Electromagnetic simulations for hydrogen internal combustion engines

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24/10/2023

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Powertrain solutions

Gasoline injection

Engineering department

Simulation team, Bursa

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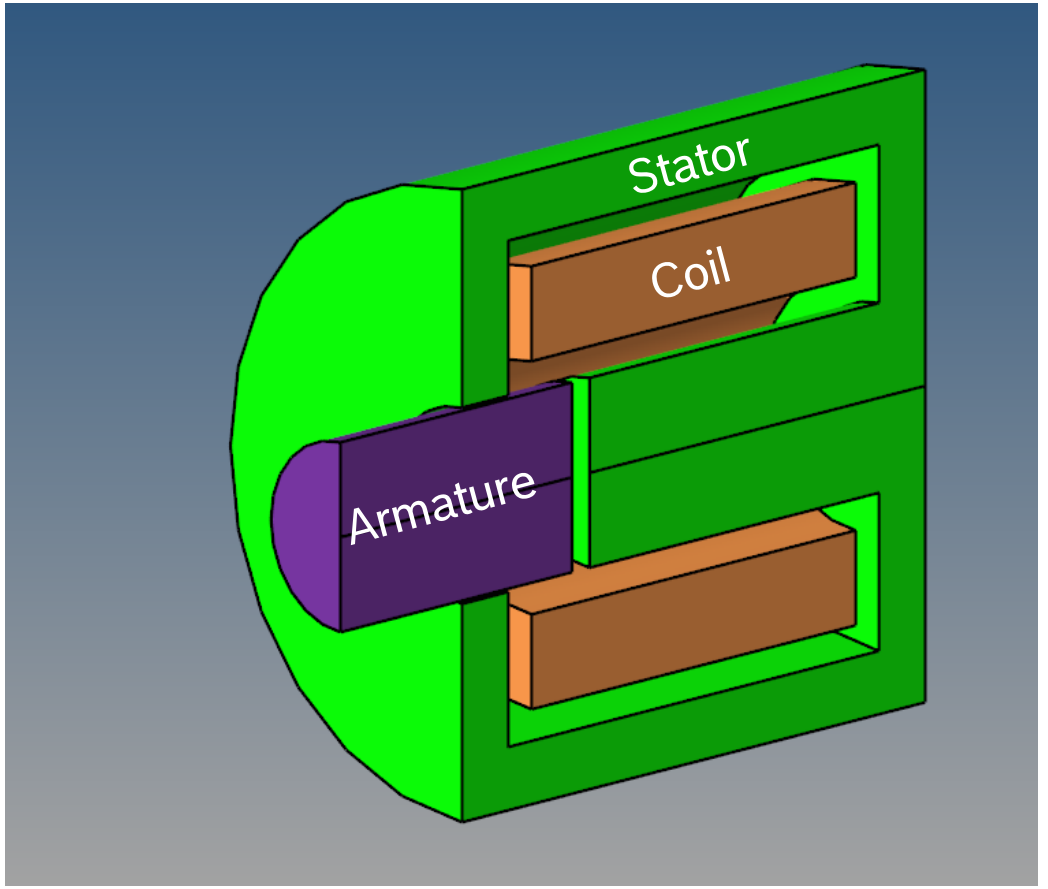
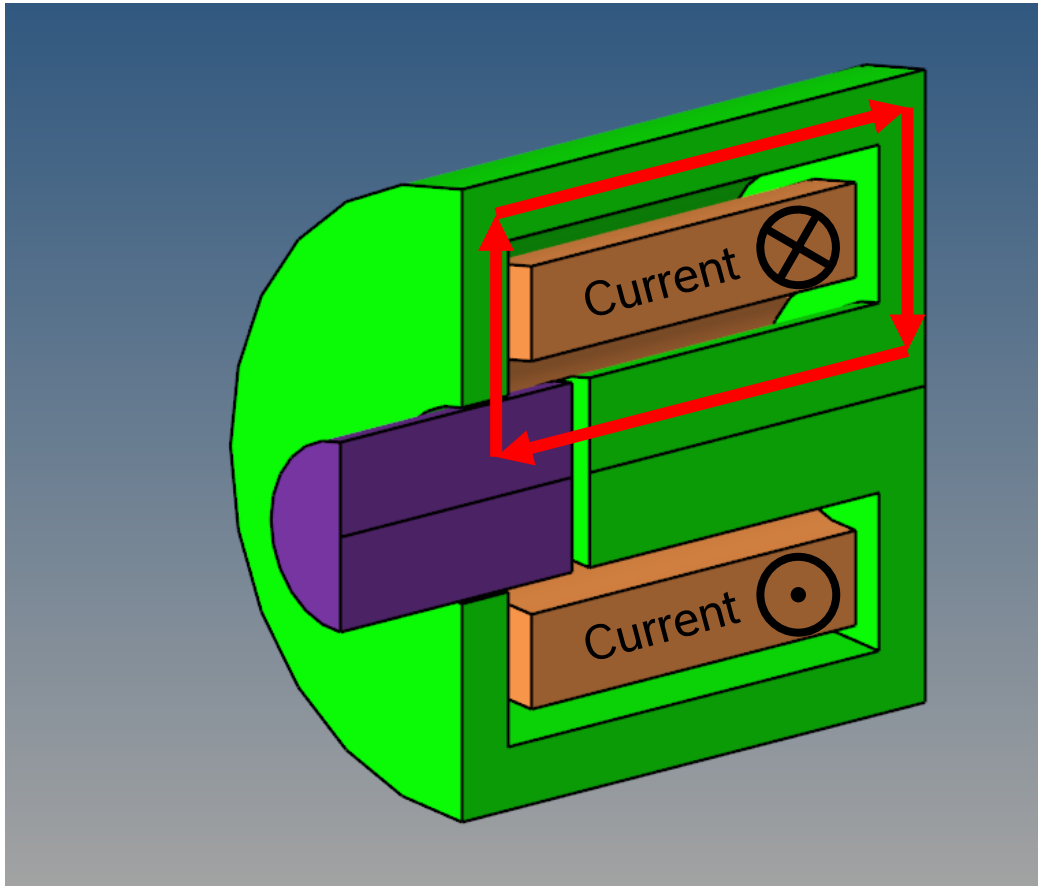
Agenda

