

Abstract

Fatigue topology optimization of a crankcase

Nowadays, CO2 emissions reduction and therefore vehicles mass reduction must be taken into account in the design process. Topology optimization tools are powerful levers to achieve lighter and more reliable conceptions. In the automotive field, the fatigue strength of parts is predominant and often drives the design. Thus, taking into account this mechanical behaviour is essential in the optimization calculation. This paper describes the first use of this new OptiStruct feature, applied to a crankcase.

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PSA PEUGEOT CITROËN

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Agenda

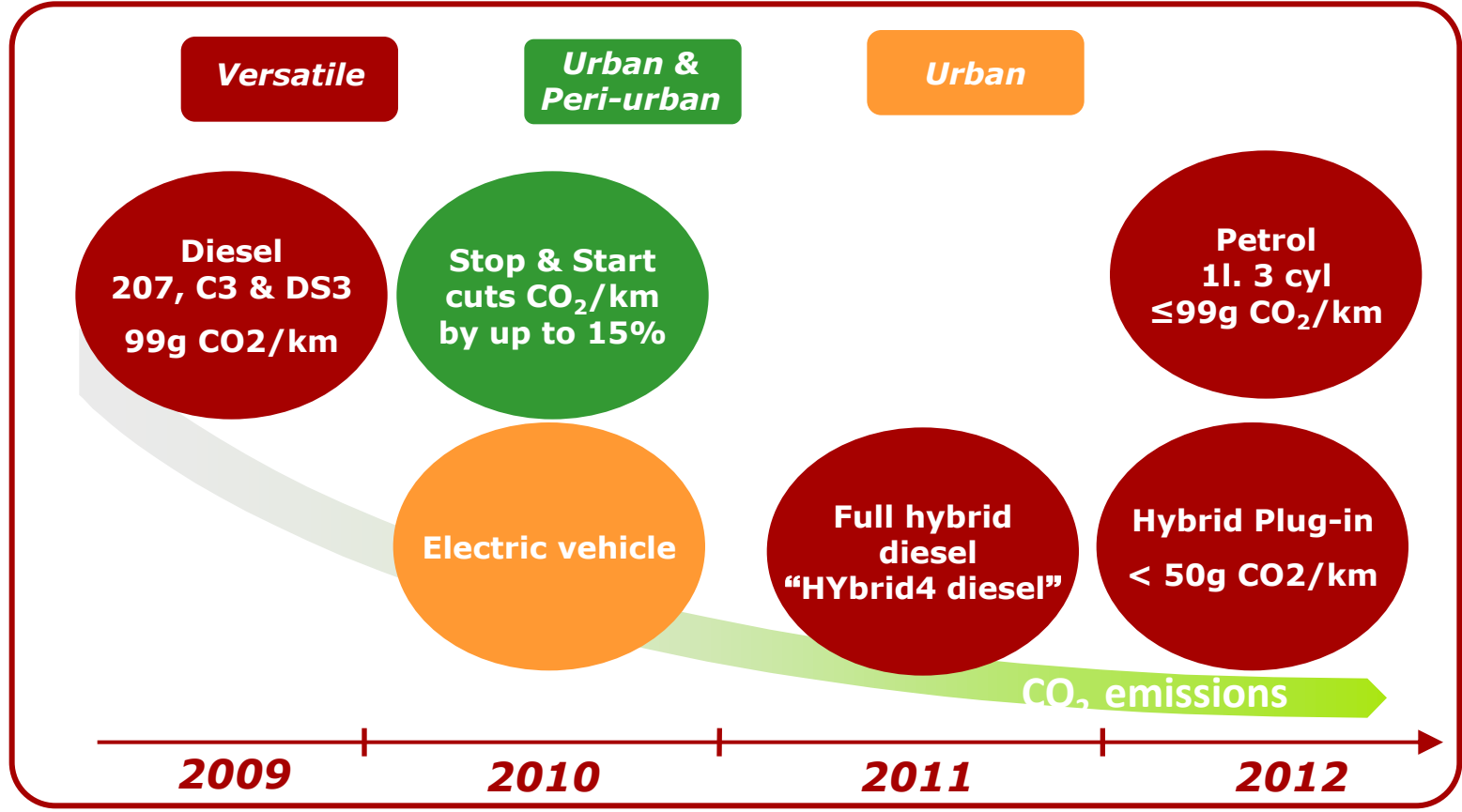
- Introduction : PSA Peugeot Citroën, Mass and CO2 emissions reduction
- Crankcase description
- Optimization approach
 - Bolt tightening
 - Fatigue formulation
 - First optimization formulation
 - Final optimization formulation
- Results and discussion
- Conclusion

