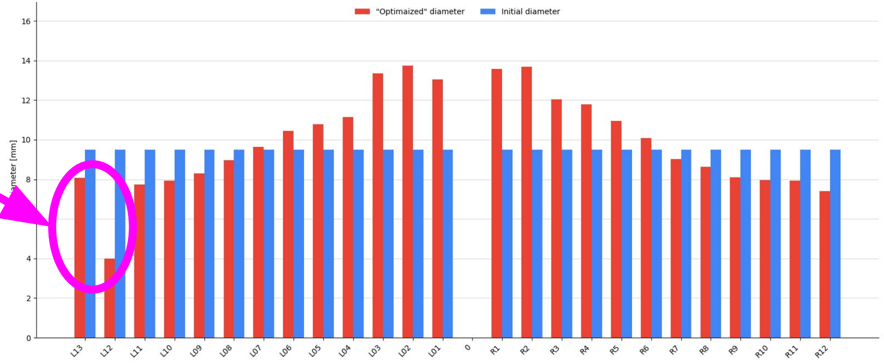

**Non-uniform mass flow distribution**

↓

Caused by the non-uniformity in the diameter trend

*The simple model generates numerical issue*

***Hp:*** *Without Plenum p_atm is applied directly at each orifice -> like a pump*

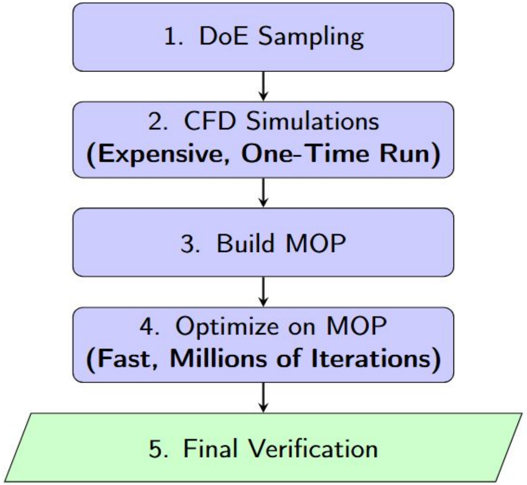



**Diameters**

# OPTIMIZATION - Current status

**Problem:** Very high computational cost of CFD simulation

## Metamodel-based Optimization




Attempt 2: **model with plenum:**

- **100 Samples**
- **CoP = 0.2**

CoP is too low - a larger sample size is required

Attempt 3: **model with plenum:**

- **300 Samples**
- **CoP = ?** *currently running*

Increasing the sample size is time-consuming

# SUMMARY

- → Assessed the static strength of the **adhesive joint.**
- → Evaluated **different optimization approaches**.
- → Defined and performed a **sensitivity analysis** and the **subsequent optimization**.

# NEXT STEPS

- → **Analyze** the final optimization results.
- → **Conduct experiments** to validate the simulation results