1. Introduction
    a. Electromagnetic simulations
    b. Hydrogen internal combustion engines
2. Results
    a. Hydrogen pressure regulator
    b. Hydrogen injector
3. Conclusion



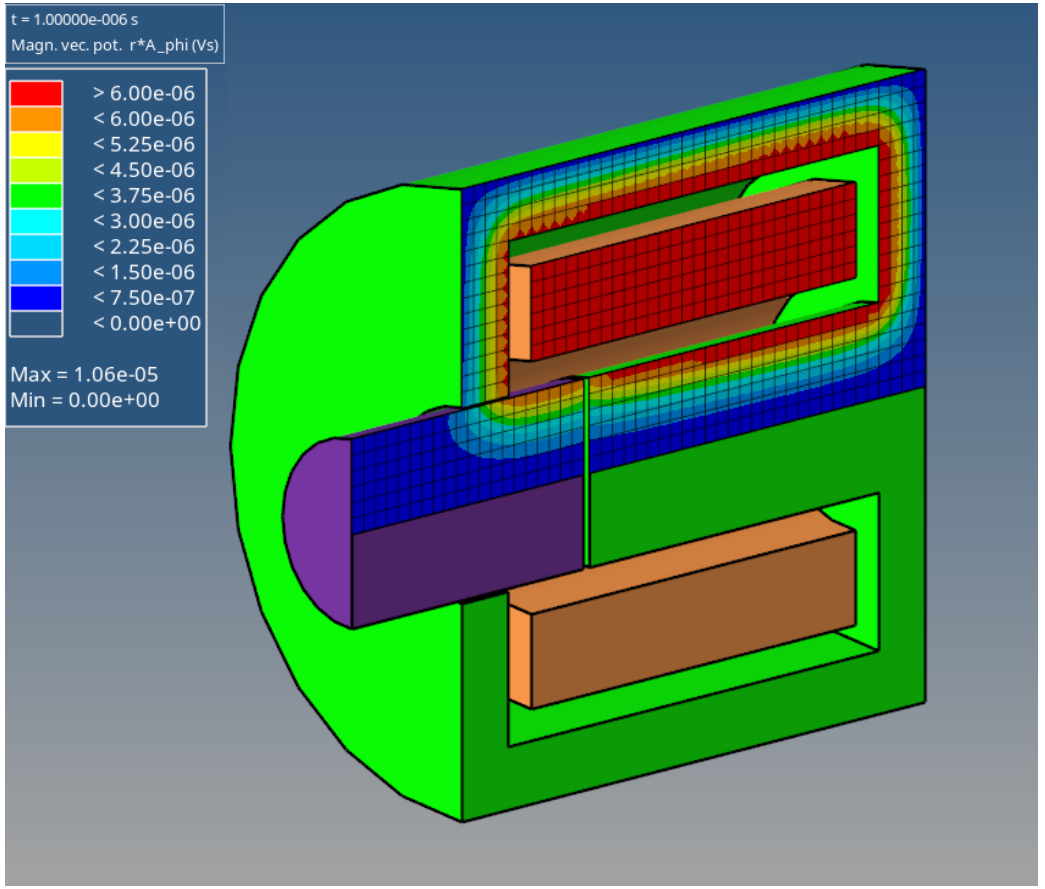
Introduction
Electromagnetic simulations

- Responsibilities:
  - Calculation of magnetic force for a given magnetic circuit
  - Providing magnetic circuit model to multi-domain system simulation responsible
- Tools used
  - Altair HyperMesh
  - Edyson (Bosch internal)



Introduction
Electromagnetic simulations

- Aim:
  - Controlling fuel flow
- Method:
  - Creating a system that moves in one direction when current is supplied
  - Moving in the other direction when current is not supplied
- Components:
  - Magnetic circuit and spring
- Workflow:
  - Simplification of technical drawings
    - Typically, 2D and cylindrically symmetric
  - Meshing simplified geometry
  - Creation of Edyson model



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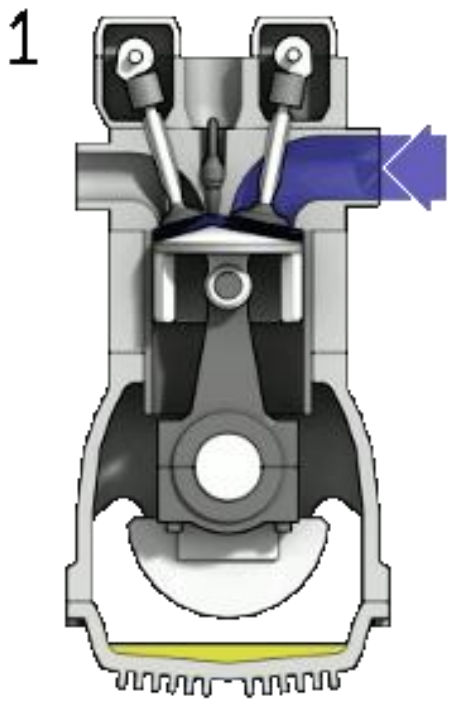
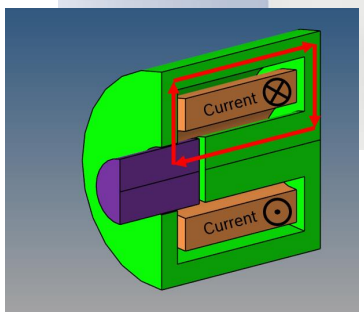
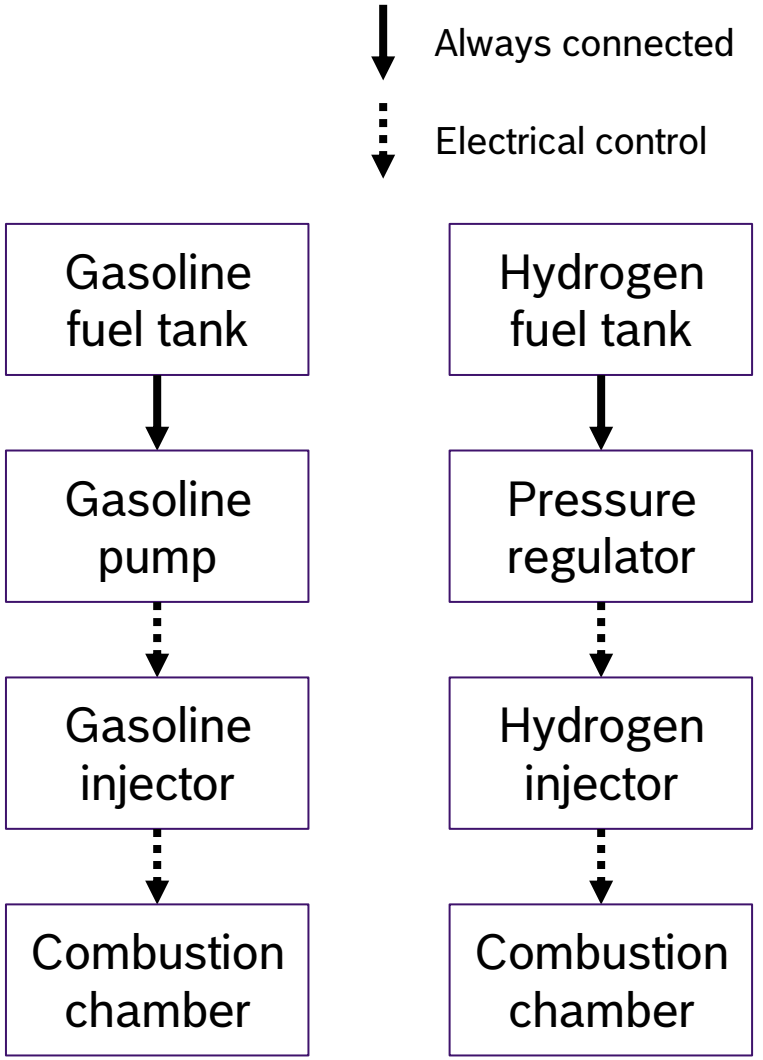
Introduction
Hydrogen internal combustion engines







