Existence and regularity of weak solutions for a fluid interacting with a non-linear shell in $3D$

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We study the unsteady incompressible Navier-Stokes equations in three dimensions interacting with a non-linear flexible shell of Koiter type. We study weak solutions to the corresponding fluid-structure interaction (FSI) problem. The known existence theory for weak solutions is extended to non-linear Koiter shell models. We introduce a-priori estimates that reveal higher regularity of the shell displacement beyond energy estimates. These are essential for non-linear Koiter shell models, since such shell models are non-convex (w.r.t. terms of highest order). The estimates are obtained by introducing new analytical tools that allow to exploit dissipative effects of the fluid for the (non-dissipative) solid. The regularity result depends on the geometric constitution alone and is independent of the approximation procedure; hence it holds for arbitrary weak solutions. The developed tools are further used to introduce a generalized Aubin-Lions type compactness result suitable for fluid-structure interactions.