EXPLICIT TOPOLOGY OPTIMIZATION

Topology optimization (TO) deals with finding the optimal material layout of a structure and it is widely used in industry as a numerical tool, especially in the early design phases to find optimal performances, reduce the cost and save mass. Traditional TO approaches such as element density (SIMP), and node based (level set) approaches describe the structure's design implicitly, through density field or nodal value of level set function. Besides, as most industry practitioners of topology optimization can attest to, a design obtained via such approaches is rarely produced as-is, and post processing is needed. This post processing often incurs in a significant detriment of the structural performance. Explicit topology optimization is receiving recently more and more attention. Unlike implicit topology optimization, design variables are often geometrical and the solution (structure's shape) is explicitly determined by design variables.

Our internship is in the context of explicit topology optimization, and its main goals are:

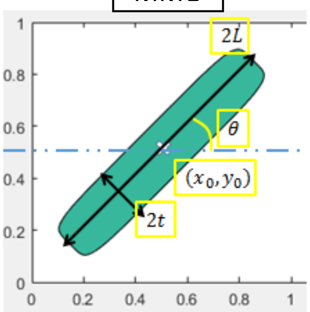
- Understand and get familiar with different explicit approaches
- Achieve some improvements and extensions to the MNA and MMC approaches
- Apply MNA and MMC to industrial 2D and 3D case from Airbus project
- Benchmarking MNA and MMC methods with several test cases and compare to reference solution given by SIMP approach

MMC approach was first introduced by (GUO et al. 2014), since then many works had been done under MMC framework (see reference). The original 2D MMC code we use is given in (GUO et al. 2015). A set of modifications had been brought to this code in order to enhance its efficiency.

As for MNA, a first method was introduced in the work of (Overvelde's thesis 2012) it was a flow-inspired meshless method based on the meshless Element-Free Galerkin (EFG) method, yet it presented many difficulties, and it was suggested that the method might be improved by replacing the EFG method with FEM.

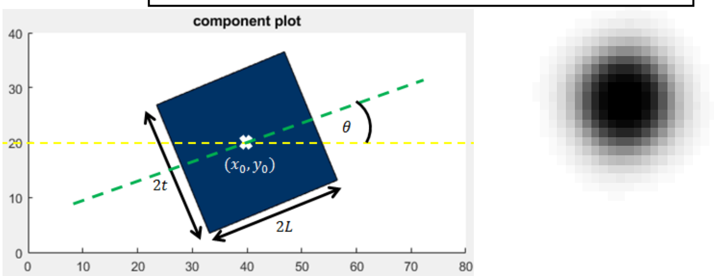
In both MNA and MMC design of the structure is represented by the layout of a set of components, traditionally, rectangular components are used, design variable for one component are shown in following figure:

MMC

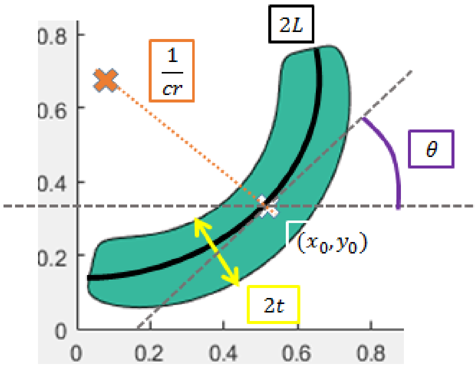


$$\boxed{X_c = (x_0, y_0, \theta, L, t)}$$

a component and its density field in MNA



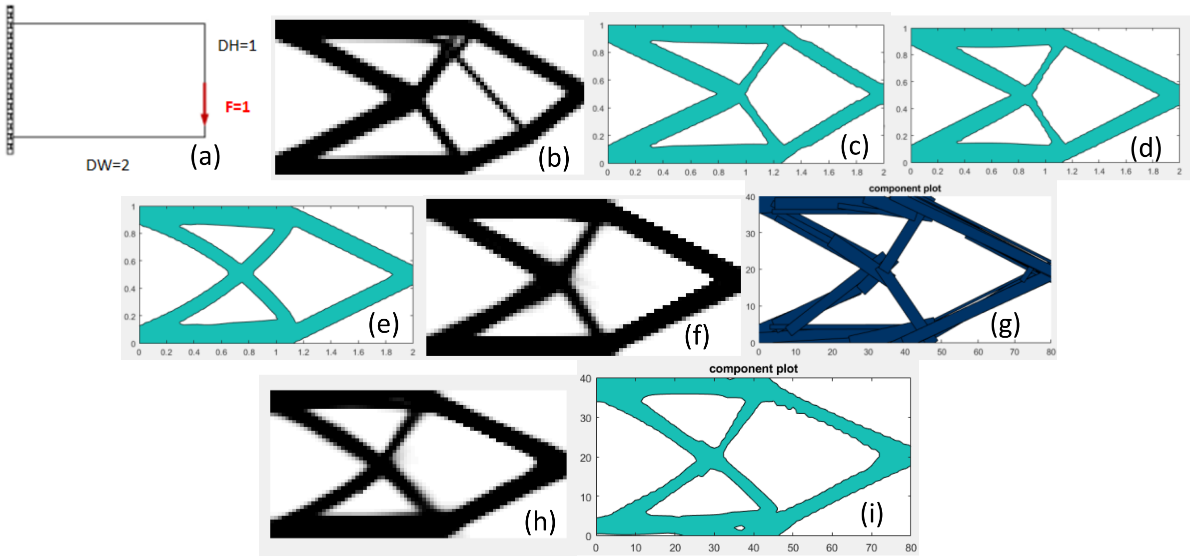
MMC and MNA frameworks were extended to circular curved component; a new design variable had been introduced (for each component): the curvature cr, it is the inverse of the curvature radius of the component's mid-line as shown in following figure:



Curvature is sought to be a generalization of straight components, which means that if the optimal design is obtained for straight components (no need for curvature) then the code with curvature is able to reach the same optimal design. However it can improve designs especially when few components are used.

Moreover, stress constraint was integrated to the optimization problem for the different codes we developed, we were inspired from the approach proposed by (Verbart et al. 2017).

Here we present results of the well-known academic test case: the Cantilever beam



a-geometry, load & boundary conditions b-SIMP c-original MMC d-enhanced MMC e-curved MMC f,g-MNA h,i-curved MNA

As for the future perspectives of this work, computing sensitivities analytically may be investigated for the MNA with curvature code. Also, a better way to plot the contour of the design needs to be developed, this important for exploiting the full potential of the explicit geometrical description of the structure's topology, in MNA as well as in MMC when irregular mesh is considered. Furthermore, a multi-grid resolution approach could be developed under MNA formulation to improve its efficiency.