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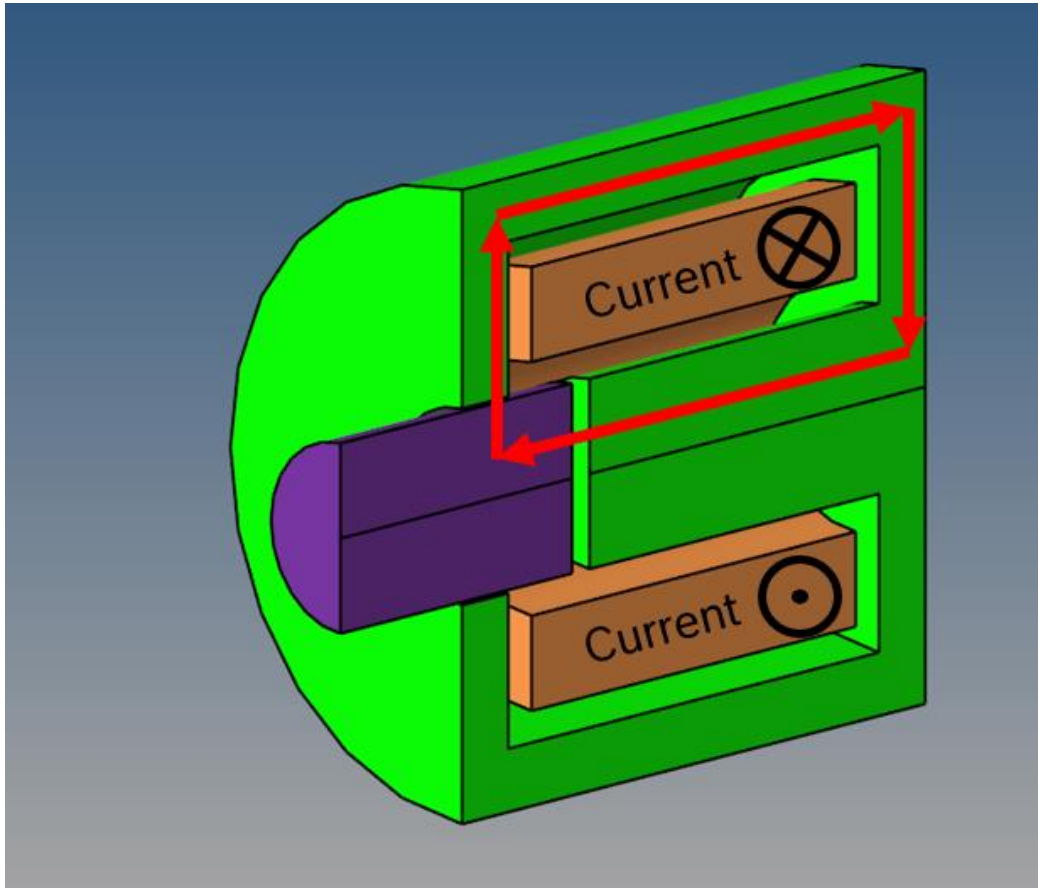
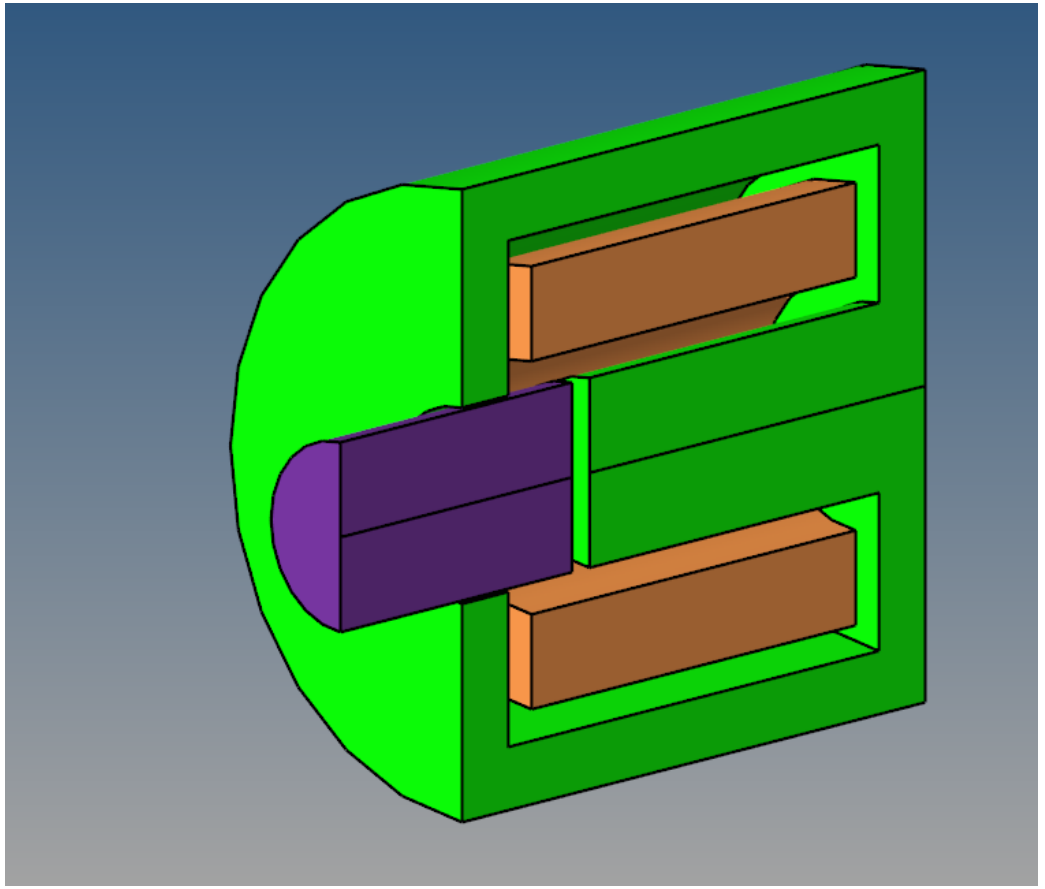
1. Introduction
    a. Electromagnetic simulations
    b. Hydrogen internal combustion engines
2. **Results**
    a. **Hydrogen pressure regulator**
    b. **Hydrogen injector**
3. **Conclusion**



