Grundfos Challenge: Design and integration of a gear unit for a hydronic valve into an enclosure box

Pumps and valves are vital components in any hydronic system and their performance can make a huge difference on the overall system performance. An essential part of valves performance is their ability to always position the valve seat correctly. Several contradictive parameters are involved in such positioning systems by which an optimal solution is achieved through best compromise. The Grundfos Challenge is therefore to provide solutions for design and integration of a gear unit for a hydronic control valve.

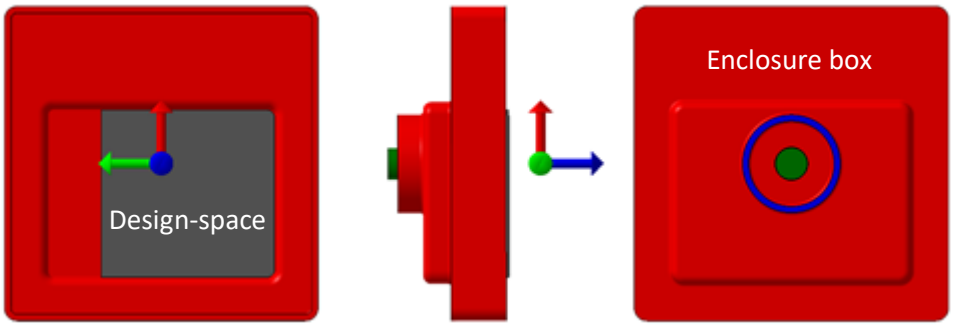
The Challenge

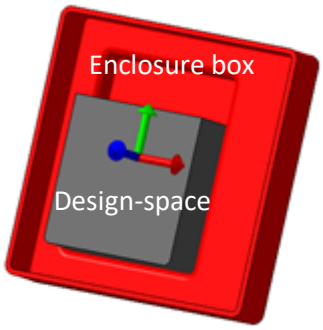
The Challenge is design and development of a gear unit for a hydronic valve that is thoroughly integrated into an enclosure box. Thus, we seek the best solution to the challenge: How can a gear drive train system, that meets certain gear box requirements, be designed, while ensuring a thorough integration of the system into the enclosure box to accommodate the structural integrity of the product? (See figures and attached CAD drawings). The solution is bounded by the technical requirements to the enclosure box, design-space envelope and gearbox (shaft output torque etc.) specified below.

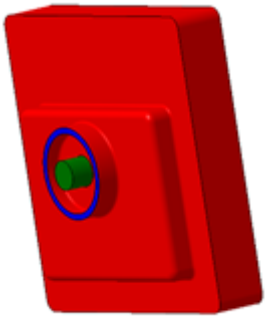
Requirements

<u>Enclosure box (red in figure below)</u>

- Enclosure box is sealed by a lid (not shown). The lid should not be designed nor be considered with respect to the structural integrity
- Outer surfaces of the enclosure box cannot be changed
- Inner surfaces of the enclosure box may be changed to form the interface to the gear system e.g. adding towers, pins etc. to transfer loads to the box
- All forces from the gear train are transferred via the box
- All degrees of freedom are fixed at the end of the cylindrical face (blue circle in figure)
- Manufacturing: Injection molding, tool disassembly direction, Z.
- Min. material thickness: 1mm
- Material: Polycarbonate 10% glass fiber – Assume linear material properties (23^{O}C): E=4.114GPa, ν=0.38, ρ=1270kg/m^3
- Assembly: Gear unit is mounted in the enclosure in the Z-direction
- Coordinate system: **X**, **Y**, **Z**

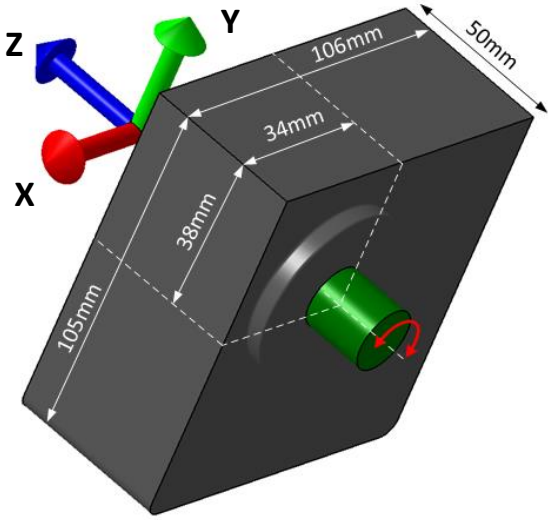






Design-space envelope

- The gear drive train system must fit within the specified design-space envelope of the enclosure box (black/grey box – see figures and attached CAD drawings).
- The motor must also fit within the design-space envelope.