PSA Peugeot Citroën : Key figures (2009)

- Turnover of €48,4 bn*
- 3,188,000 vehicles sold worldwide
- 186,220 employees worldwide
- Europe's No. 2 vehicle manufacturer with market share of 13.7%
- Environmental leadership with sales of 1 million vehicles sold in the world emitting less than 130g of CO₂/km
- Leadership on the light commercial vehicles market, with market share of 22.2%



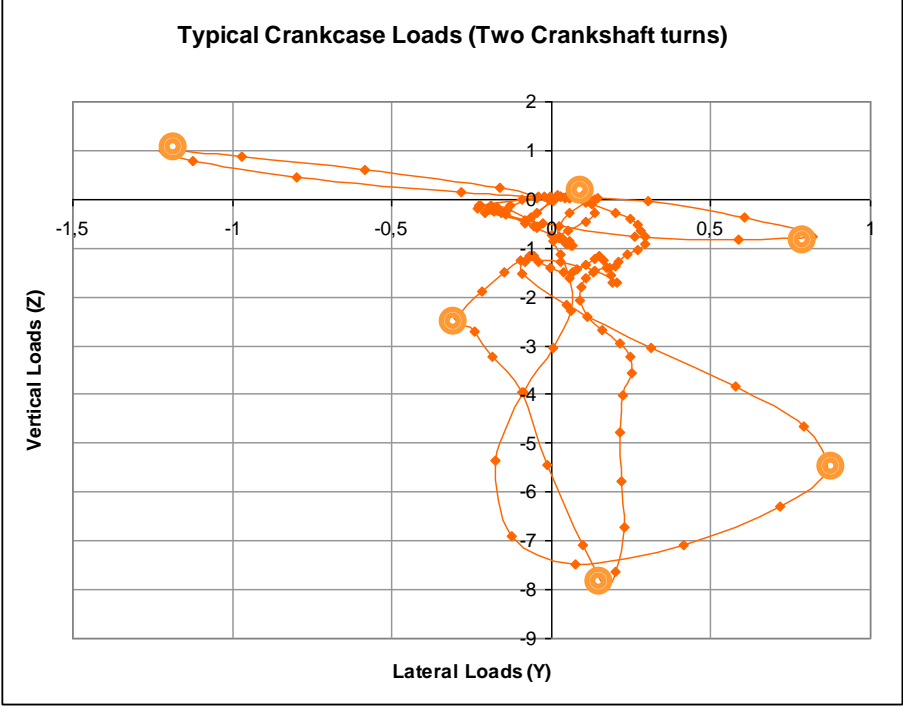
Mass en CO2 emissions reduction : a priority



