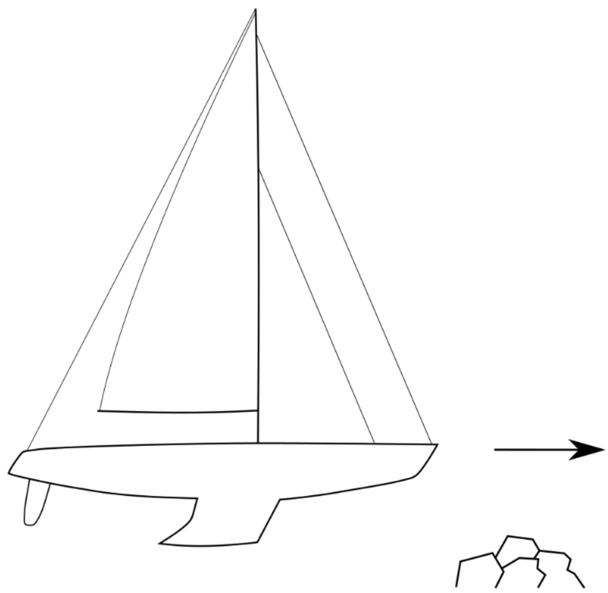
Adventure 40

Grounding – March 2023 Update



In the previous paper and AAC article, we took a look at grounding-readiness and determined that the candid « make the keel stronger! » approach, while understandable, fails to address the core of the issue. This is because grounding is primarilly a shock-absorption situation, and must be dealt with as such. Embracing the shock-absorption way implies arranging for some material to break or deform in the event of an impact, and the best place for this material is the impact point iself: the leading edge of the keel. Thus we determined that we should:

- arrange some « bumper » at the front of the keel, that will « cap » deceleration, and thus the forces (efforts) transmitted from the keel to the boat,
- define the keel-to-hull structure engineering requirements not on the basis of some handwaving, but as steming from this prior step.

We also learned that, while the shock-absorption approach is generally not explicitly put into practice on production boats, it happens to be present, to some degree, on some of them: lead keels already happen to perform some shock-absorption function. The qualitative record of modern production boats that experienced groundings provides a solid hint that, « all things being equal » (and keel-to-hull structures being what they are, from seriously engineered structures to more debatable solutions), carrying a lead keel substantially reduces the damage, or increases the speed above which damage is done, when compared to a similar keel out of rigid cast-iron. And this is on boats where no in-deep thought was given to grounding-readiness.

In order to pre-assess lead as a shock-absorbing material, we computed simplified preliminary simulations, showing that, if we set a goal of absorbing impacts up to 8 knots of initial speed, unalloyed lead seems to have about just the right ductility, and lead alloyed with antimony, the one usually used for keels, to be slightly « harder » than ideal.

We also stated that, although lead is not necessarilly the only option for the bumper, the perspective of using it as a bumper may create a point for going all the way to a lead keel, instead of the less expensive cast-iron that was our primary option, and gain some sailing performance and ease of maintenance (no rust) in the process.

A SWEDISH CONNECTION?

The process of sharing our thoughts at AAC yielded more learnings:

- AAC member Carl Johanson pointed to the « Keel-Pro » by company Svenska Koster, a « hollow rubber nose mounted on the keel » (in Carl's own synthetic words) that seems to save some hull structures from destruction in Swedish waters every summer: http://www.svenskakoster.se/page6/index.html
- Someone else pointed to the keel of the Linjett 43, which makes use of yet another idea: https://www.linjett.se/en/linjett-43/

It was great to learn we're not the only ones wanting to solve the issue – there seems to be something going on in the Baltic!

GOING TO THE EXPERTS

Our further investigations started by paying a visit to François at the lead foundry « Fonderie Lemer » (http://www.fonderie-lemer.com/) – the first one by far in France for lead keels, provider of many renowned builders. However bluntly their easily-translated tagline, « Lemer – l'expert », puts it, they do gather tons of expertise: on the day of my visit, the mold of an Imoca bulb (torpedo) was being prepared before casting (I saw details of the fastening with the keel foil that I'm not allowed to tell!), and the mold of a JPK racer keel was next in line. Other than that, dozen of molds of keels by various builders are to be found on the factory premises, as well as a nice stock of replacement keels for the Bénéteau Figaro 3 fleet.

GROUNDING ABSORBERS ARE ALREADY A THING!

… but in a very different realm.

The first thing I learned from François is that some superyacht lead keel bulbs are already designed with shock absorption in mind. Those bulbs feature cuts, or other shapes, in the forward part in order to improve the deformation of, and thus absorption by, the lead in case of a frontal impact. How nice to learn that we're not alone looking for this kind of solution!

One of the « impact-ready » superyacht torpedoes casted by Fonderie Lemer. Other implementations have featured different cutout geometries, removed volumes, etc.

