Keel Maintenance

Introduction

What is the last thing you look at as the boat is being lifted out of the cradle and into the water? It is the same thing that you looked at as the boat was being set into the cradle six months earlier, the keel, and that is about as much thought that we usually give it. After all for most people these are the only times that we can actually see it, I hope, without swimming.

I would like to both confess to a similar condition in my youth and tell that with a little understanding you can gain the same level of knowledge about the keel as you have for other parts of the boat such as the sails and rigging. You may not be able to do the work; I do not wish to make everyone a keel maker or a boat builder, just to offer them insight, so that you will have a better understanding of what you see know when things look right and wrong.

As a young boy I would look at this shark-fin looking thing on the bottom of the boat every year, scrape some loose paint off it and paint it again. My Dad said paint the bottom, and polish the hull, so I painted the bottom and polished the hull. What else was necessary? The keel didn't seem to change from year to year. After all it was always there, it always looked the same, it seemed fine to me.

Years later, while working at the same marina I saw the same thing every spring, well meaning, capable people trying to finish that last bit of painting before the boat was lowered in to the water, "could you just wait a minute while I finish the bottom of the keel?" seemingly ignoring or not understanding that a the very apparent open hull keel joint is not good or normal.

In this article I would like to explore the two major types or materials used in production boats, namely lead and iron. A brief outline of the production of both keels will be offered, as a starting point. From there the three major maintenance issues will be explored, keel surface concerns, keel bolt deterioration and casting deterioration. Please be aware that this article is not meant as comprehensive technical manual, only as an offering of my personal experience. I strongly encourage any one with concerns about their keel to seek out the advice of a skilled and qualified person.

The Keel

To understand the maintenance of any keel it is important to have a general understanding of the production process. This will allow you to understand where to look for concerns (in terms of yearly maintenance) and to generally know if what you are looking at is a concern as well as what caused it and how to repair it.

General Keel Production

There are two main materials used on production boats, namely cast lead and cast iron.1 Both types of keels start off from the same point, the creation of a design. From the design they then move into the production process. This process begins with

the creation of a pattern, the same way the boat starts with the plug. (This pattern can be made a number of different ways and from a number of materials; I will not go into that in this article.) The difference between lead and iron keels starts to be seen at the pattern stage. The pattern used for lead casting is generally made to be used once; it is used to produce the mold, then not used again unless the mold has to be replaced after many casting cycles. A ceramic based lead keel mold can be used up to 50 or more casting cycles2 . While the iron pattern must be more robust, it has to withstand the sand casting process many times. The casting process for an iron keel involves the packing of foundry sand in flasks and around the pattern for every keel cast. A separate sand mold must be made for each casting. This molding process puts the pattern under heavy and repeated pressure each time.

In terms of the actual casting there are process differences between iron and lead. The different processes in turn require differences in such things as the installation of the keel bolts, the condition and inspection of the bolts being a maintenance issue. Generally speaking the keel bolts in a lead keel are cast in place, while the bolts in an iron keel are drilled and tapped after casting. The actual bolt material used in each type of keel is similar. The keel bolt materials are generally 304 or 316 Grade Stainless Steel. There are many other materials available, such as Bronze, Monel, High Strength Stainless Steels, but these are the most common today.

The exception to the rule for lead keels is traditionally built wooden boats. On many wooden boats, both present and past, the keel bolts in the lead keels were and are not cast in but were installed by the boat builder after casting. After the keel is positioned under the hull the bolt holes are drilled through the floor bearers, keelson and or deadwood into the keel. The bolt or hanger is then threaded into the keel. One of the reasons this was done to ensure that the bolts and the holes in the dead wood, keelson and floor bearers all line up. I would suggest that the offer reason is that the lead casting process had not evolved to a point where it could offer the builder the dimensional accuracy that is possible today.

Keel Maintenance

The most typical maintenance concerns for both lead and iron keels are the exterior surface condition and the keel bolts. Lead and iron keels have similarities and differences in these two matters. I will deal with them in the following order.