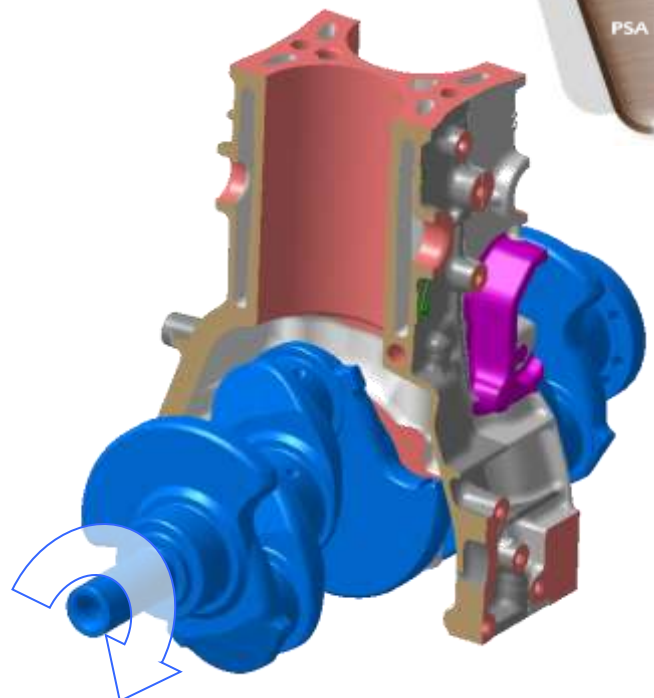
Crankcase description

A massive metal part

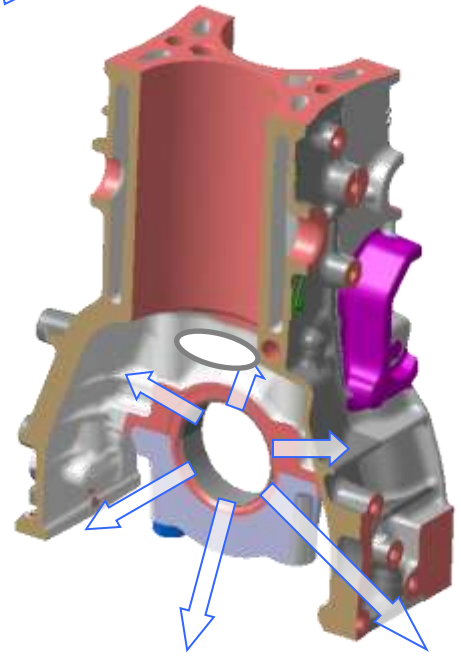
- Aluminium or cast iron made
- Subject to crankshaft rotating loads



- Design is driven by fatigue resistance
- Functional requirement : vent hole is needed



