Manifold block design: benefit from Additive Manufacturing to optimise internal flow with SmartOptim®

Manifolds are circuit blocks used to distribute fluid to other components. Additive Manufacturing (AM) can be used to produce these blocks as it offers the possibility of limiting their weight while preserving their mechanical strength and operating objectives. However, it is possible to optimise more than just weight using this manufacturing technology: the internal design of the flow path can be optimised as well, leading to innovative shapes that cannot be achieved by cross drilling.

CFD-Numerics has developed SmartOptim®, a topological optimisation solution for fluids, which can be used to design internal paths based on flow objectives, which may include pressure drop reduction and flowrate balance on each outlet.

To illustrate the methodology, let's consider the manifold block presented below (Figure 1). It includes three different paths: two of them have one inlet and one outlet (Path-1 and Path-2) and one has one inlet with five outlets (Path-3).

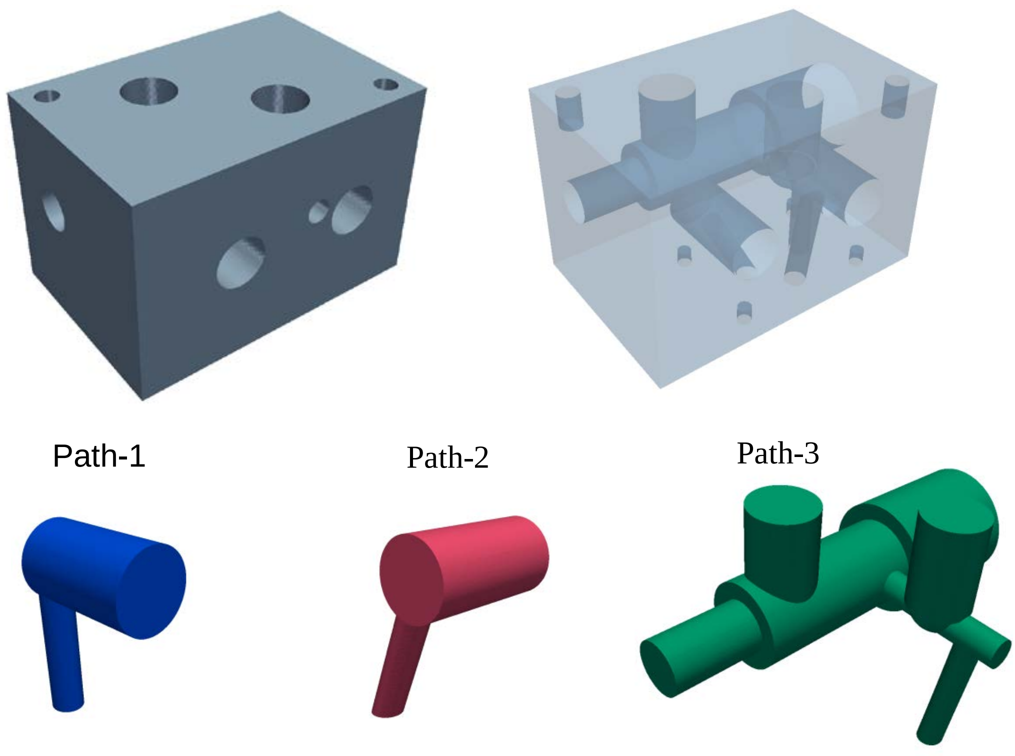

Figure 1: Manifold block - geometry

The flow in this block for each path is computed by applying a constant flowrate at the different inlets and a 0 Pa static pressure at each outlet. Fluid is considered incompressible at constant temperature and flow is simulated using a standard k-ε turbulence model associated with standard wall function treatment. The results obtained are presented in Figure 2 with the streamlines in each path.

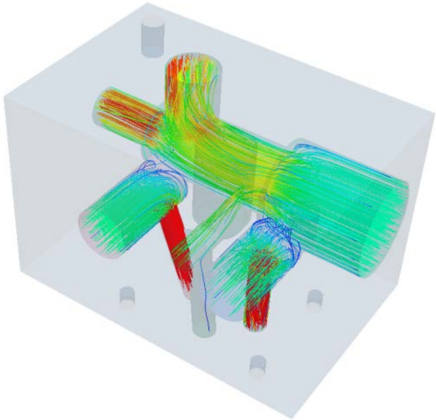

Figure 2: Manifold block - flow analysis

The graph presents the pressure drop for all the paths in Figure 3. For Path-3, the pressure drop is estimated by averaging the total pressure on the 5 outlets.