Results
Hydrogen pressure regulator

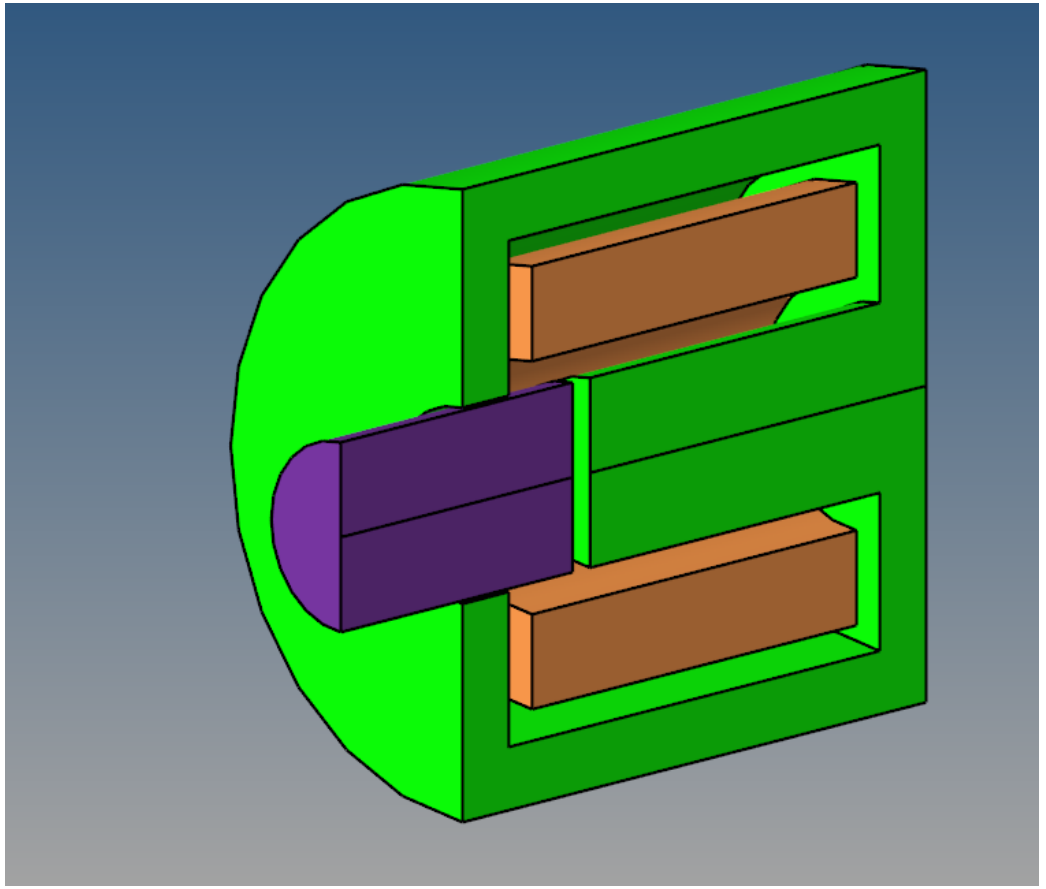
- Challenges of developing a hydrogen pressure regulator:
  - Displacement of armature needs to be tripled
    - Hydrogen flow requires a greater clearing compared to gasoline
  - Increased displacement → increased magnetic flux loss → decreased magnetic force
    - %84 drop in magnetic force for geometry on RHS
  - Multiple approaches to increase magnetic force
    - Supplying more current etc.
  - PS-GI/ENG3-Bu's responsibility
    - Investigation of possible geometrical changes with Altair HyperMesh