Crankshaft rotation

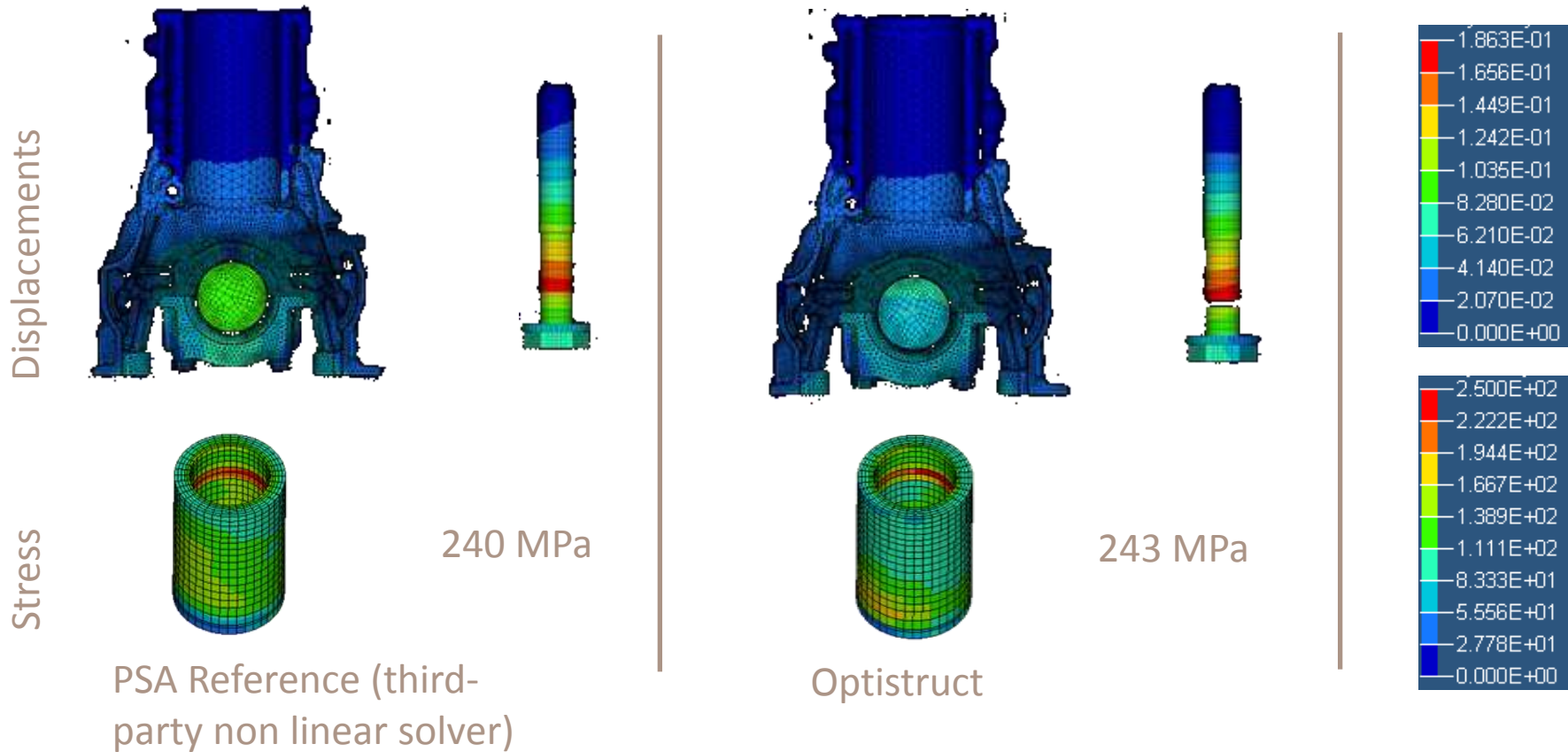


Loads

Optimization approach : Bolt tightening

Optistruct model with contact and bolt tightening

By using GAP element with F0



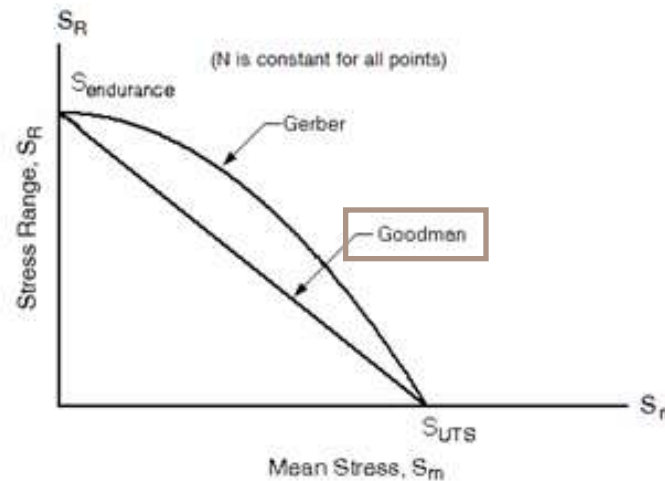
→ First application of bolt tightening – Real improvement

Optimization approach : Fatigue formulation

SN-Method

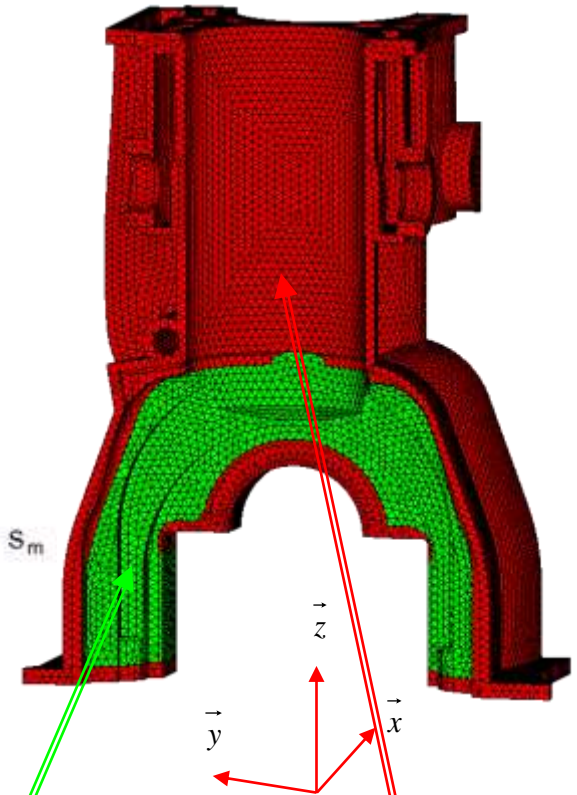
- Based on the Von Mises Equivalent Stress
- Mean stress correction (Goodman)

