



Story And Photography By Steve D'Antonio

# SHAFT

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It's a subject that gets far too little attention: alignment of a vessel's running gear, the propeller shaft, bearings, and engine. Yet, all too often I encounter poorly aligned shafts on both new and used vessels alike. Having inspected and/or supervised the correction of many such shafts, I have a few ideas on how and why this occurs and how new installations and repairs should be carried out.

While it encompasses all running gear components—from motor mounts to cutless bearings—from this point forward I'll refer to the process simply as shaft alignment. Insult is added to injury by the fact that shaft misalignment is insidious; contrary to popular belief it doesn't always offer up clues, at least not obvious ones. Indeed, vibration can be an indicator of shaft misalignment; however, I've sea-trialed many vessels that ran smooth and vibration-free only to learn upon haulout that the running gear was seriously misaligned, so much so in some cases that I was unable to turn the propeller and shaft even when applying 145 pounds to the effort. I know that I applied precisely this much effort because my feet were off the ground. I've encountered folks in the industry who write this off with responses such as "dry bearings" or "all boats are like this when hauled, it's different when they are in the water." Nothing could be further from the truth. Rest assured, with "wet" bearings (they can be lubricated with diluted dish detergent, but never oil or petroleum-based lubricants) shafts should turn with no more effort than one would use to lift a carry-on suitcase and in some cases, just fingertip pressure.

Why is misalignment an issue if the symptoms are often so subtle? Shaft misalignment causes increased wear to both shafts and cutless bearings and it may also lead to wear of other components, components that are neither designed to support nor make contact with the rotating shaft. The primary area of unintentional contact affected by misalignment is the shaft log, the tube through which the shaft passes as it exits the vessel. This drag increases fuel consumption and damages both shaft and log. In a few cases it may lead to vibration, although that's not necessarily a given.

## ALIGNMENT 101

Some have accused me of being fixated with shaft alignment, or at least proper shaft alignment, saying that I take it to an extreme. I categorically reject that notion. Fixation doesn't begin to describe how frequently I think, write, and sometimes dream about this aspect of boatbuilding and repair. Obsession is a more apt description. I spent a good part of my professional career studying and honing my understanding of this skill. Thus, when I received an email from Chris Brown, shaft alignment specialist and proprietor of appropriately named Straight Line Marine in Ft. Lauderdale, I immediately recognized in him a kindred spirit. His note was in response to a column I'd written regarding propeller nuts and the order of their installation, a suitably esoteric subject that signaled to me that this guy was not only a detail-oriented gearhead, he walked the walk when it came to running gear. It didn't take long for the dialog to progress to an invitation for a tour of his shop, which I readily accepted. Straight Line Marine, also known as High Seas Yacht Service, is located at Lauderdale Marine Center. I



# ALIGNMENT



**&** Straight Line  
**MARINE**



Chris Brown, Straight Line proprietor, started life working in the marine industry, then took a turn toward corporate America. Now he's back and clearly enjoying every minute.

was able to break away from the Ft. Lauderdale Trawler Fest last January and spend a few enjoyable hours with Chris, meeting his crew, and talking shop, shafts, and the marine industry.

Before detailing that experience, a primer on the subject may help you to fully appreciate Straight Line's efforts and accomplishments. There are essentially two types of alignment, that of the engine to the shaft and that of the shaft to its supporting bearings. In the former case, the engine is jacked or shifted to align the transmission's output coupling flange with the propeller shaft's flange. The goal is to ensure that the two couplings are centered on each other and parallel to within a few thousandths of an inch. Depending on the diameter of the couplings, the goal is usually somewhere between .003 and .007 of an inch. By comparison, United States paper currency is about .004 of an inch thick. Savvy alignment technicians pride themselves on their ability to adjust this gap to the lowest possible figure.