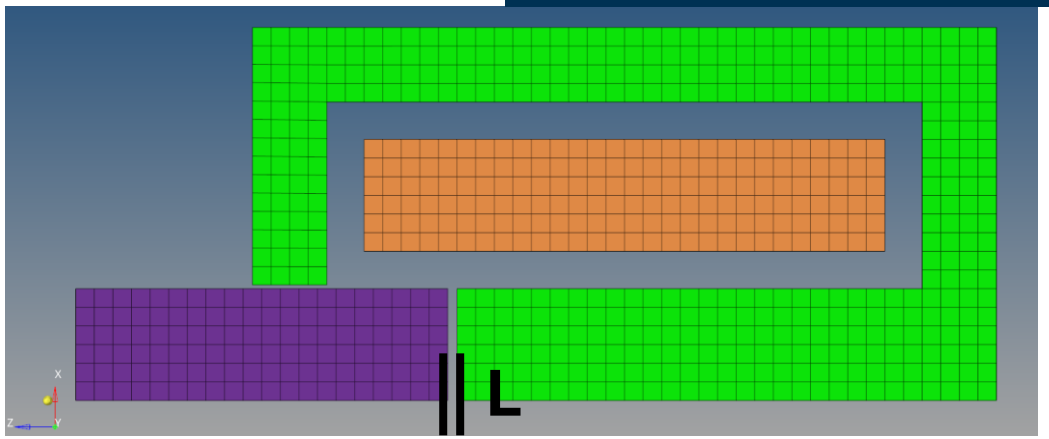


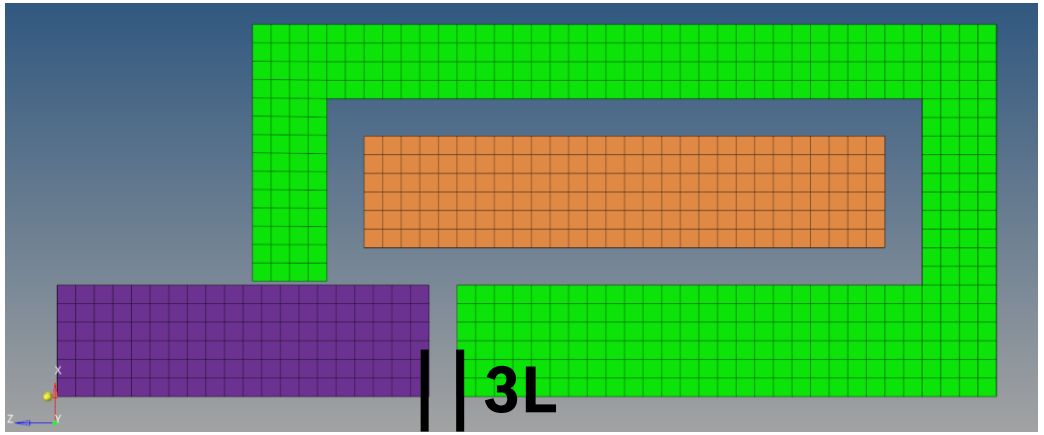
Results
Hydrogen pressure regulator

L → 3L

Loss in magnetic force: %86







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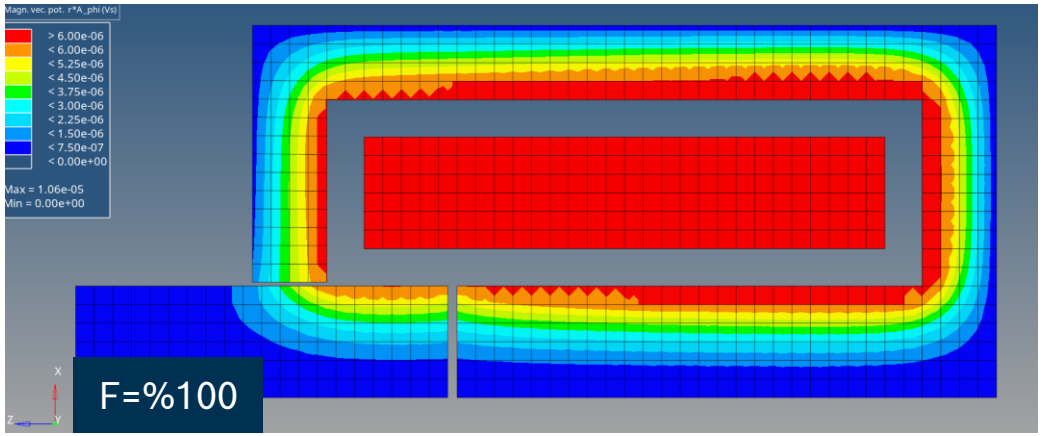
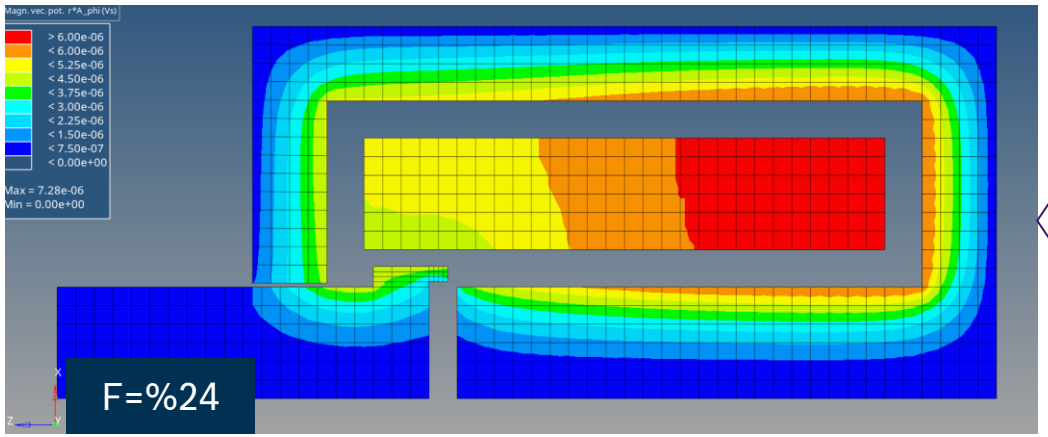
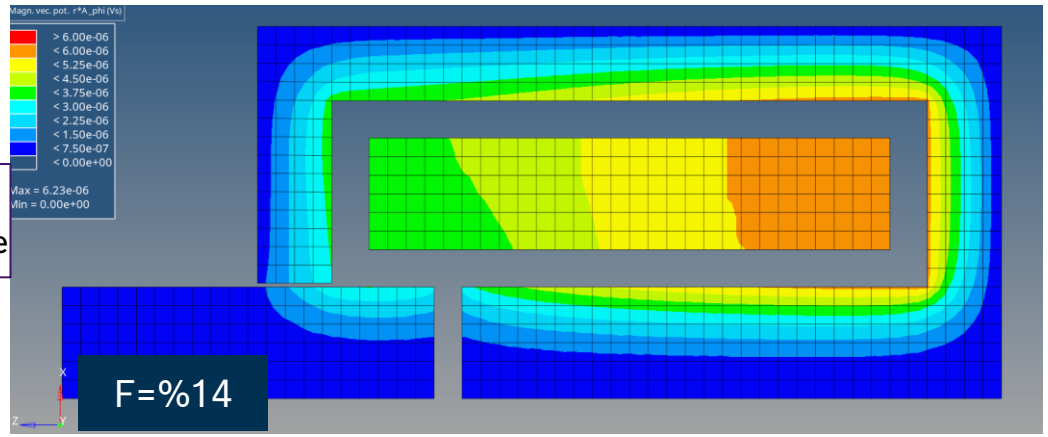
Results
Hydrogen pressure regulator