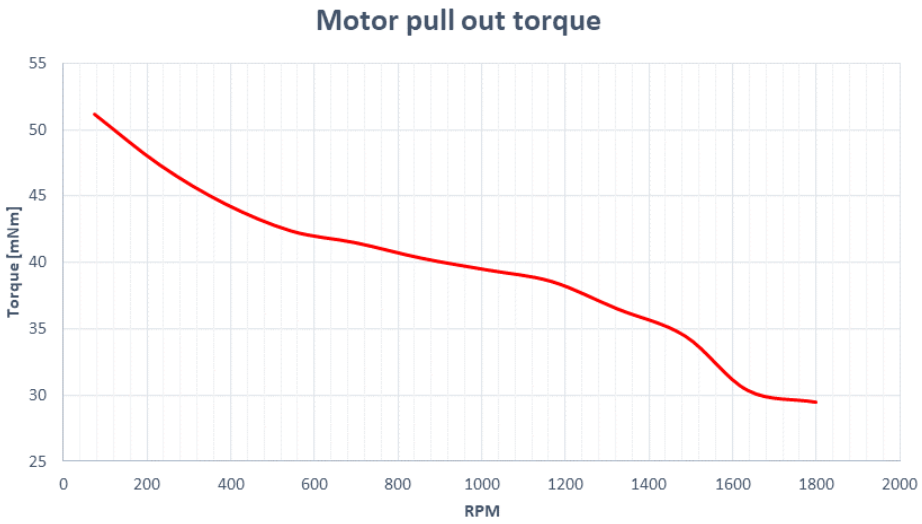


Gear system

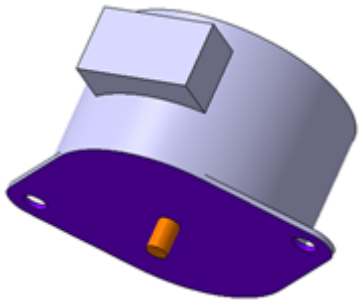
- No fixed gear principle e.g. planetary, worm, spur etc.
- Minimal maintenance systems are preferred

Electric motor

- The motor for the gear system is pre-specified and provides a well-defined input torque: See motor pull out torque curve (clockwise and counter clockwise).



- Allowable RPM range: 500-1500RPM
- Dimension: See CAD file



- Shaft connection: Flat shaft
- Operation mode: 3 sec ON followed by 7 sec OFF

Output shaft

- RPM: 1 RPM +/- 5%
- Torque: 20Nm +/- 1Nm (at 1 RPM)
- Radial rotating force: Maximum 300N at tip
- Movement: Bi-directional (open/close of valve) – 360^{O} in both directions (no fixed stop)
- Hysteresis: < 3^{O}
- Material: Steel – E=200GPa, ν=0.3, ρ=7800kg/m^3
- Shaft connection: Oldham

Miscellaneous - Environmental

- Ambient temperature: -10 to 50^{O}C
- Pressure: Atmospheric
- Relative Humidity: 95%, non-condensing
- Gear unit is not exposed to dust or UV light.

Judging criteria

1. Are the technical requirements meet?

    - Within the design-space envelope?
    - Is assembly in Z-direction possible?
    - Etc.
2. Is the solution considered reliable and robust?
3. Is the gear principle novel and maintenance free?
4. Designs with the following features are favored:
    - Non-lubricated gear systems
    - Compactness of solution (considering potential thermal risks for gear unit and PCBs in the enclosure box)
    - Low weight
    - Low cost
    - Low hysteresis on output shaft
5. Alternative and creative features to improve the product and/or its application further e.g. out-of-spec. application, added value, improved robustness, manufacturing, high life time, maintenance free etc.

Submission

- Submit CAD files in STEP format
- Screen shots in various views (preferably rendered)
    - Screen shots of simulation results (if applicable) and a small description of the setup (so that it can be replicated by the jury)
- Documentation incl.
    - Gear ratio
    - Bill of material incl. material composition
    - Design considerations e.g. on manufacturing, assembly, reliability etc.
    - Description of alternative/creative features
    - Etc.

Attached files

- CAD files of motor and enclosure box incl. design-space envelope
- Figures of CAD drawings
- Motor torque vs. RPM curve