Raising and lowering the engine to bring the flange faces into *vertical* parallel, is accomplished by turning the jacking nuts on the motor mounts. To close the gap at the 12 o'clock position on the coupling, for example, the forward end of the engine might be raised or the aft end lowered, while maintaining center orientation between the couplings. That can be tricky, but it gets better. The range of motion is limited to an inch or two at the most so the onus is on the boatbuilder to get the initial engine bed set-up very close. If the range of motion of the mounts is inadequate, shims are added to raise them. If the engine needs to be lowered beyond the mounts' lowest adjustment, this can often only be achieved by cutting or modifying the engine beds or stringers. If the builder did his or her job, this should

never be necessary. Motor mount adjustment should be considered fine-tuning to be sure.

Adjusting the engine laterally to achieve acceptable gaps on the port and starboard side of the coupling faces can be a bit more challenging; it requires pushing the engine from side to side, often with the assistance of a hydraulic jack. Conducting this sort of alignment can be a bit of a brainteaser. For instance, to close a gap at the 2 o'clock position on the coupling faces, the front of the engine may have to be raised and moved to the left, while reducing a gap at the 6 o'clock position could require lowering of the front of the engine, raising the rear of the engine, or varying degrees of both. However, as tricky as this all may sound, it should be well within the capabilities of any experienced marine mechanic and it typically doesn't require anything more than common wrenches, a lever bar, and/or a hydraulic jack kit.

The other type of alignment, the shaft to its bearings, is an entirely different matter. Once installed, a shaft's support bearings are not designed to be easily moved or adjusted. Boatbuilders should be getting this right from the start. Unfortunately, that's not always the case. Sometimes, those carrying out running gear repairs lack the skill or experience to ensure proper shaft alignment and it can spell costly trouble for the boat owner.

If shaft alignment is suspect, clues may include pinched cutless bearings, prematurely worn shafts and bearings, or evidence of shaft contact with the shaft log, as well as vibration. The first step in correcting any of these problems is an accurate and quantifiable assessment. The traditional approach involved removing the shaft and then utilizing a length of piano wire passed through the bearings up to the transmission. Pulled taut, the wire simulated the shaft's centerline and formed a reference point against which measurements could be taken using a caliper. It works; however, it's primitive and for lengths over about 12 feet, the sag in the wire, no matter how tightly it's stretched, induces some error.

An alternative to the piano wire, and one I've used for much of my career, utilizes a laser and targets that are placed in cutless bearings and at the transmission flange. This next generation of alignment is not only significantly more accurate, it also makes life much easier on those making adjustments. Then, there's optical alignment, the approach Straight Line has used for many years. Its accuracy and the advantages it affords technicians, not to mention customers who benefit from it, is an order of magnitude beyond the laser. We'll come back to that process shortly.

Once the state of the bearings' positions has been assessed, correction isn't easy; however, it's straightforward enough. Bearings and/or their supports, struts, or shaft logs, are unshipped from the hull and shifted into a position that brings them, ideally, into perfect alignment with the centerline of the shaft when



it's re-installed. Typically, struts are "mushed" into a thickened epoxy mixture and supported in place until cured, forming a custom fit and sturdy foundation. Shaft logs can be more challenging, as many are an integral part of the hull, meaning their removal can require significant surgery. Yet, I've never encountered one that couldn't be moved provided the necessary skill, experience, time, and funds were available.

Regrettably, few yards are adept at the assessment process and fewer still are capable of carrying out the realignment of bearings, struts, or shaft logs. For over a decade I managed a yard that specialized in this sort of work, and because shaft alignment issues are so common, there was no shortage of customers. The folks who carried out this work, including those I worked with—you know who you are—deserve credit. It requires skill and familiarity with a variety of tools, from feeler gauges, dial indicators, and calipers to lasers or optical sights, not to mention hefting into place struts that can weigh 50 pounds or more, with precision that's measured in thousandths of an inch. To those who do it well, my hat's off to them. Because of this familiarity with and appreciation for the process, I was intrigued by Chris' offer and was intent on making the visit.