- Reason for drop in magnetic force:
  - Gap is too wide
    - → Although coil is feeding the system with same current, the magnetic field is localized far away from the gap
- Solution:
  - Adding a protrusion to outside of the gap
    - %14 → %24 (%71 increased magnetic force)





%71 increase



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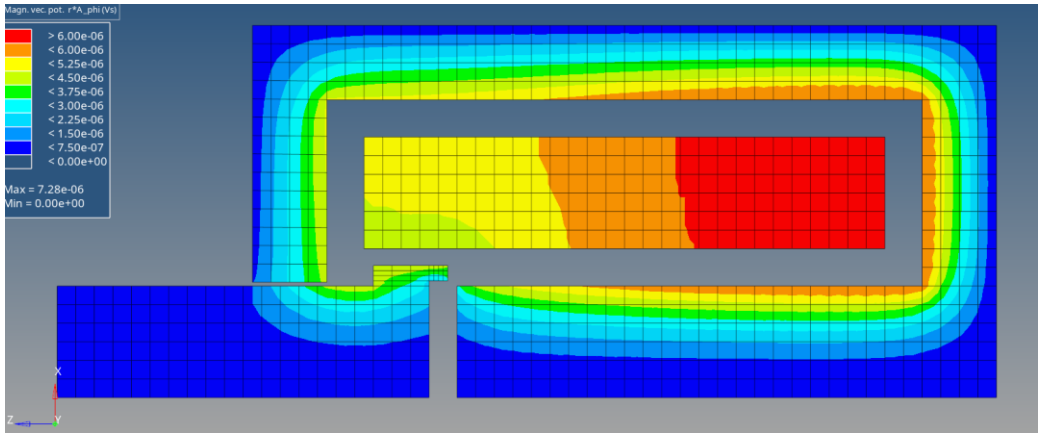