Surface Conditions

In terms of the surface condition, both keel types can be very easily inspected for problems, such as groundings, strikes, impacts or general deterioration. The timely, (that is to say repairs carried out shortly after the flaw is found,) solutions to these concerns while being slightly different for lead and iron keels can be accomplished relatively easily with the appropriate materials and guidance. It is in the long term results of allowing and surface flaw to go un-repaired that the differences in an iron and a lead keel can be seen.

The Lead Keel

After a surface flaw is found the lead keel will generally not show any particular signs of deterioration for quite a period of time. Lead is relatively stable. Some corrosion may develop but it is generally very small amounts of trace metals that are present in the casting alloy breaking down. The trace elements would only represent perhaps 1/10% of 1% or less of the material in the casting, a very small amount. Any surface corrosion that is present can be quite quickly and easily removed with a coarse sanding. The water will tend to loosen the fairing on the keel if the surface flaw is left for a period of time. Please be aware that lead is dangerous if swallowed or in hailed; therefore always use proper protective clothing should be worn, including coveralls, goggles, gloves, work boots and most importantly a proper fitting respirator. Consult a local safety supply dealer or physician if in doubt about what to wear when you are working with lead. 3 Once the surface is prepared, the lead is clean (lead will appear as shiny silver) and it is roughened (there has to be a “tooth” or roughness on the surface of the lead to assist the fairing to adhere) the re-fairing can be done. This can be done with a range of materials, from polyester to epoxy based fillers. In outdoor applications, where the spring temperatures can fluctuate widely the faster drying polyesters are a good choice. The epoxy or vinylester based fillers are better barriers to water and water varpour but the extended curing times coupled with spring weather can lead to incomplete curing or water contamination. Paint and filler manufacturers are working on developing quick drying epoxy fillers to solve this necessary compromise. You can fair right over the prepared lead surface or if desired you can seal it with a barrier coat such as Interprotect 2000E before applying fairing. You can even apply polyester based fairing materials over the epoxy barrier coat, according to a technical advisor from Gueonge Brothers maker of West System Epoxy. I spoke to recently, something that was not done years ago. The polyester filler will bond to the epoxy sufficiently, while it is still very unwise to attempt to glass over epoxy using polyester based resin, the bond will not hold. Once the chosen materials have been applied and sanded smooth the appropriate number of coats of an epoxy barrier coat should be applied, based on the manufacturer’s recommendations. Great care should be taken to inspect the faired surface for any pin holes; these will not be filled with the barrier paint and will remain as passages for the water to the keel surface. These holes can end up wasting all of the time and money spent repairing the surface, not to mention the frustration of finding lifting filler next fall. The holes can be spot filled with the chosen filler before the barrier coat or after the first coat, using thickened barrier coat as the filler. I have never checked with paint manufacturer to see if they approve of thickening their paint but I have never seen any failures of it. After the spot filling the rest of the barrier coats build up is applied. The final set would be the application of the anti-fouling paint.

The Iron Keel

Based on irons tendency to corrode when exposed to water an iron keel with a surface flaw will begin to corrode relatively quickly. As in the case of the lead keel the water will tend to loosen the fairing on the keel. The exposure to water will lead to a cycle of fairing failing, exposing more of the iron to water and more corrosion, making the problem worse. The solution is a rather time consuming chore of either grinding or blasting the surface rust off the casting leaving a clean surface to fair to. This process is

not easy because of the hardness of the iron and the roughness of the cast surface, present in sand castings. The other difference in the repairing of the surface other then the amount of time is the use of an etching primer before the first coat of barrier and the required fairing. From here on the fairing process is the same as a lead keel or for that matter a hull.