### FROM SAILING, BOATBUILDING, AND CORPORATE AMERICA TO SHAFT ALIGNMENT

As Chris escorted me into Straight Line's shop I felt very much at home, it had all the requisite sights, sounds, and smells of a busy shaft and machine shop—a huge lathe with a large shaft "chucked up," the hum of operating machinery, and the unmistakable aroma of cutting oil. I glanced at the wall and there were a number of technical articles and bulletins posted, primarily for visiting customers and vessel captains (the latter can be a tough sell on "new" techniques), including one on the subject of—you guessed it—propeller nut installation. I smiled when I saw this because it indicated to me that Chris Brown understood one of the most essential aspects of this business: Knowledge and its dissemination to those making decisions about vessel upkeep and repair is critical to ensuring that vessels are seaworthy, safe, and reliable.

High Seas Yacht Service started life in the 1980s as a mobile marine repair service, sending trucks and crews out around the Ft. Lauderdale area, to both boatyards and residences, where they carried out all manner of routine service and repair work. In the late 1990s, capitalizing on a need and the skills of its crew, and filling a hitherto vacant niche, High Seas became running gear-exclusive. Straight Line came into being in 2003, the name being chosen to highlight these capabilities.

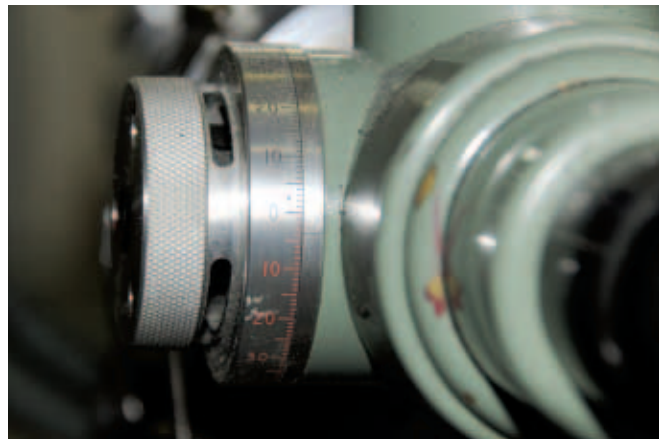
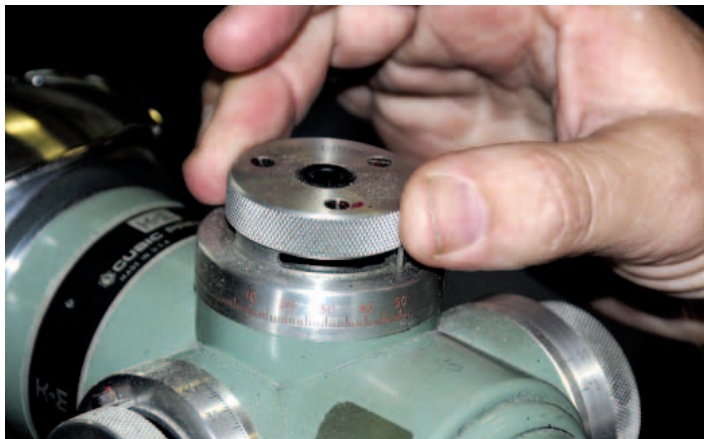
Although I never would have known it until he revealed it to me, Chris only purchased the business three years ago. He projects an air of confidence and



Top: Machinist Chris Zylka prepares to check the run-out on a shaft coupling extension. Above: A pneumatic jack used to support shafts as they are measured and straightened.

expertise that belies his short time as the CEO. What he lacks in longevity on *this* job, however, he more than makes up for in enthusiasm and a thorough understanding of the work the company does. While he's extremely modest and is quick to point to the skills of his crew as the business's strength, some of whom have been with the company for over a decade or more, Chris quickly and accurately answered a variety of serious technical questions I posed in rapid-fire succession, as well as a score of questions I emailed him in preparation for this article. In short, he knows running gear and alignment intimately.