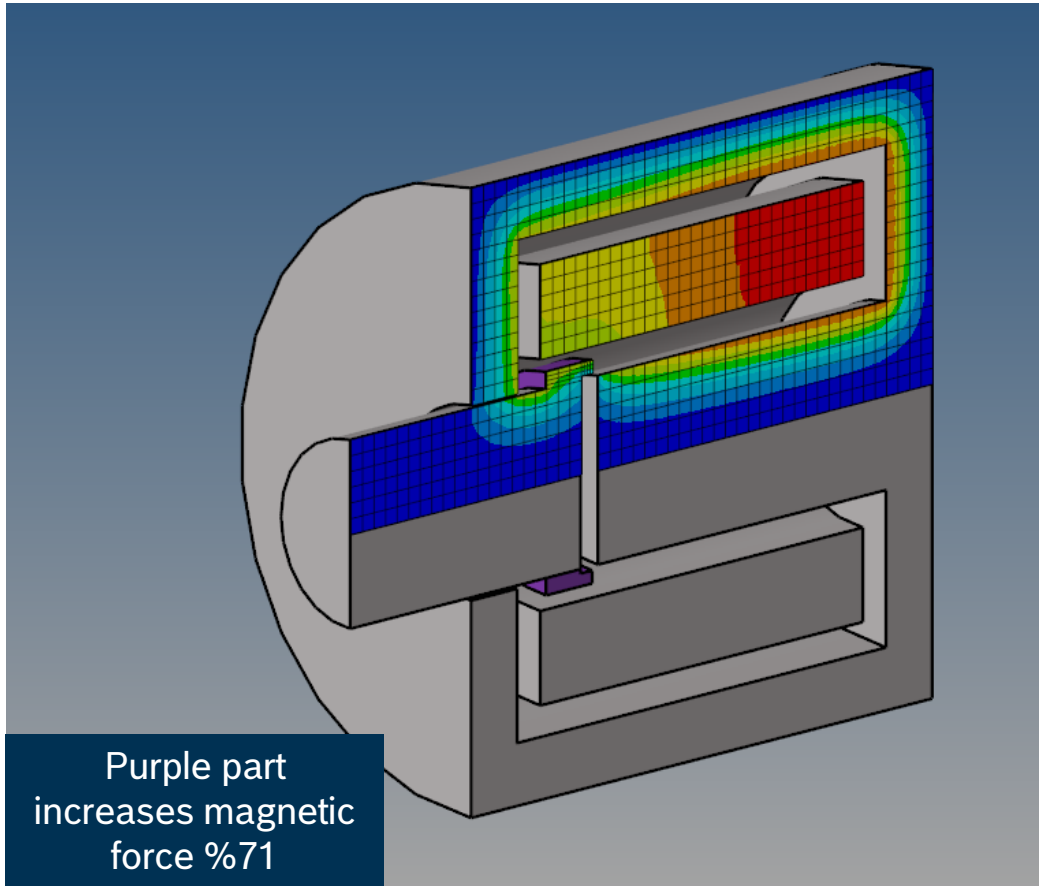

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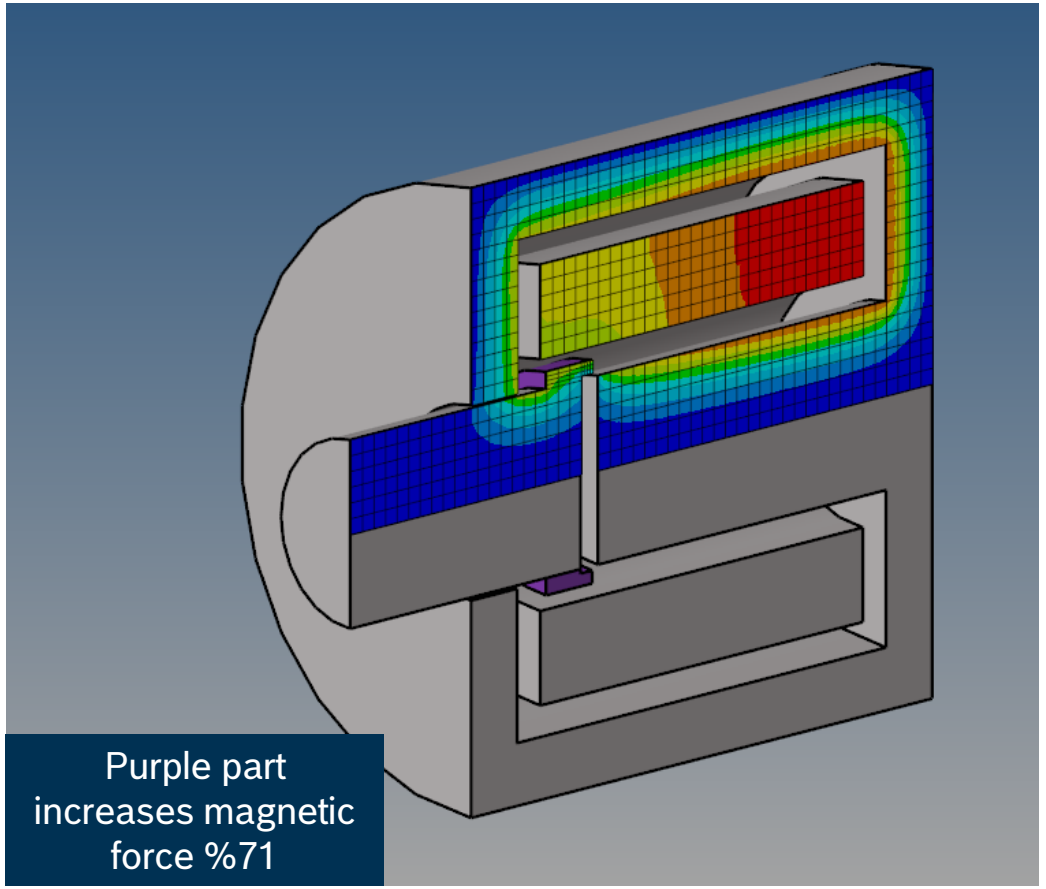
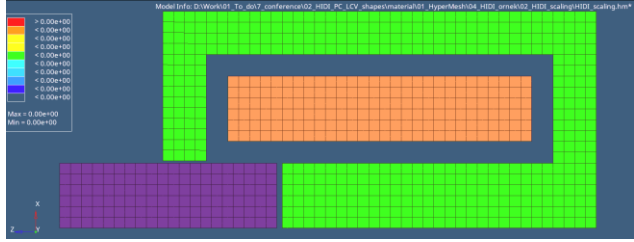


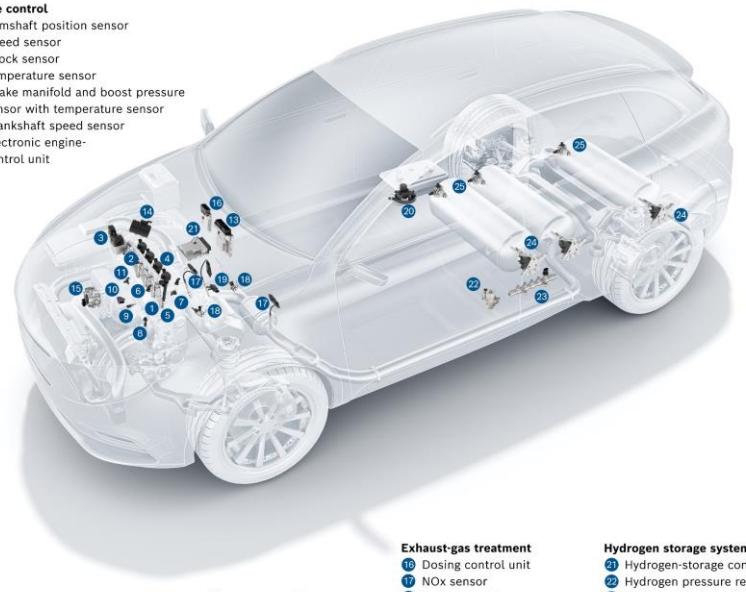
Results
Hydrogen injector



Hydrogen fuel injection equipment
1. Hydrogen direct injector
2. Rail with pressure and temperature sensor
3. Electronic pressure regulator

Ignition system
4. Ignition coil
5. Spark plug

Engine control
6. Camshaft position sensor
7. Speed sensor
8. Knock sensor
9. Temperature sensor
10. Intake manifold and boost pressure sensor with temperature sensor
11. Crankshaft speed sensor
13. Electronic engine-control unit



Air management
14. Hot-film air-flow meter
15. Electronic throttle valve

Exhaust-gas treatment
16. Dosing control unit
17. NOx sensor
18. Dosing module
19. Differential pressure sensor
20. Supply module

Hydrogen storage system
21. Hydrogen-storage control unit
22. Hydrogen pressure regulator
23. Hydrogen tank manifold
24. Hydrogen tank valve
25. Hydrogen tank plug