$$S_e = \frac{S_a}{1 - (S_m / S_u)}$$



- Damage accumulation with Palmgreen Miner rule

$$\sum D_i = \sum \frac{n_i}{N_{if}} < 1.0$$

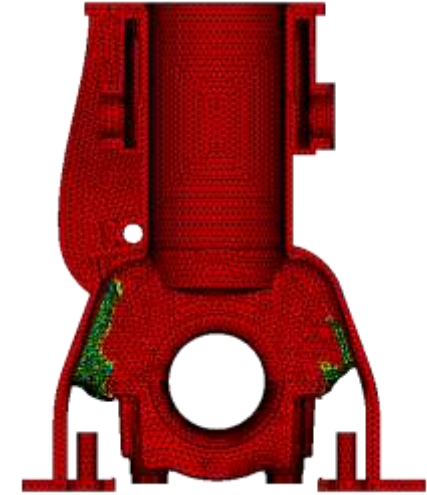


Optimization approach : First optimization formulation

Two « natural » approaches :

- Formulation 1 : Mass minimization
 - With lifetime $> 1^E6$ cycles (DS + NDS)
 - With split draw direction along crankshaft axis

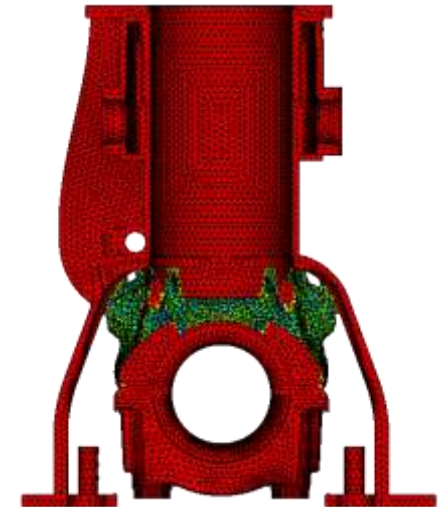
→ Limited mass removal :
solver needs more guidelines



Density Results

- Formulation 2 : Compliance minimization
 - With Volfrac $< 20\%$
 - With lifetime $> 1^E6$ cycles (DS + NDS)
 - With split draw direction along crankshaft axis

→ Real mass removal, but lifetime constraint is
violated (lifetime less than 1^E4 cycles)



Optimization approach : Last optimization formulation

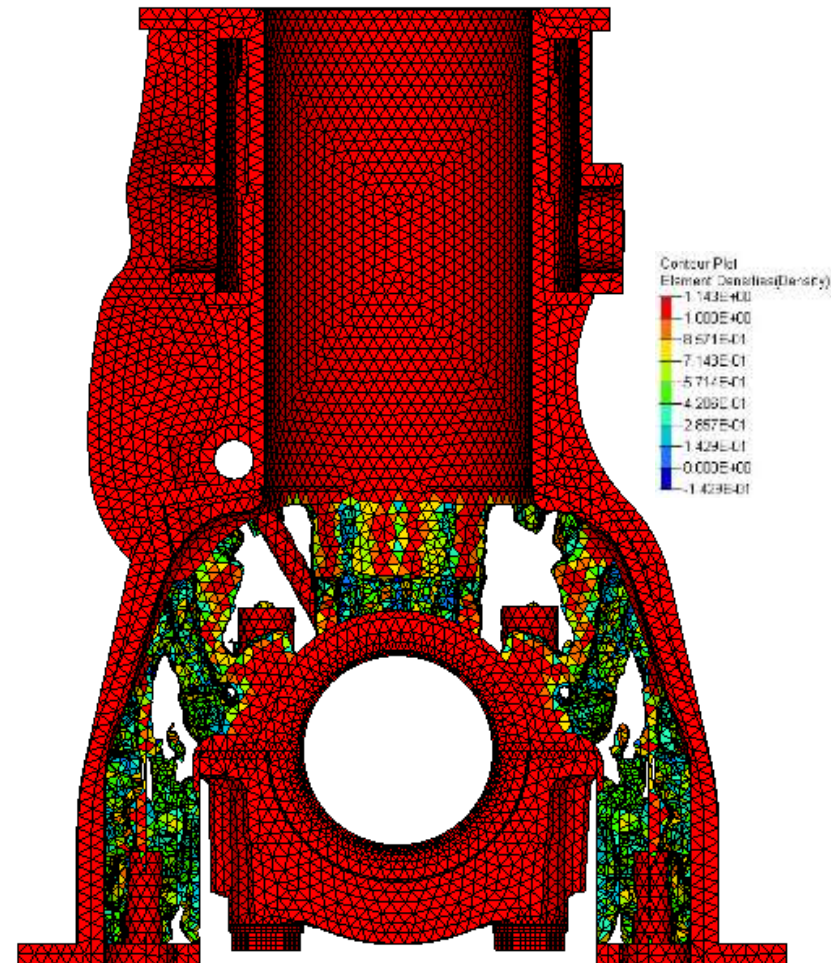
Other constraints have been added :

