

um
2026

Design optimization with ESTECO modeFRONTIER

Shaped charge device case study

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Agenda

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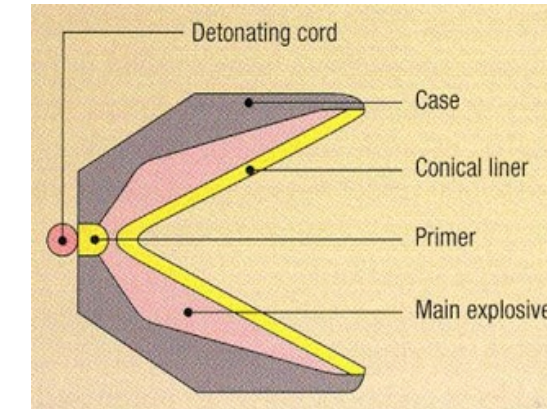


What is a Shaped Charge?



What is a Shaped Charge (SC)?

- A Shaped Charge (SC) warhead is an explosive device designed with a concave, metal-lined cavity that focuses explosive energy into a high-velocity, hypervelocity jet (jet tip velocity even exceeding 10 km/s), allowing it to penetrate armor, concrete, and steel.
- Due to the velocity gradient present in the jet, the jet tends to elongate until it breaks.
- The penetration performance of the jet is related to the length of the jet and therefore to the Stand-Off Distance (SOD).
- There is a value of SOD that maximizes the length of the jet and therefore the penetration capabilities of the jet which can be up to 10 times the calibre of the liner cone.
- Target: tanks, armored vehicles, fortifications and bunkers.



Base layout of Shaped Charge

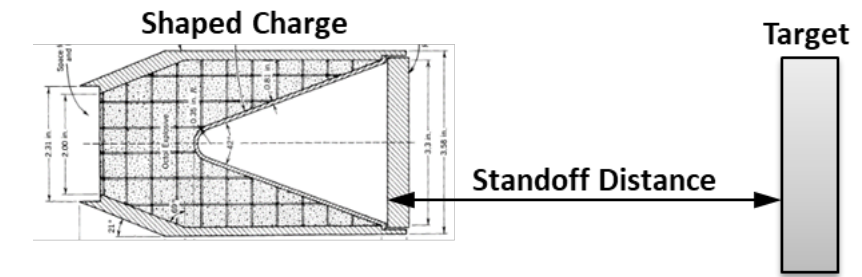
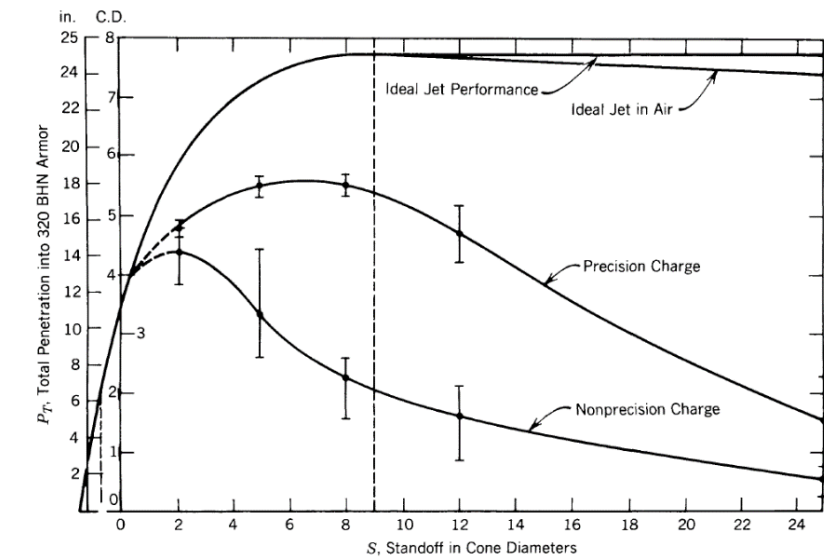
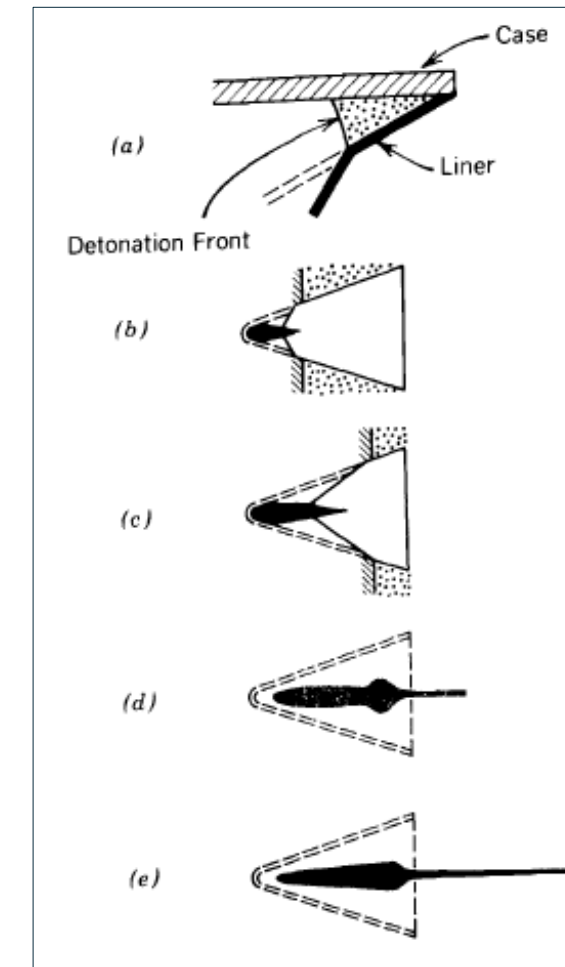