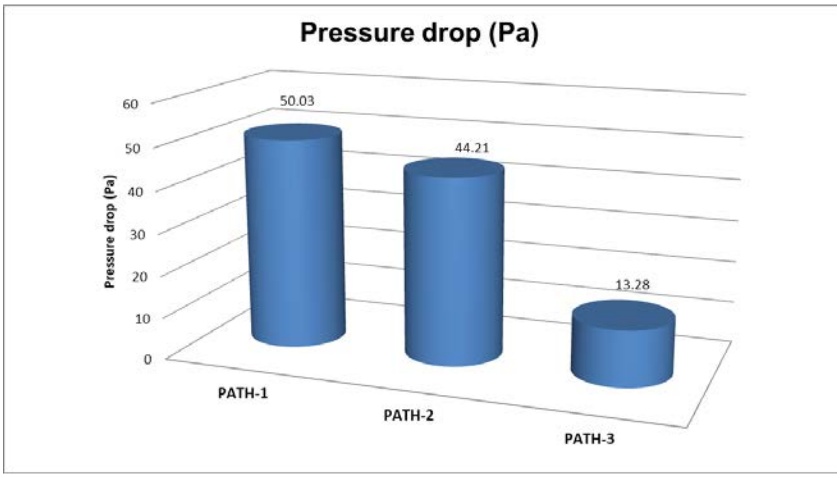

Figure 3: Manifold block - pressure drop

Looking specifically at Path-3 (Figure 4), it is worth noting that almost no flow is going through Outlet-3 and Outlet-5.

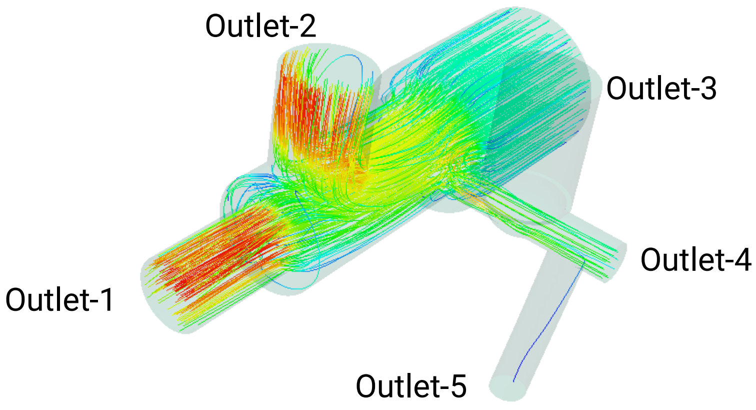

Figure 4: Manifold block - flow analysis in Path-3

The graph below (Figure 5) provides the flowrate deviation per outlet for Path-3. A perfectly distributed flowrate would lead to 0% deviation on each outlet.

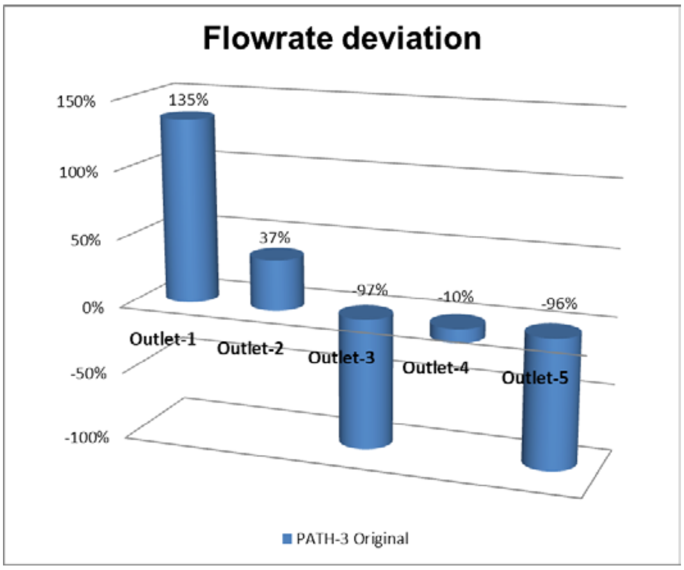

Figure 5: Manifold block - flowrate deviation in Path-3

Outlet-1 has a flowrate exceeding the targeted value by 135% while Oulet-3 and Outlet-5 is 97% below the target.