François also confirmed that he's never heard of this kind of solution implemented for smaller sailing craft.

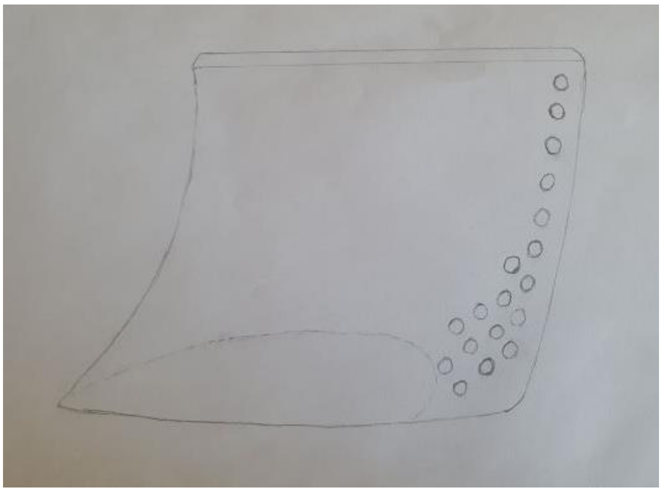
SIMPLE AND ELEGANT WILL ALWAYS WIN OVER COMPLEX

(A40 Core principle #10)

We did imagine various ideas, featuring more or less the same level of complexity as the « baltic » solutions above. For instance, lifting keels can be a great solution if the engineering is done right. But long story short: we have a simpler one that works.

In the process of thinking through the ideas and weighting the pros and cons, two things kept coming back on the table: our demanding longevity target (think 50 years at least), and the associated low maintenance goal. Many a bright idea looks less attractive after it is confronted to these two.

In contrast, lead allows us, with the advice by Fonderie Lemer, to devise a solution that works and is plain simple. It consists in casting the keel out of the usual lead alloy (which by the way comes from lead batteries recycling and contains 2.7% antimony), while, since according to our preliminary work this will likely be just a little less ductile than would be ideal, weakening the bumper volume by embedding cavities in it. We say plain simple because this solution doesn't involve any additional work, when compared to casting a regular lead keel: as long as we respect a few simple geometric constraints, the « holes » can be left by the keel mold. All that will then remain to do is filling the holes with foam, as part of the keel finishing work.



For the record, here is the « original drawing » of our solution. Note that some lead protudes forward of the bulb (torpedo), so as to avoid the too massive bulb to be « mobilized » by the impact. Mere cylindrical cavities weaken the leading edge, making it in effect the bumper we were looking for.

WHAT ABOUT THE KEEL-TO-HULL STRUCTURE?

At this stage, the specifics of the keel-to-hull structure are not decided. The thing is, there is more than one way to do the structure right, and selecting one rather than another is best done in the detailed design phase, when the input from everyone involved in the build can be taken into account. That said, we can underline a few principles:

- we will prioritize the longevity of the structure, and make visual inspection of its state as practical as possible,
- we will avoid falling for the usual fallacies, and choose a solution that according to solid engineering *is* strong, rather than *looks* strong,
- we will factor large safety margins in the sizing of the structure.

Let’s underline that in any case, we don’t need to make the keel long and massive to make it solidly attached to the hull. We can have a faster boat than that! The usual bottom-of-hull damage in groundings is a function primarilly of no shock-absorption being taken into account, and in some cases of poor design or sizing of the keel-to-hull structure. Let’s solve these issues rather than compromise the fun factor!

Also, there won’t very likely be a bottom-of-hull steel structure, because the required load-transmission can be done with composites, associated with substantial backing plates for the bolts – it’s a matter of sound engineering and sizing, just like a skeg rudder is not *intrisically* better than a spade rudder.

WHAT DOES ALL THIS CHANGE TO THE ENGINEERING OF THE BOAT?