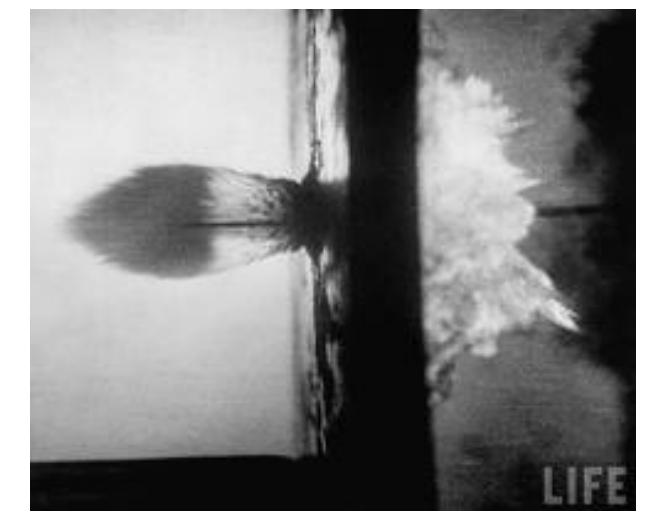
Illustration of the concept of Standoff Distance



Representative performance of a Shaped Charge as Standoff Distance varies.



Physics of jet formation.
Liner is "collapsed and squeezed" by the detonation front



Impact of the jet generated by a Shaped Charge against target

Shaped Charge jet formation (ABSTRAO 3D γ SPH simulation)



Introduction and overview



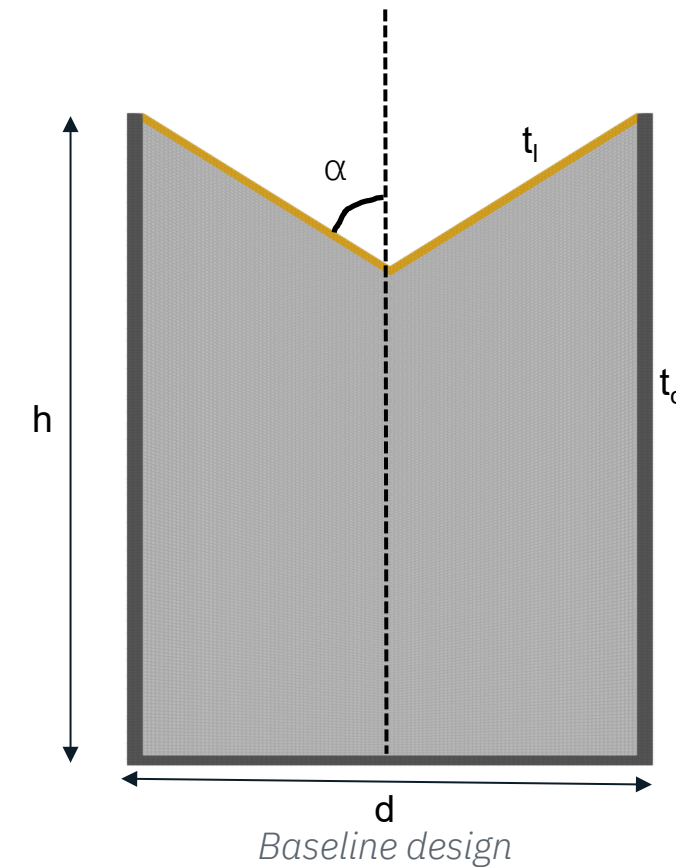
Why set up an automated process of Design Optimization of a SC?

- In the preliminary concept phase there is a need to explore a great number of designs to understand which has the best trade-off given the requirements to satisfy.
- Without an automatic process, the number of concepts that can be designed, assessed and post-processed is quite low and requires continuous man-work hours.
- So, the use of ESTECO modeFRONTIER is due to the need to manage for each concept these operations:
 - the geometry generation and the following structured mesh generation;
 - the simulation of the experiment;
 - the post processing activity.
- ESTECO modeFRONTIER is used to address the generation of the design of the new concepts using genetic algorithm MOGA II having as objective functions a set of characteristics subjected to the performance requirements and as constraints functions dimensional and performance requirements.
- The experiment that is simulated is the detonation of a Shaped Charge warhead that generates a jet hitting a target having a certain thickness.