From the point of view of flowrate balancing, the flow in this manifold block is not optimised and pressure drop has to be reduced.

Based on the existing inlet and outlet positioning, we now propose to use SmartOptim® to add value to the design process of the flow paths and consequently to the manifold block. First, the “available volume” for each path (Figure 6) is defined, taking into consideration a minimum solid thickness between each volume to preserve the mechanical and manufacturing constraints.

It should be noted that there is no need to perform CAD parametrisation to run optimisation with SmartOptim®.

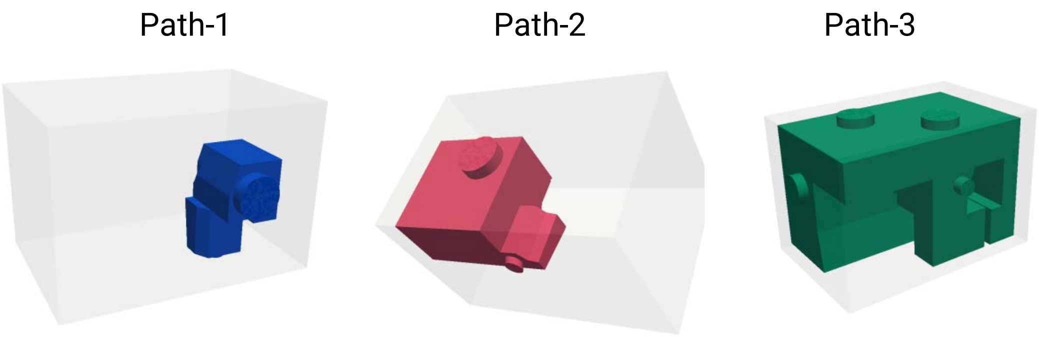

Figure 6: Manifold block: "available volumes" for optimisation

SmartOptim® is then applied to optimise the device using two main objectives:

1) Reducing the pressure drop in each path;
2) Improving the mass flowrate balance between each of the 5 outlets of Path-3.

By solving the adjoint equations, SmartOptim® will define the best shape for reaching the two objectives. During the run, SmartOptim® modifies the volume to fulfil the objective requirements using the adjoint solution.

Below is the final volume for each path with the resulting streamlines (Figure 7).

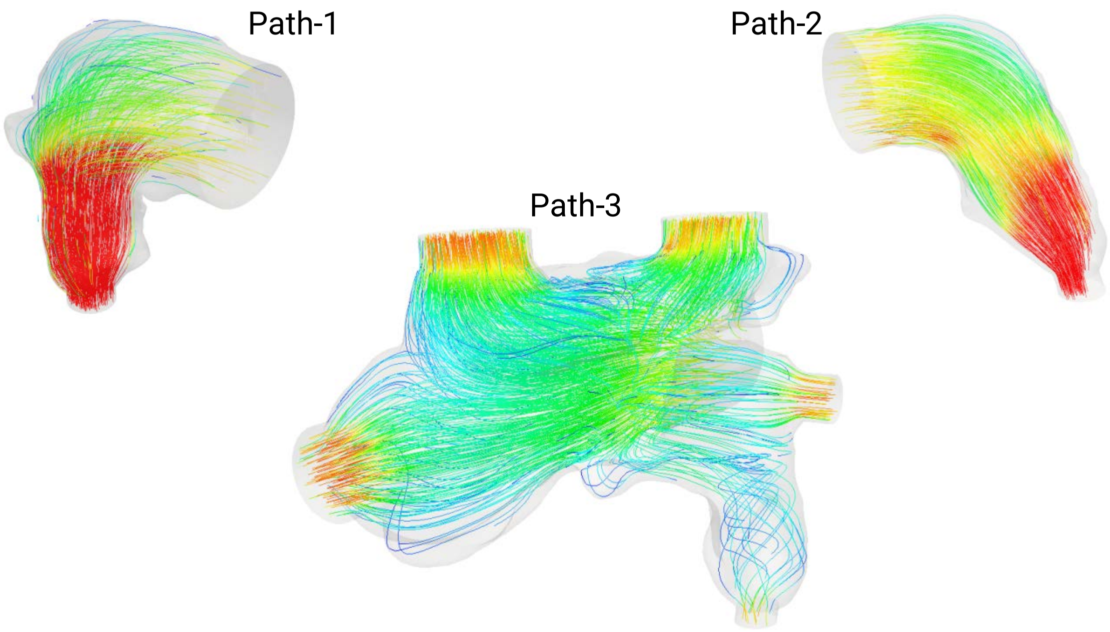

Figure 7: Manifold block - streamlines in the optimised shapes

If the flow results presented in the graph below for the optimised shapes (Figure 8) are analysed, it can be seen that pressure drop is drastically reduced for each path as the flow path is smoother (removal of sharp angles) and more suited to the flow direction.