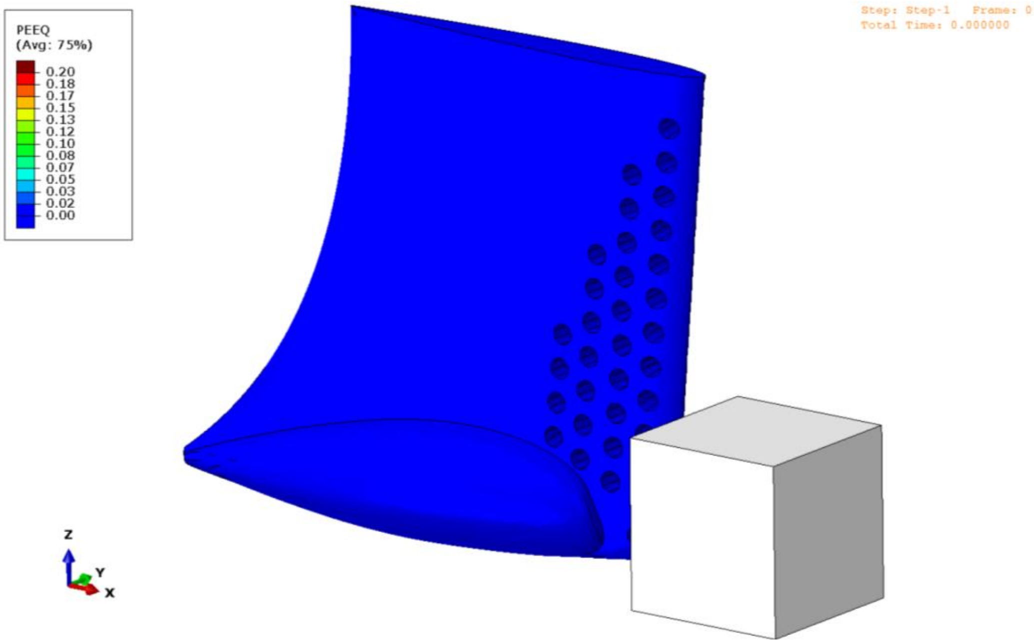
Of course, any new sailing boat goes through the computer and expertise of a structural engineer, and is certified based on that process. The question here is how our solution interferes with this process, and what specific needs it adds.

The great thing is, our solution is consistent, and purposely so, with the main engineering task performed in this process – that is, static loading calculations under various scenarios. The point of absorbing the impact is to cap the resulting forces. Once these forces have been assessed by a model of the very impact, we can safely and easily transfer them into the static loading computations.

Moreover, recognized naval engineers confirmed that our solution and methodology is fine to them, and that they will gladly dimension the boat to the static efforts arising from it.

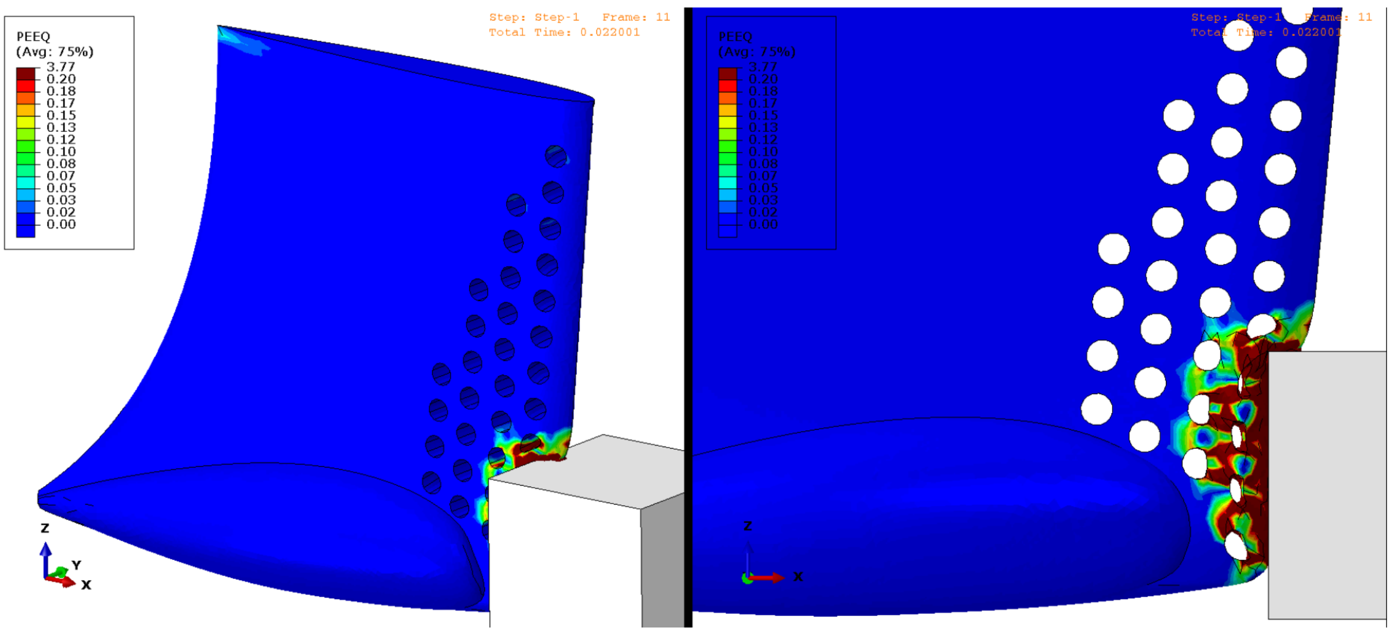
These naval engineers also pointed that involving shock absorption is uncommon, to this day, to the sailboat industry, and thus advised that we work with a specialized engineering office on this specific part.