Input, Output, Objective functions and Constraints

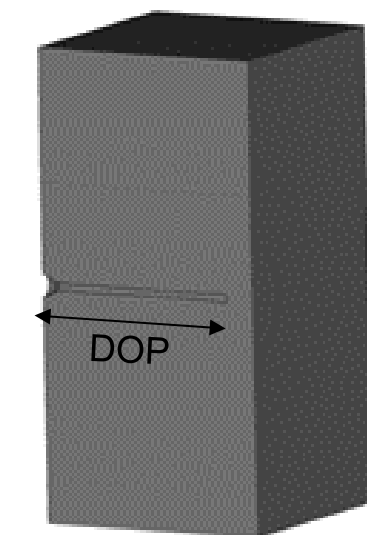
Geometric input functions

- The thickness of the liner (t_l min < t_l < t_l max [mm])
- The semi-aperture angle of the liner cone (α min < α < α max [deg])
- The thickness of the case (t_c min < t_c < t_c max [mm])
- The axial length of the device (h < h max [mm])
- The diameter of the device (d < d max [mm])



Output functions to be maximized

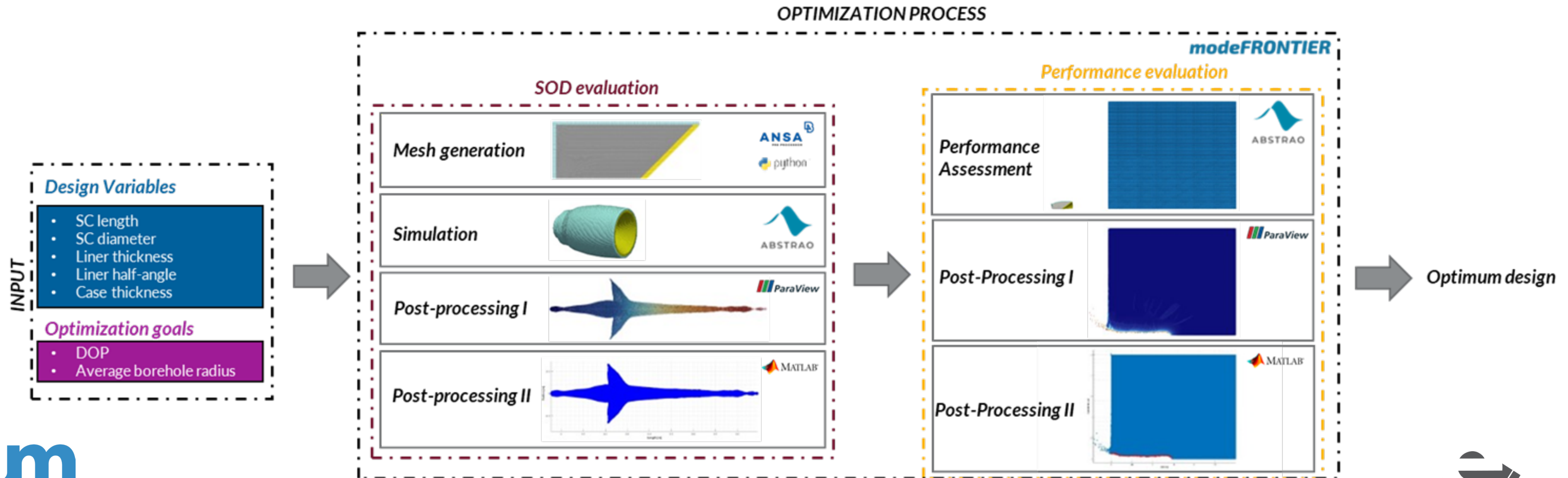
- The Depth of Penetration (DOP) created by the jet into the target
- The average radius of the borehole created into the target



Example of borehole generated into a steel target

Schematic representation of the optimization process

- It is a two-step optimization process.
- In the first step, the design mesh is generated and a simulation of the shaped charge alone is performed to determine the SOD at which the jet breaks up.
- In the second step, the shaped charge is simulated against the target placed at a distance consistent with the SOD value obtained in the previous step (i.e. just before the jet breaks up, to maximize the DOP, which is proportional to the length of the jet at the impact).