- Objective : compliance minimization
- Constraint n°1 : lifetime $> 10^6$ cycles (DS + NDS)
- Process constraint n°1 : split draw direction along crankshaft axis
- Process constraint n°2 : Maximum member size of 20 mm

Functional requirements

- Constraint n°2 : Volfrac $< 40\%$
- Constraint n°3 : Von Mises Stress in some areas of Non Design Space < 120 MPa to guaranty lifetime

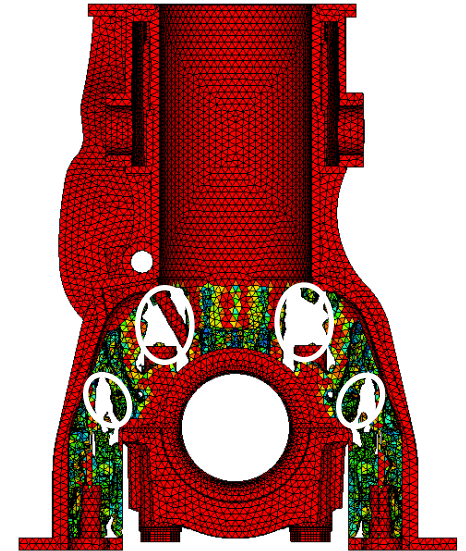
Solver guidelines



*Life time is at least **2.8⁶**
cycles*

Results and discussion : optimization results

- Lifetime is respected
 - Only if a Von Mises Stress constraint is added
- Optimization formulation is a bit tricky
 - Constraint on Von Mises Stress must be finely tuned to obtain correct lifetime and an acceptable mass reduction
- No central vent hole suggested by Optistruct, but a real potential for lateral vent holes (2 or 4)
- Topology is naturally almost symmetric :



Only split draw direction

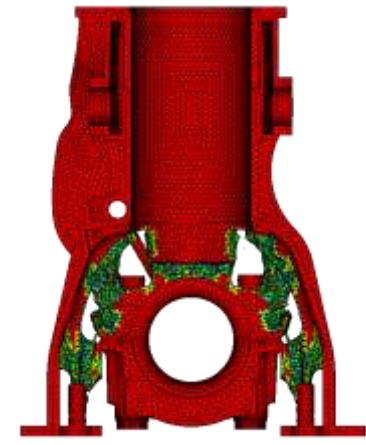
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Split draw direction + 1 symmetry constraint