The following images, and associated video, were provided by engineering office https://www.ec2-modelisation.fr/, who gathers a large experience in such shock modeling for other industries (automotive, maritime works, etc.) and will, in the project phase (ie after the final investment decision), do the modeling and optimization of shock absorption by our keel.

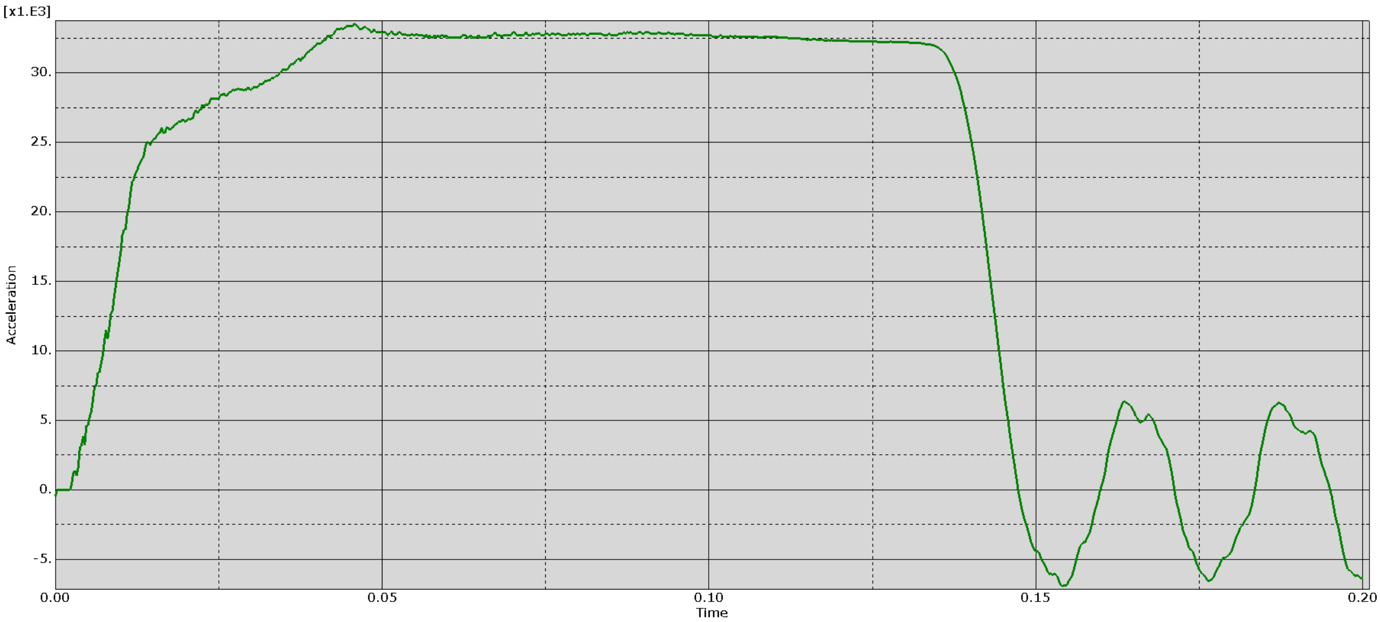


A40 keel, as modeled by architect Vincent and EC2 Modélisation

Until then, the video is purely illustrative of the tools they will use – the main parameters are likely correct but were not thoroughly tuned and verified. And the most acute viewers will notice that the model in this illustrative video doesn't feature a proper keel structure, which alters the behaviour.



Same keel undergoing a serious impact – very preliminary computation…



… and associated boat deceleration – the kind of curve we'll be looking at when doing the bumper optimization.

CONCLUSION

Everything is now in place to provide the A40 with a keel and keel-to-hull structure that will greatly reduce the danger that grounding generally is to fiberglass sailing boats and to their crews.

And while in the process we changed from the initially-envisionned cast-iron keel to lead, reaching our goal won’t involve any complex feature that could distract us from the other tasks of boat design, and won’t introduce any long-term weaknesses or maintenance constraints!

CAVEATS

Two caveats were made at the end of the previous paper, and still hold unchanged:

« First, hitting a rock at speed with the keel is not the only way a grounding can happen. Another type of grounding to be feared is hitting the ground vertically in a repeated way - for instance, over a sand bank with even a minimal amount of swell. This can be extremely destructive, even to the strongest keels and hull structures. There is no way our absorber will do anything to ameliorate this situation.

Second, a grounding with the keel at high speed endangers the crew in two ways:

- if applicable, by compromising the structural integrity of the boat. This is what our absorbers seeks to minimize;
- but also, before that, by direct wounds, when the crew falls unexpectedly, if not overboard, onto whatever is there to hit a head or anything else. The absorber will do little to this. »