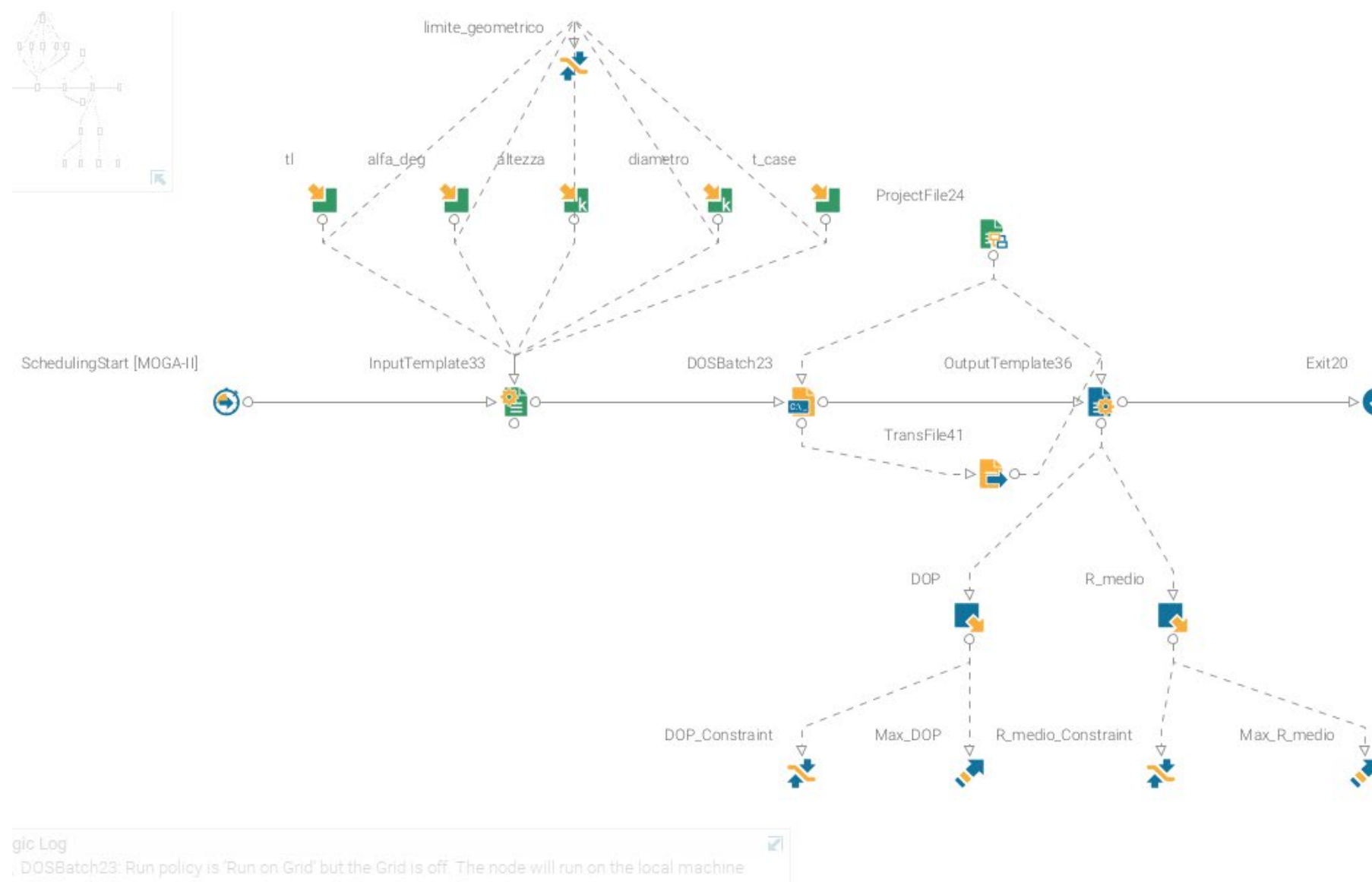


ESTECO modeFRONTIER set-up



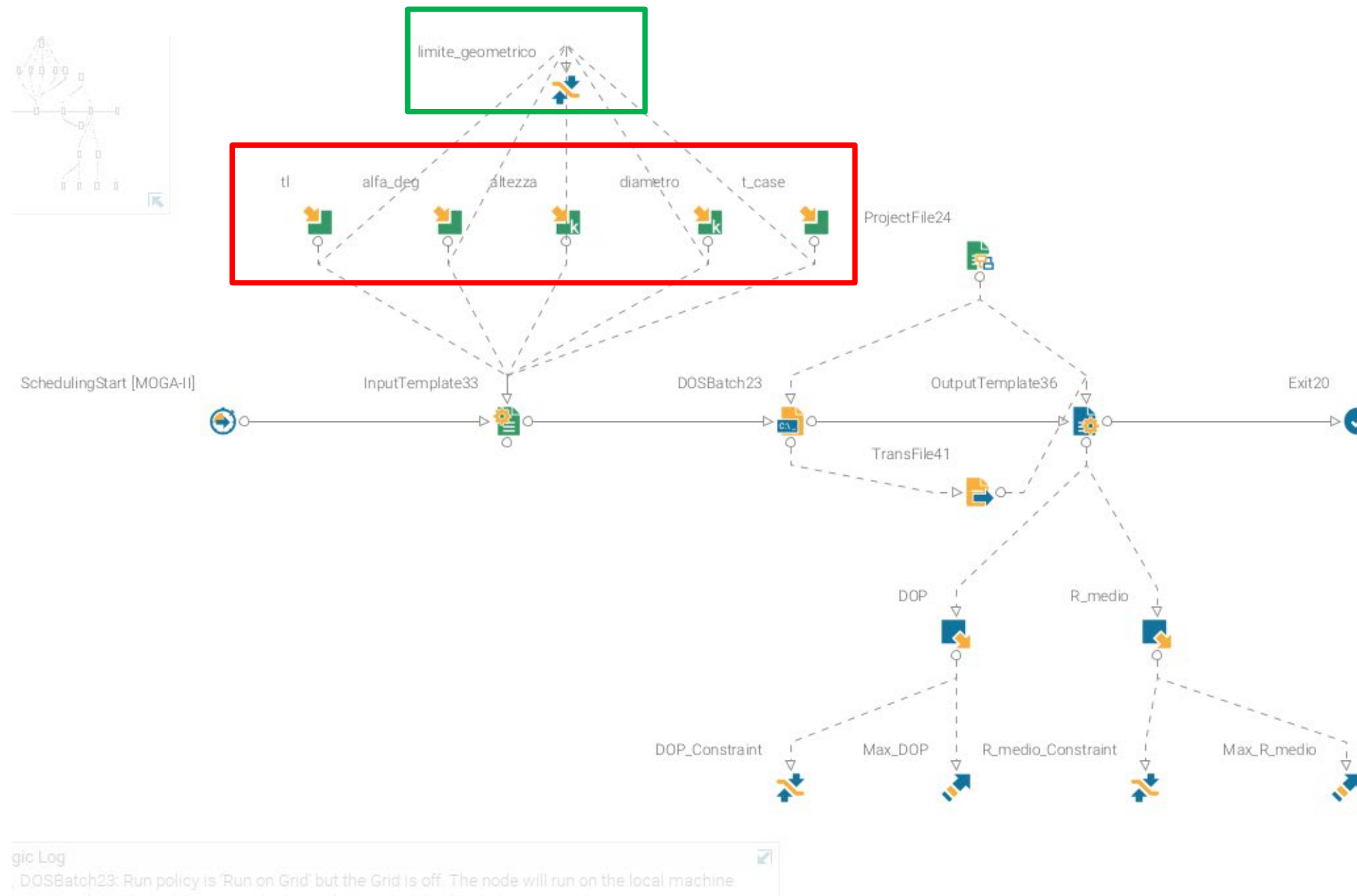
ESTECO modeFRONTIER workflow

- The optimization process is realized with the use of the genetic algorithm MOGA-II.
- The optimization process is implemented in the modeFRONTIER software.
- Each generation has a number of individuals equal to 16.
- The number of generations is set to 19.
- The first generation is selected through the Uniform Latin Hypercube method (first iteration).