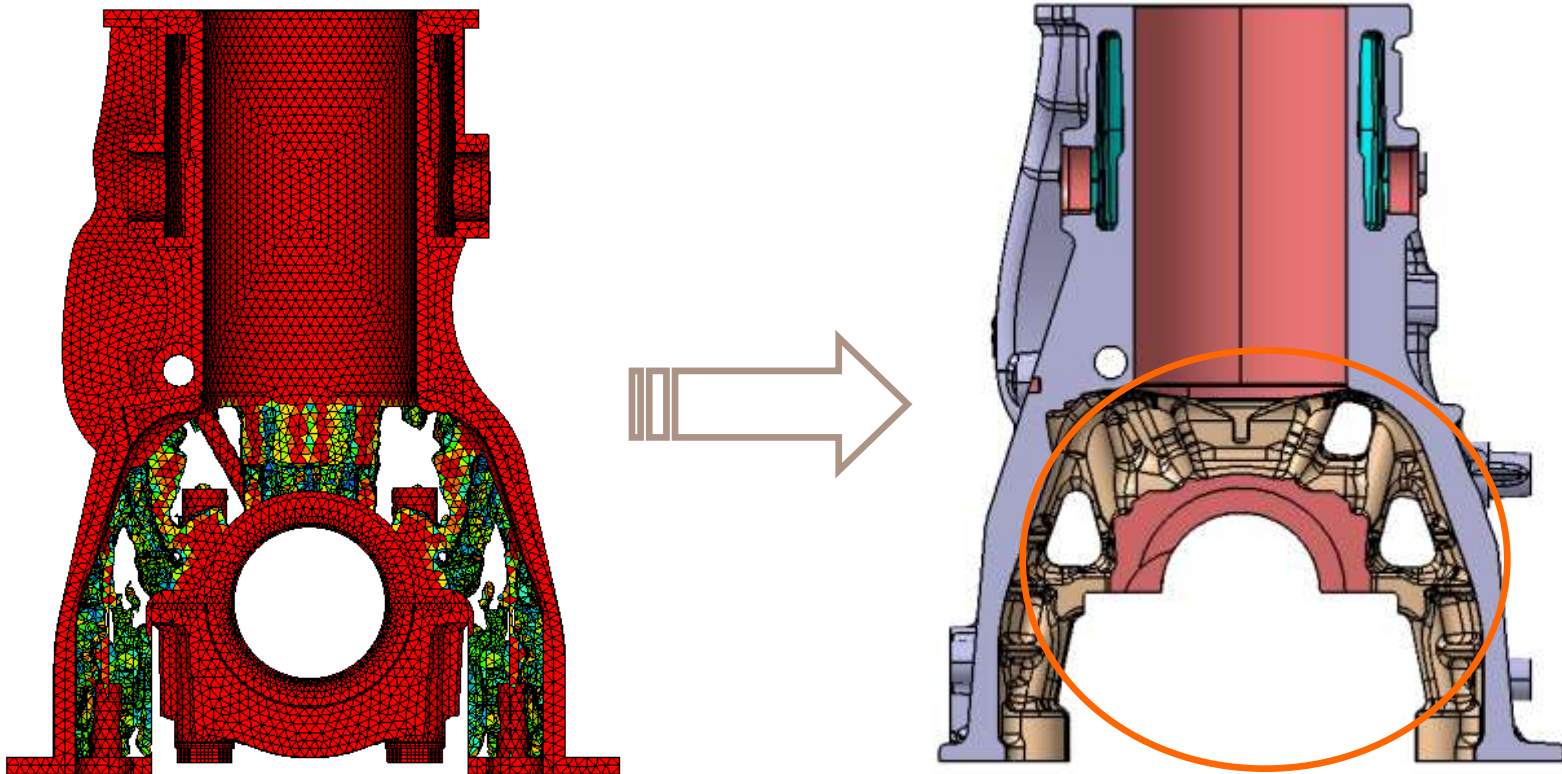
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Split draw direction + 2 symmetry constraint

Results and discussion : interpretation

A reconstruction based on Optistruct Result and taking into account detailed process constraints has been done