Keel Bolt Deterioration

To return to the production process and how it reflects on the maintenance of the keel, both lead and iron, the other major concern is that of keel bolt damage or deterioration due to water. In general terms as boats age, the keel bolt condition is certainly something that you want to be aware of. The result of neglect can be costly at best and potentially life threatening. The problem arrives when you want to check for the bolt corrosion. Corrosion of the keel bolts is not easy to find. The majority of the corrosion will take place on the portion of the bolt that passes through the sump or hull, out of sight and reach for you but not the water. The signs of deterioration of the keel bolts are generally the same for both lead and iron keels. There are however significant differences in the technique in repairing any concerns in iron and lead keels.

"Will my keel bolts hold?" The first and most important thing I can say at this point is, if in doubt have them checked, by a capable and qualified yard or surveyor. Please do not take it upon yourself to assume the bolts are in good condition if there are any exterior signs of a problem. The most common signs that there is some kind of a concern with the keel bolts are:
☒ Unexplained water in the bilge, reappearing over time after it was dried out. o NOTE: The water could be coming from a number of other sources that have nothing to do with the keel; they should be checked before a concern with the keel is considered. Such non keel related issues are,
☒ Rain water coming down the mast and into the bilge.
☒ A leaking deck fitting or opening port or hatch.
☒ The stuffing box leaking.
☒ A through hull or plumbing problem. Concerns that point to a keel concern.
☒ Loss keel bolt nuts.
☒ Corrosion stains around the nuts in the bilge. This maybe the result of long term water standing in the bilge, or a leak through the hull keel joint. If the above have been ruled out and water seeps in around the keel bolts there is a concern.
☒When the boat is being hauled or moved does the hull keel joint open, is water weeping from it. Signs of concern with the keel bolts
☒ The keel wiggles on the sump when the weight is off it during haul-out or launch. But the keel should not move independent of the hull or sump.
☒ Corrosion trails on the outside of the keel. Even Stainless Steel will corrode, especially in the anaerobic environment around the bolts.

Inspection Method

You may be able to see some evidence of the corrosion by removing a keel bolt and the washer or backing plate, but remember that unless you are able to retighten the nut to the required torque do not disturb it. Ask a capable yard to check under the nut and washer plate for you.

Solutions

The simplest solution to the offered list of concerns could be as simple as having the keel bolt nuts tightened again. The torque specifications for each bolt should be available from the builder. The concern that we make boat owners and yards aware of is, if see the any of the above conditions even doing something as seemingly simple as retightening a nut the keel bolt might break off or might start it to spin in the casting, (that would be our friend Murphy again.) Therefore if there are any visual signs of further damage, be aware this might only be the start of the repair. Before you put a wrench on the nuts it is a very good practice to ask an experienced and qualified person to see if it will solve the problem or make it worse. As a boat builder I was always nervous about putting a wrench on a keel bolt. It was only done after the bolts and boat were checked carefully for warning signs of failure.

(We, at MarsKeel have been asked many times for this information, all we can offer is general numbers, we always strongly suggest getting hold of the after market division of your boats manufacturer for the specific torque settings.)

For both lead and iron keels if there are sufficient signs of concern as listed above, a more comprehensive inspection may be warranted. This usually means that the keel has to be loosened and lowered for a further visual inspection. This will cost additional labour and possible equipment time, travel lift usage. If the keel is truly in distress, loss, (once the keel is stabilized in a brace, the nuts removed and the boat lifted) the keel will drop right down with little effort and the inspection and a repair process can start. Otherwise the removal work could take a day or more and a lot of blood sweat and tears. When I worked at C&C Yachts in Niagara-on-the-Lake I saw a keel being replaced on the shop floor, it took two men working carefully but hard and steadily 8 hours to get a keel on a new C&C 37 to move. The best out come is that the bolts are found to be in good condition and the keel can be re-bedded and tightened into place. In a matter of a day or so your boat is back in one piece with a newly sealed hull keel joint.

If you have an iron keel and a bolt is found to be loss or corroded and requires replacement, it requires great care and skill, nothing that should be attempted by the owner. The bolt or bolts in question might turn out, but probably will not; you know Murphy's Law will bite us here. The replacement process should be done by a skilled and qualified person, meaning very likely that the old suds will have to be milled out, requiring a machine shop. The shop should also check the condition of the threads in the casting to ensure that they can hold the required load. Once all it found or made satisfactory a new stud is installed and the keel can be reinstalled on the boat.