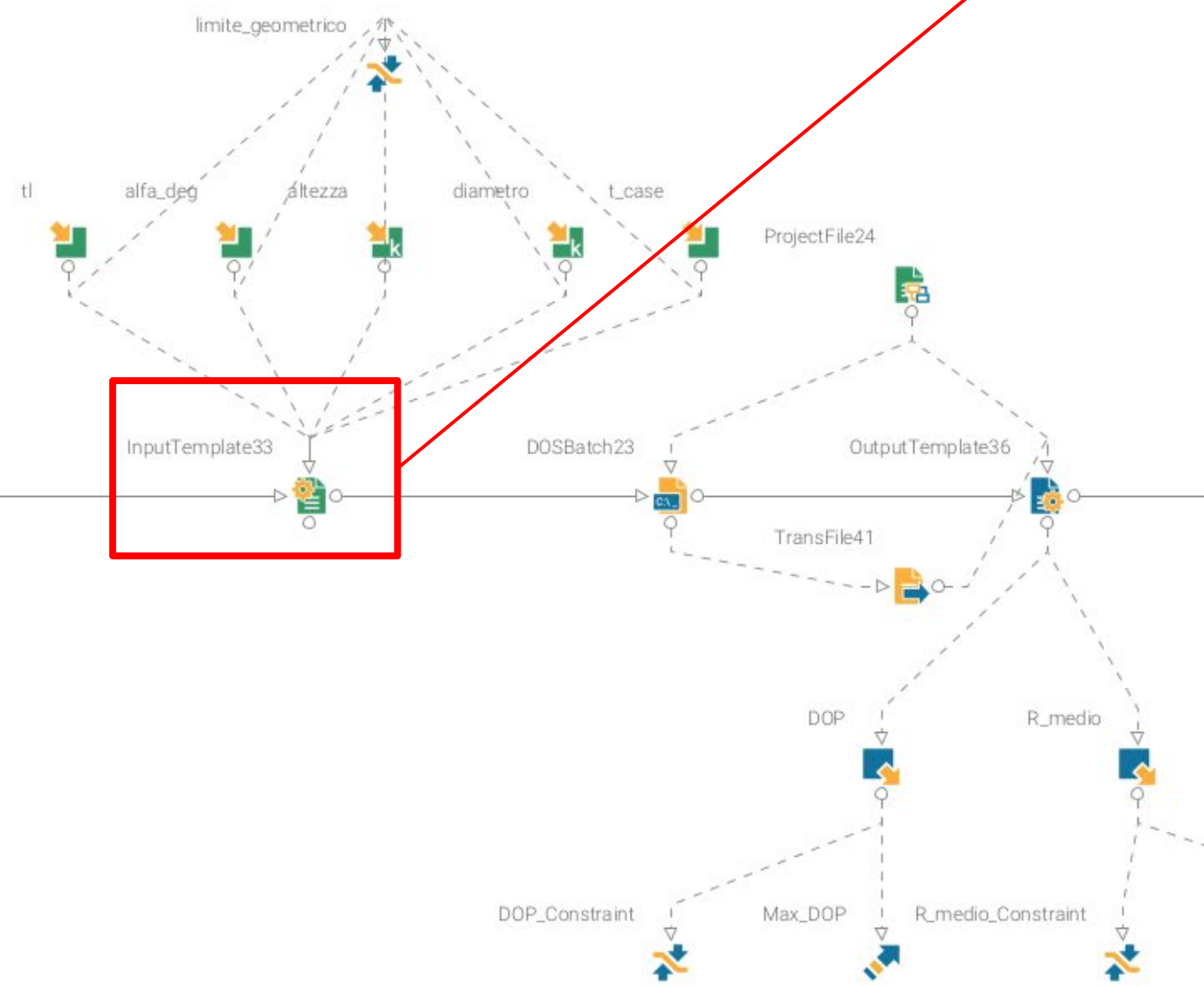
Input declaration

- **Here** are declared the geometric input parameters
- They have “Var – Discrete ordered” as the type
- Lower and upper boundaries are defined
- The step is defined
- A **constraint** on the possible values of the input variables is defined to ensure that all designs are physically feasible.



Input file

- Here are loaded the files in which the values assigned to the input parameters are inserted.
- The files uploaded are the Python script that generate the geometry and the mesh, and the main of the two ABSTRAO simulation (with and without target).



```
1 # PYTHON script
2 # INFO RELATIVE A PATH IN CUI STAMPA SONO IN FONDO AL FILE
3 import os
4 import numpy as np
5 import match
6 import ansa
7
8 from ansa import session
9 from ansa import base
10 from ansa import constants
11 from ansa import mesh
12
13 def main():
14     # Create a new session
15     session.New("discard")
16
17     # Set tolerances
18     ConsMatchingDistance = 0.1
19     NodeTolerance = 0.1
20     CurvesResolution = 0.1
21
22     base.ConsMatchingDistance(ConsMatchingDistance)
23     base.SetNodeTolerance(NodeTolerance)
24     curves = base.CollectEntities(constants.LSDYNA, None, "CURVE")
25     base.SetCurvesResolution(CurvesResolution, curves)
26
27     ### GEOMETRY GENERATION ###
28     # geometric optimization parameters [mm]
29     t1 = 2.000E2 # thickness of the liner
30     alfa_deg = 16 # angle in degrees
31     alfa_rad = np.deg2rad(alfa_deg)
32     altezza = 2.000E2
33
34
35     # non optimization parameter [mm]
36     t_case = 3.000E2
37     diametro = 1.000E2
```

```
1 *PARAMETER
2 standOff = 500 / 1000
3 diametro = 1.000E2 / 1000
4 altezza = 1.000E2 / 1000
5
6 ref1 = 2
7 ref2 = 1
8 tilt = [0*pi/180]
9 init_pc = 10e-6
10 dx = [2*3e-3 / %ref2]
11 tend = 300e-6
12 nout = 30
13
14
15
16 *UNIT_SYSTEM
17 SI
18 *TIME
19 tend
20 # --- PART ---
21 #PARTS
22 *PART
23 "PC A1 Liner"
24 1, 1, 1
25 "PC HE"
26 2, 2, 2
27 "PC A1 casing"
28 3, 3, 3
29 #MESH PC
30 *GEOMETRY_MESH_2D
31 "PC A1 Liner"
32 1, 111
33 mesh_SC.k, 1, 1e-3, 1e-3, %ref1
34 *GEOMETRY_MESH_2D
35 "PC HE"
36 2, 111
37 mesh_SC.k, 2, 1e-3, 1e-3, %ref1
38 *GEOMETRY_MESH_2D
```

```
1 *PARAMETER
2 standOff = 1.2
3 diametro = 1.000E2 / 1000
4 altezza = 1.000E2 / 1000
5
6 ref1 = 2
7 ref2 = 1
8 tilt = [0*pi/180]
9 init_pc = 10e-6
10 dx = [2*3e-3 / %ref2]
11 tend = 5e-3
12 nout = 5
13
14
15 *UNIT_SYSTEM
16 SI
17 *TIME
18 tend
19 # --- PART ---
20 #PARTS
21 *PART
22 "PC A1 Liner"
23 1, 1, 1
24 "PC HE"
25 2, 2, 2
26 "PC A1 casing"
27 3, 3, 3
28 *Target
29 101, 100
30 #MESH PC
31 *GEOMETRY_MESH_2D
32 "PC A1 Liner"
33 1, 111
34 mesh_SC.k, 1, 1e-3, 1e-3, %ref1
35 *GEOMETRY_MESH_2D
36 "PC HE"
37 2, 111
38 mesh_SC.k, 2, 1e-3, 1e-3, %ref1
```

gic Log
DOSBatch23: Run policy is "Run on Grid" but the Grid is off. The node will run on the local machine



Project files

- Here are uploaded all the files needed to realize each simulation and to post-process them in order to register the desired results.



