Case Study: Hydraulic valve block redesign for additive manufacturing

By VTT Technical Research Centre of Finland Ltd & Nurmi Cylinders Oy
Case Overview

- **Nurmi Cylinders Oy**: Finland-based manufacturer of hydraulic cylinders for heavy-duty applications in offshore, industrial, marine and mobile environments

- **Design Challenge**: Redesign a hydraulic valve block to take full advantage of the benefits of additive manufacturing

- **Traditional valve block**
  - Straight and circular drillings
  - Auxiliary drillings that need to be plugged afterwards
  - Initial weight: 2.5kg

- **Benefits of AM**
  - Improve shape of internal channels for optimal flow
  - Eliminate need for auxiliary drillings – reduced potential for leaks
  - Reduce size & weight
  - Produce small, tailor-made series to suit customer’s needs

[Source: http://www.vttresearch.com/]

Initial design space provided by Nurmi Cylinders Oy
Initial Printability Check

- Original channel design requires supports → difficult/impossible to remove
- Solution: Internal channels are now straight (~45° to base plate) with elliptical cross-section

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Engineering Requirements

- Safety factor
  - Yield stress: 1.8
  - Tensile strength: 2.7
- Material should withstand marine environment
  - Corrosive resistant material
  - First iteration H13 Tool steel
  - Final material: still under investigation
- Elongation: 11-20% acceptable

Loads

- Channel pressure: 300 bar (optimization), 420 bar (final test)
- Bolt preload: 17.9 kN
- Side loads: 100 kg

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Optimization & Result Interpretation

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Preliminary Design Analysis

- Material: H13 tool steel
  - Maximum acceptable stress: 640 MPa (tensile/2.7)
  - Maximum stress: 946 MPa (*note – only a few elements have stress levels above 500 MPa, all are in non-design space and can be modified)

Colored elements have stresses exceeding 500 MPa

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Smoothing + Final Design Analysis

- Mass after smoothing operations: 578.4 g; compared to original mass 2.5 kg → 76% reduction
- Reanalysis with test pressure (420 bar)
- Design meets defined stress requirements

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Support Design and Printing
After Support Removal

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Summary

- Designing specifically for AM makes it possible to take full advantage of the design freedom offered by this manufacturing technique.

- Successful printing of a part necessitates knowledge about the specific requirements for a given AM technology, material being printed, build direction and orientation, supporting structures and their removal, and post-processing procedures.

- VTT has experts in advanced manufacturing techniques, structural design and analysis, and material science all under one roof. Knowledge sharing within these areas of expertise can help ensure successful design and creation of additive manufactured parts.

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- Significant mass reduction leads to lower material cost & faster print time
- No need for auxiliary drillings, less chance of leakage
- Improved flow due to smooth transitions between internal channels
- The bionic design and small series were ideal for AM
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DESIGN OUTSIDE THE BOX