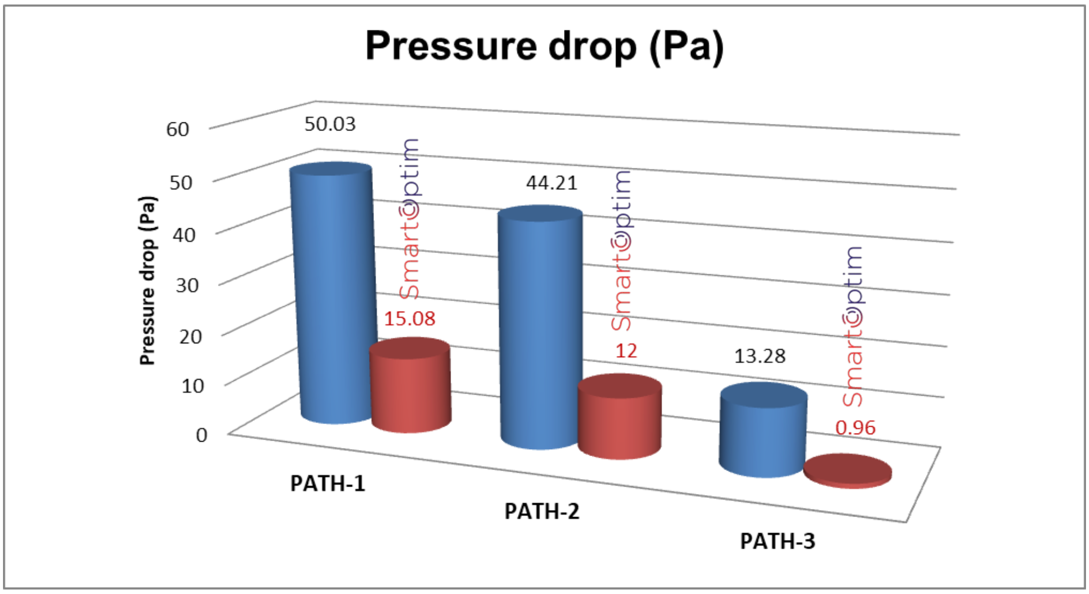

Figure 8: Manifold block – pressure drop comparison

Concerning flow balancing for Path-3, SmartOptim® obtains a maximum deviation of 15% on each outlet as presented on the graph below (Figure 9).