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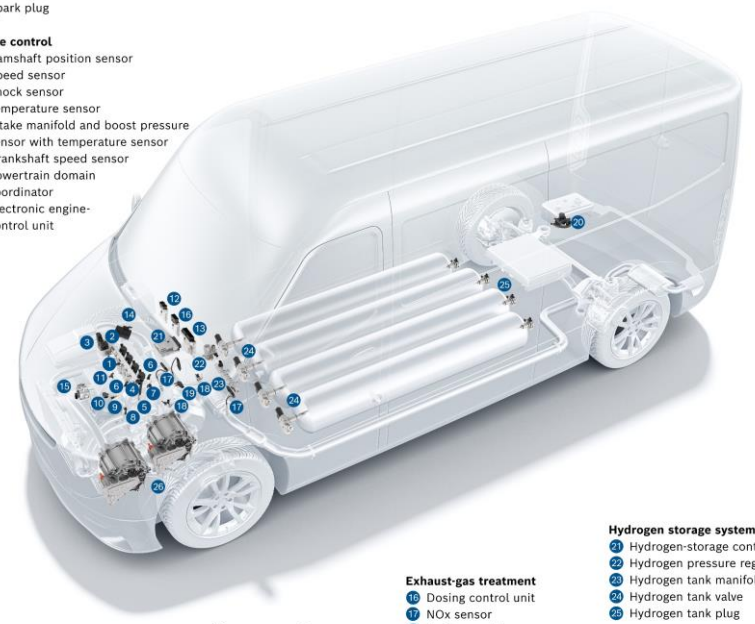
12. Powertrain domain coordinator
13. Electronic engine-control unit



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Electric drive
26. Electric motor

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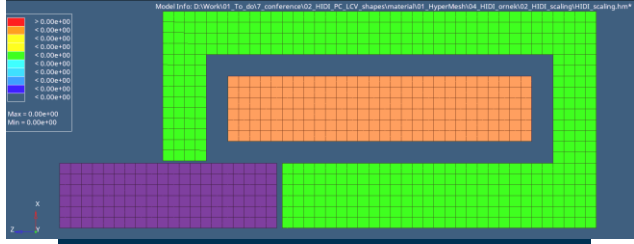
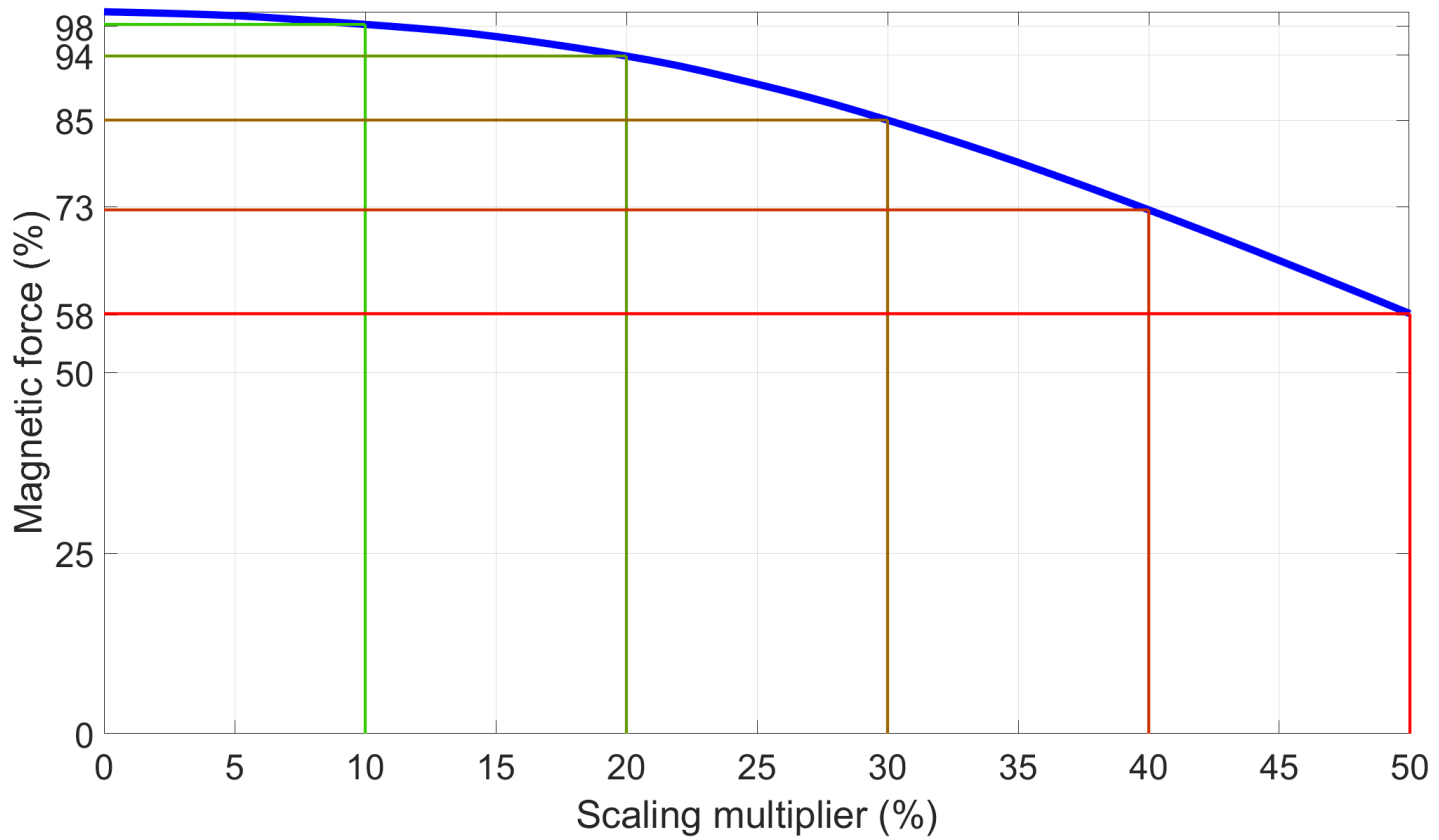
Results
Hydrogen injector





Contribution of PS-GI/ENG3-Bu:

Providing scalable models for multi-domain simulations

Ex: Simcenter Amesim is a multi-domain simulation tool that can run electromagnetic simulations in combination with pneumatic simulations

Conclusion

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- Bosch Sanayi Tic. A.Ş. – PS-GI/ENG3-Bu is providing electromagnetic simulation support to product development of hydrogen internal combustion engines
- Altair HyperMesh is used for these simulations
- Bosch Internal product, Edyson, is developed considering capabilities of Altair HyperMesh