mf Project files

Files/directories

+ Add X Delete | ⋮

Name	Last modified	Size
projectfiles	26/05/2026 03:36 PM	
brbgkmsrq.m	05/12/2025 02:19 PM	493 B
brbgkmsrq_pt2.m	05/12/2025 02:20 PM	493 B
copia_file.m	03/12/2025 08:20 AM	1.7 kB
plot_profil.m	16/02/2026 10:25 AM	1.7 kB
Post_Process_Paraview_Liner.py	02/12/2025 04:39 PM	3.2 kB
Post_Process_Paraview_Solo_Ge...	02/12/2025 07:58 AM	63.6 kB
Post_Process_Paraview_Target_...	16/02/2026 10:11 AM	19.3 kB
Solo_Getto.m	16/02/2026 09:50 AM	2.3 kB
sost_abstrao_solo_jet.m	01/12/2025 03:13 PM	377 B
Target.m	16/02/2026 09:50 AM	2.4 kB

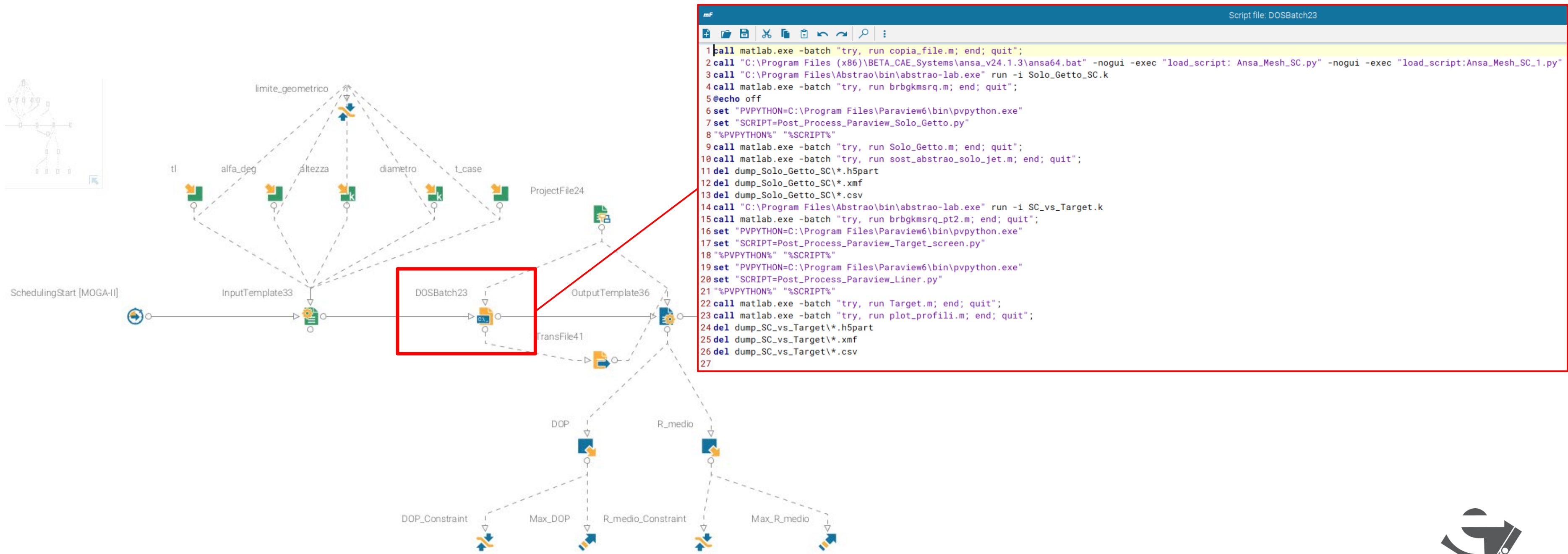
OK Cancel

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DOSBatch23: Run policy is 'Run on Grid' but the Grid is off. The node will run on the local machine



DOS Batch (1/2)

- Here is uploaded the DOS Batch file which contains all the instructions to execute:
 - Geometry and mesh generation
 - γ SPH ABSTRAO simulations without target (to evaluate the Stand off Distance) and with target (to evaluate the penetration performance)
 - Paraview and Matlab post-processing which saves the desired results in txt files
 - Delete all the unuseful files in the new folder



gic Log
DOSBatch23: Run policy is 'Run on Grid' but the Grid is off. The node will run on the local machine

