Design of COMPASS-U support structure cooling

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INTRODUCTION
COMPASS-U will be tokamak characterized by high toroidal field (5 T) and hot wall (~ 500°C). It will be situated in place of current tokamak COMPASS at IPP, Prague.

COMPASS-U is designed to be relevant to future devices like ITER and DEMO.

Basic parameters:
- Major radius: $R = 0.894$ m
- Minor radius: $a = 0.27$ m
- Tor. field intensity: $B_t = 5$ T
- Plasma current: $I_p = 2$ MA
- Flat top length: $t_{flat} = 2$ s
- Triangularity: $\Delta = 0.5$
- Elongation: $K = 1.8$
- Plasma volume: $V_{plasma} = 2$ m$^3$
- First wall temp.: $T_{wall} = 500$ °C

SUPPORT STRUCTURE
- Copper coils will be cooled down to 80 K to get significantly lower resistivity and thus ability to reach requested magnetic field and plasma current.
- All the coils will be held in place by so called „support structure”, allowing them to withstand resulting magnetic forces.
- Support structure consists mainly of 16 C-frames, 2 compression discs and 2 wedgeplates. Each C-frame consists of 7 big parts, this means whole structure consists of ~120 big parts!
- All components will be made from stainless steel (~ AISI 316LN)

To compensate for and to follow thermal shrinkage of copper coils (up to ~10 mm), whole support structure will be also cooled to 80 K in sync with coils.

This means no easy task, because of size of the structure and huge possible thermal input.

GLOBAL THERMAL MODEL
To help with design and analysis, 2D global thermal model was created in cooperation between IPP and PPPL (mainly by H. Zhang). This enables us to approximate heat fluxes between all components, including support structure.

It includes 3D heat radiation by implementation of radiation loops.

Resulting cryogenic heat loads for full power operation (vessel@770 K):

<table>
<thead>
<tr>
<th>Component</th>
<th>Heat Load (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central solenoid</td>
<td>550 W</td>
</tr>
<tr>
<td>PF coils</td>
<td>635 W</td>
</tr>
<tr>
<td>TC coils</td>
<td>535 W</td>
</tr>
<tr>
<td>Support structure</td>
<td>4450 W</td>
</tr>
</tbody>
</table>

PIPING OPTIMIZATION
To optimize and balance whole cooling system, 1-D piping simulation was run on complete piping geometry.

Input pressure was 5 kPa (minimal dp for SS cooling), coolant temperature 80 K.

Simulation outcome
Resulting bus diameter is 60 mm, connection pipes are with diameter 10 mm.

Flow inhomogeneity is below 20%, which is acceptable.

CONCLUSION
System of drilled cooling channels with diameter of 20 mm was design and verified by simulation. Distribution busses and connection pipes were optimized to get best performance with reasonable space requirements.