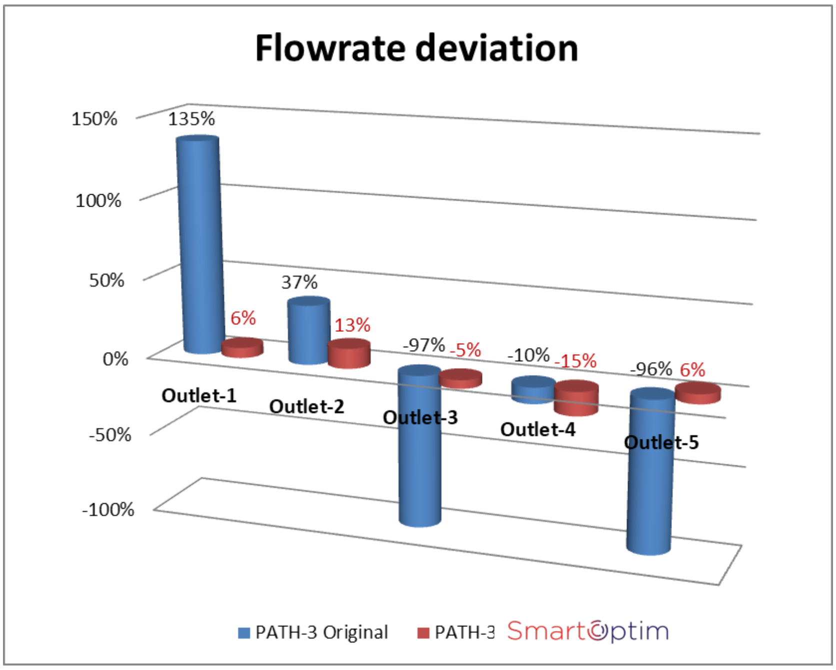

Figure 9: Manifold block – flowrate deviation comparison Path-3

The new design proposed by SmartOptim® is not intuitive (Figure 10) but it can be used by the AM process directly or analysed by design engineers to build a better-shaped device.

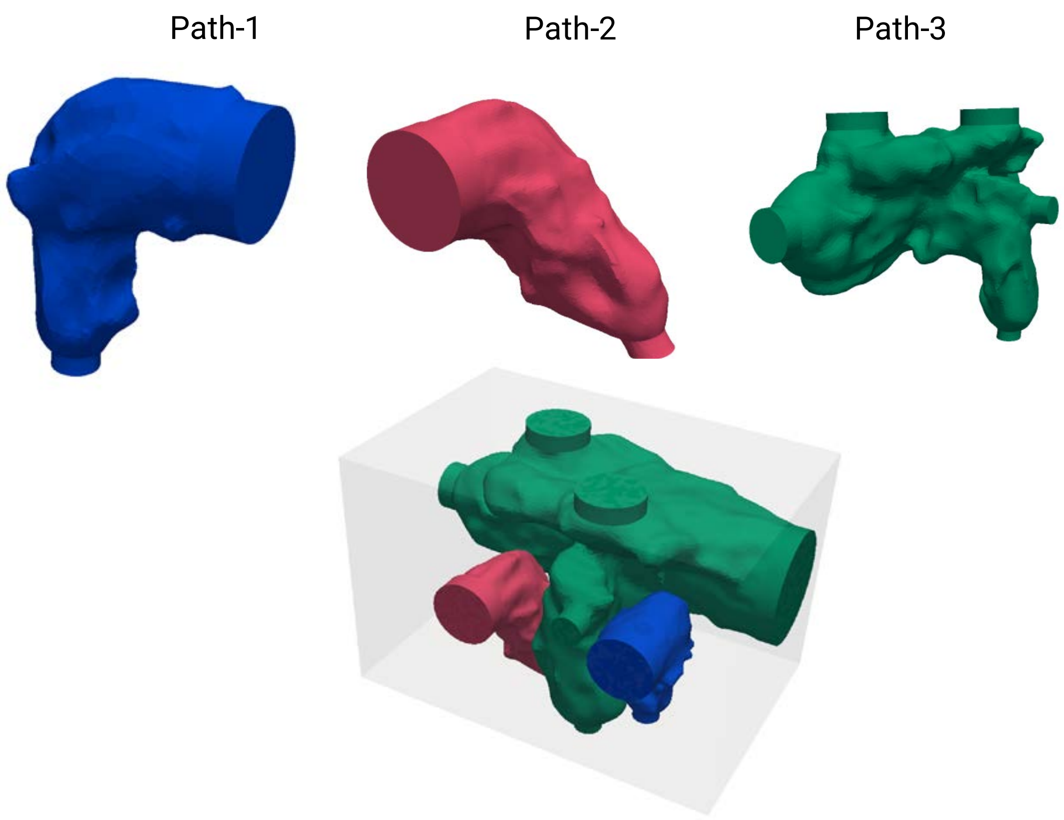

Figure 10: Manifold block – final optimised paths

The surfaces are smooth and available in STL format or STEP format on request. Mechanical/Design engineers can use these optimised surfaces to generate a better design of the manifolds adding some other constraints such as mechanical of manufacturing constraints.

SmartOptim® is a robust solution that can be easily integrated into the design process. For this manifold block, optimised shapes have been generated and validated in less than 5 days. The new design can thus be a first step in achieving an innovative design solution.

About CFD-Numerics

CFD-Numerics is an engineering services company specialising in numerical simulation for fluid dynamics, heat transfer and combustion.

CFD-Numerics offers expertise to analyse, improve and optimise industrial products and processes. The company also proposes the innovative in-house design solution SmartOptim® based on topological optimisation applied to fluid dynamics.

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