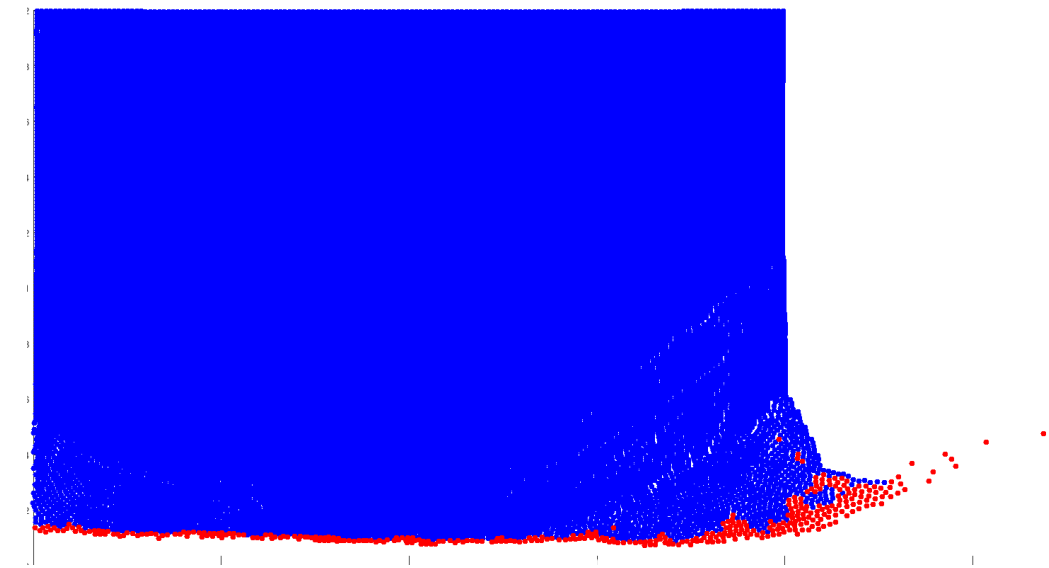


DOS Batch (2/2)

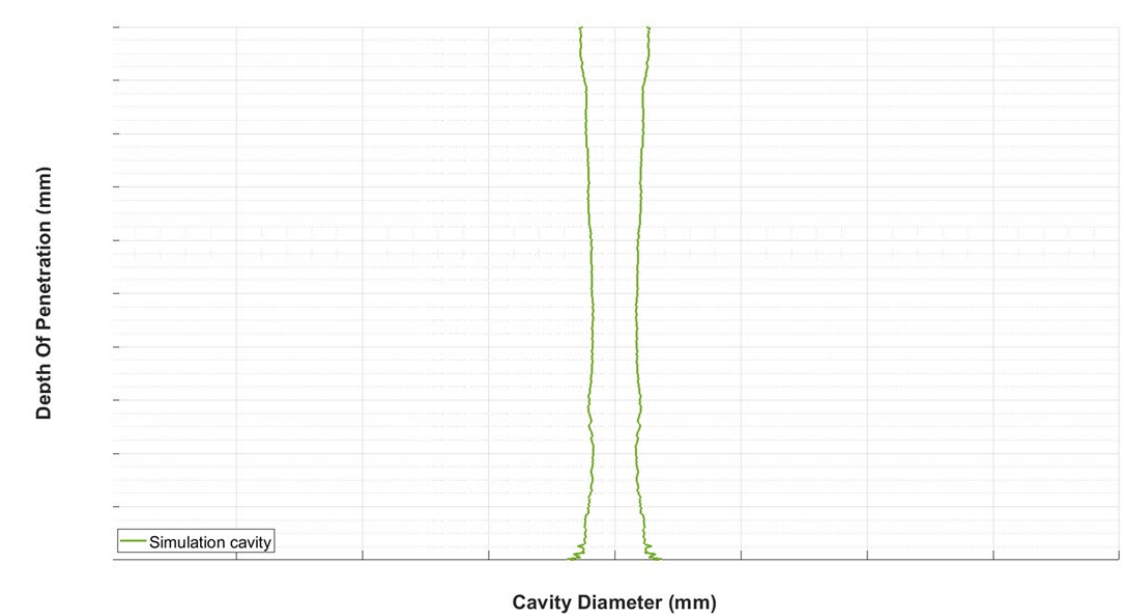
- The post-processing of the simulation of the shaped charge alone makes it possible to estimate when the jet will break, and thus to position the target correctly in the next step.
- Post-processing of the simulation of the shaped charge against the target allows to extract the positions of the target particles from Paraview.
- The positions above are then fed into MATLAB, which calculates the profile of the borehole for each slice obtained by cutting the target with transverse planes placed every 10 degrees.
- The profiles are then averaged to obtain the average profile.
- The average profile allows to evaluate the DOP, a parameter to be maximized.
- From the average profile, the radius of the hole is extracted at various predefined points along the axis.
- The average of these radii gives the average radius, a parameter to be maximized.



X-ray images of the shaped charge jet at two successive time points (ABSTRAO γ SPH 3D simulation, design based on literature).
It can be seen that the jet breaks apart at the second time step, resulting in reduced performance.



The post-processing code highlights the profile of the borehole (red) created in the target (blue), and extracts the positions of the particles in the profile.



Example of the average profile of the borehole generated into the target.

Objective functions and Constraints

- Here are selected the output functions to be maximized that shall be greater than a certain value, so:
 - The depth of penetration
 - The average radius of the borehole generated into the target



gic Log
DOSBatch23: Run policy is 'Run on Grid' but the Grid is off. The node will run on the local machine

Conclusions



Conclusions

- Thanks to the use of ESTECO modeFRONTIER, it has been possible to realize a campaign regarding the design optimization of a shaped charge that explores hundreds of designs.
- ESTECO modeFRONTIER has permitted us to find a small set of candidates (Pareto Frontier) to be further analyzed in the next phase.
- The small set of candidates above is characterized by an improvement of more than 30% in the performances with respect to the reference design.
- For future works, we are considering using the designs generated and further assessed as a dataset that can feed machine learning algorithms and/or be used to generate response surfaces (RSM). The first tests have been realized, but better refinement of the models and the dataset are needed.

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Thank you

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