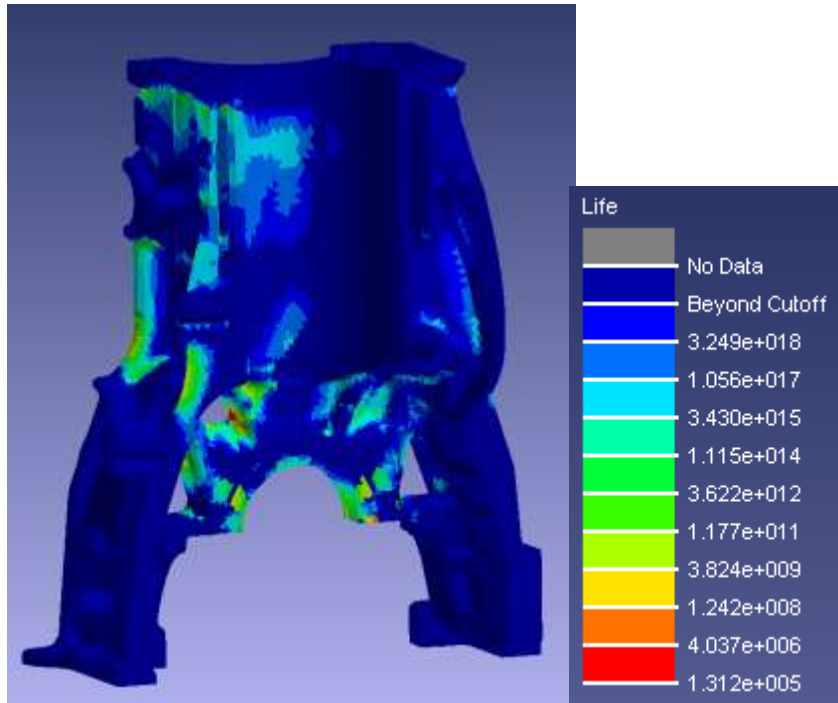


→ 40 % mass reduction in the Design Space (compared to initial Design Space)

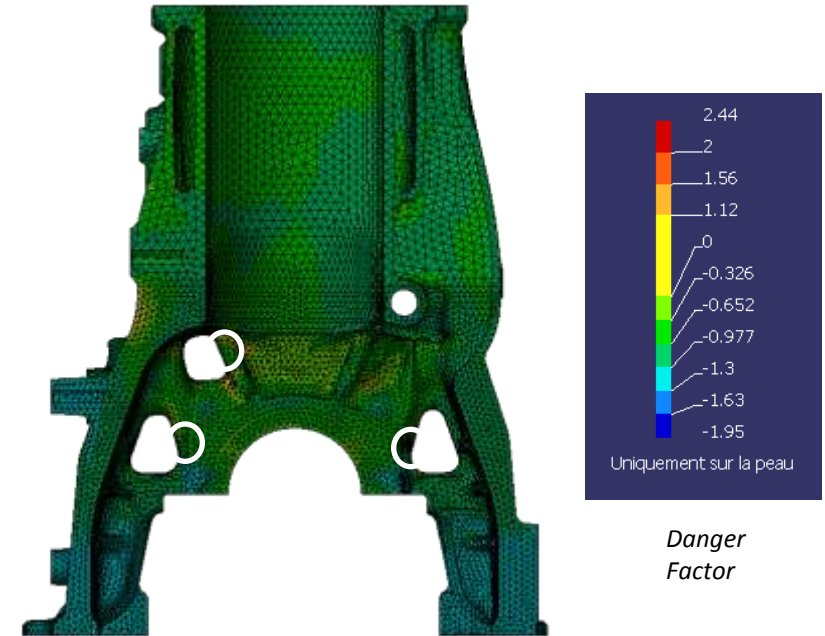
→ 10 % mass reduction in the area of interest compared to a classical designed definition (almost 3 % on the entire crankcase)

Results and discussion : validation of the final design

Fatigue resistance evaluations have been done, with Optistruct SN method and with PSA reference Method (Dang Van criterion) :



SN method : lifetime $> 1^E6$ cycles for 50% of parts



≠

Multi axial criterion : areas with safety factor < 1 for more than 1% of parts → not acceptable

Results and discussion : summary

This work reveals a real potential for fatigue topology optimization :

- This Optistruct feature gave us good results : the validation calculation, realized with the same SN method, predicts an acceptable lifetime, just like Optistruct results
- A significant mass reduction (about 10 %) in this case
- A much faster development time (60 % faster) in this case



But it raises some questions:

- Why using only a lifetime constraint did not work ?
 - Using a Stress constraint like we did is a bit unnatural...
- No direct equivalence between fatigue methods
 - We have to be careful of using the right limit to have an acceptable design production wise



→ A positive study assessment, and an important milestone !

Conclusion and perspectives

- In the Automotive field, fatigue is a high priority in part design.
- Optistruct, with this new features, would find more uses
- To really fit our needs, Optistruct could propose more fatigue criterions and methods (and particularly the multiaxial assessment)...
- But it is a really interesting first step !

Thank you for your attention !