In the case of a lead keel MarsKeel can assist you. We have the ability to replace the completely the corroded keel bolt in the existing keel casting. I do not suggest that either a yard or an owner attempt this repair. If it goes wrong tremendous damage can be done to the keel, or worse a complete refusing is not done weakening the keel. A brief outline of the repair procedure is,

- The keel is removed from the boat, and sent to MarsKeel. This done for a number of reasons other then sending it to us. 1. To protect the rest of the boat from the heat of melting lead, the amount of heat required would very likely burn the sump of the boat. 2. For safety reasons, the act of removing the keel bolts makes the boat unable to balance the keel in the vertical position. 3. Environmental precautions, we have all the required procedures in place to deal with the use of lead, most yards do not. 4. Access to the bolts, the repair procedure, removal and replacement, requires that the keel be sitting horizontally.
- The existing keel bolts are removed from the keel.
- A new keel bolt is fabricated. 1. The keel bolt may be simply “j” hooked, or have a nut and washer welded to its end, or the bolts maybe originally caged together. Whatever the circumstances it will be duplicated for the new keel bolt.
- The new bolt(s) are fitted into the casting in the same place as the old one. This is possible because during the removal process undisturbed portion of the lead creates a saddle to hold the new bolt.
- New lead is refused over the new bolt, locking it into the keel. This is a very important and difficult step, the ability to refuse lead without destroying the keel.
- The entire keel, both sides is re-faired, and coated with the required number of coats of epoxy barrier coat. The root cord is checked and the keel is prepared for re-installation on the boat.

The repaired keel will be as good or better then it was originally. The benefits of this style of keel bolt replacement are,

1. There is on need for a new keel. Very important because many of the older keel molds and even the drawings of the keels have been long since destroyed, making production of a replacement keel as expensive as a fully custom keel. A price that is usually too high for older boats.
2. The replaced keel bolt will be as strong and secure as the original.
3. The keel bolt material can be up graded to a better Stainless Steel
4. Any unseen bolt deterioration is removed.

I have heard of other fixes for damaged keel bolts, with the keel left on the boat and additional holes are drilled through the glass into the lead and a new stud is then installed. I would not recommend it for anything other then an emergency fit to get you to a yard that can repair the keel properly.

Casting Deterioration

The consequence of not dealing effectively with a keel bolt issue can lead to casting failure. This is a long and almost undetectable problem, until it is almost too late.

The cause is water and the winter freeze that the boaters in Northern climates deal with every year. We winterize our on board systems, the engine, the water systems etc. but we can't winterize the keel. What happens is that over time if the hull keel joint is opened water will find its way to the keel bolts. You can see the water weeping out of the joint as the boat sits in the slings after being hauled or after it is set in the cradle or stands. Once the water has access to the bolts it will begin the corrosion but it will also begin working its way down the bolt. With each freeze cycle the now trapped water pushes on the casting from the inside. Not unlike water pushing out frost plugs on an engine block. After time this action weakens the connection between the casting and the keel bolt. In a lead casting the result can be seen as a swelling in the keel surface, the lead is being pushed out by the water, ice. In an iron keel I have never seen the same kind of swelling; it shows as a crack in the casting, and a rust line. The end result of this can be the keel bolts are loose or start to spin when they are tightened. The good news is that if it is found early enough or if the damage is not too great the bolt can be replaced and the keel repaired.

Summary

Keel maintenance is like any other maintenance on the boat, it is a matter of keeping an eye out for any tell tail signs of water, or corrosion or wear. If you can stay ahead of it, it is extremely unlikely that major maintenance concerns will arise. My hope is that you will better understand potential keel concerns and what it generally takes to fix them. If nothing else I hope that this article has motivated discussion, the generation of timely awareness is a good thing.

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