There is a big difference with respect to the design of a ship and that of an airplane. To design a new type of airplane the industry takes 4-6 years to design it, do a number of test flights and adapt the design if necessary. After that 500-5000 planes are built using this design. In contrast to that every ship is designed from the start. Also if there is a series of ships, most of the design is done again due to adaptations in the requirements. This implies that the design of a ship should be fast (a couple of months).

At this moment the maritime industry is booming in The Netherlands especially for special ships as there are: dredging, heavy lift, super yachts, etc. After a ship is designed, it is necessary to check if the properties of the new ship are good. Some of the properties can be checked by model experiments, but nowadays most of the work is done by Computational Flow Dynamics. MARIN (Maritime Research Institute Netherlands) is one of the leading institutes in the world, that is able to do the required computations and simulations for the design of a new ship. At this moment, it can take more than one month to do all the required computations. The aim is to reduce this in the near future to one week. In this paper we describe how one part of the simulations has been accelerated with more than a factor 5 in wall clock time.

In order to do the Computational Flow Dynamics for a ship, the Reynolds averaged Navier Stokes (RaNS) equations are used. They are discretized by a finite volume method with a colocated placement of the unknowns on an unstructured grid. This leads to a huge non-linear system of algebraic equations. The method of choice to solve this systems is the SIMPLE (Semi Implicit Pressure Linked Equations) iterative method. It is important to choose the correct under-relaxation parameters, but then one obtains a robust (but slowly converging) solver.

At the TU Delft, we have a lot of experience with Krylov methods, which can be used to solve linear systems. We also develop robust and efficient preconditioners to solve incompressible Navier Stokes equations. One of these preconditioned methods is the GCR-SIMPLER method used to solve the flow in a glass furnace [1]. In 2010, we have the idea to use the SIMPLE solver of MARIN in combination with a Krylov method to obtain an acceleration of the solver. To do this, a number of adaptations has to be made. One example is the inclusion of the stabilization term in a correct way.

<table>
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<tr>
<th>grid</th>
<th>CPU cores</th>
<th>SIMPLE</th>
<th># its</th>
<th>Wall clock</th>
<th>KRYLOV-SIMPLER</th>
<th># its</th>
<th>Wall clock</th>
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<tbody>
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<td>16h 37mn</td>
<td>1330</td>
<td>3h 05mn</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) SIMPLE  
(b) KRYLOV-SIMPLER

**Highlights**

Fast ship simulators
Furthermore, in the traditional solver only one iteration is done for the linear velocity pressure system and then the next non-linear iteration is done. To use the Krylov SIMPLER method, we do a number (5-10) iterations for the velocity pressure system, before we go to the next non-linear iteration (this resembles a Newton-Krylov method).

The results are very good for most problems. The figures show the results for a full-scale tanker. Note that this is a real challenging problem, where the Reynolds number is $2 \times 10^9$ and the maximum aspect ratio of the finite volumes is 930,000. However, the Krylov SIMPLER method does a really good job. The number of non-linear iterations is down by a factor 20, whereas the wall-clock time is reduced by a factor 5. For more examples we refer to our paper [2].

**REFERENCES**