Growing up in South Florida, Chris was quickly drawn into the world of boating and the marine industry, mostly on the sailing side of the aisle. Shortly after college he took his first boatyard job, as a fiberglass repair apprentice (in other words, this was boot camp and he was a boot). As he tells it, on his first day he was handed a grinder and a dust mask and ushered toward



Optical sighting raises running gear alignment to a level hitherto unachievable. The tools of the trade, seen here, are high-quality optics used in surveying and industrial applications. Micrometer adjustments make it possible to “dial in” a shaft to within just a few thousandths of an inch.

a boat at \$3.50 an hour. As an industry insider, I can say this is a test of a young person’s resolve, one I’ve used on more than a few occasions: *“So, you have this dream about working around boats? OK, here’s a long board, go make that wavy hull fair and don’t come back until it’s done.”* I’ve seen many of these kids go to lunch on the first day and never come back. Chris wasn’t one of them. He rose to the occasion and ultimately gravitated toward building and sailing ultralight offshore racing sailboats. He then worked as a yard manager for a few years, further broadening his industry horizons.

In the late 1980s he took advantage of an opportunity that transported him from one extreme to the other, leaving boats behind to become a corporate warrior practicing product development, sales, marketing, and strategic business planning, all of which were heavily focused on customer support. The position offered a superb on-the-job business education and a chance to globe-trot. And that’s what Chris did for the next 25 years. As gratifying as the work was, he found himself longing to own his own business and



return to his roots as it were, in the marine industry in South Florida. He found High Seas, or it found him, via a business broker on the very day it went up for sale. Some would say that’s fate, perhaps, along with some good fortune and a solid grounding in the trade. Savvy people tend to be in the right place at the right time to take advantage of opportunities. Whatever you call it, the fit seems like a natural one. You see, my research for this article involved working with Chris in a business capacity, helping solve a persistent vibration issue aboard one of my clients’ vessels. It involved reviewing running gear that had been gone over by a number of other folks on multiple occasions



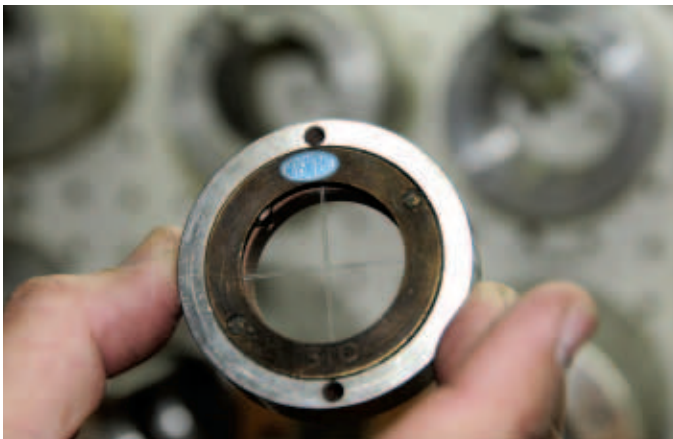
with a variety of “fixes” being carried out, none of which had a meaningful effect. Needless to say, Chris and his crew nailed it once they got their hands on the running gear, quickly discovering a serious, inherent manufacturing flaw.

### SHOP TALK

We walked to the back of the shop, to what I call the tool crib, where Chris showed me Straight Line’s primary weapon in the war against misalignment, a series of precision optical scopes. Traditionally, these scopes are used for land surveying, in the industrial world for setting up alignment on equipment, and even

large gaps in the world of shaft alignment) are possible. An optical alignment will get within .003 to .005 of an inch. Lasers also require careful handling to avoid eye damage. While I still believe lasers are an effective alignment tool, especially for shorter shaft lengths, and considering their return on investment (they are comparatively inexpensive), that explanation made the advantages of optical alignment crystal clear. Now, I wanted to see it in action.

There wasn’t a scope set up on a boat in the yard at the moment, so Chris’ crew set up a demonstration for me in the shop. After peering through the scope and seeing just how sharp it was,



Left: The target for optical sighting, note the cross hairs. Right: Lasers like this are used for determining how much a vessel’s hull moves, and accounting for it, during the hauling process.

inside very large ships’ engines. They are essentially telescoped with a set of cross hairs—similar to a rifle scope. Optical targets are 2-inch diameter pieces of glass with micro-line cross hairs in the center. In the hands of a seasoned professional, the optical scope can deliver accuracy that is simply sublime (if you are an alignment junkie like me, that is).

Many folks, myself included up to this point, have the impression that a laser is, well, a laser beam. It’s precise, as in laser precision (you don’t hear folks say, “It has optical precision.”) I posed the question, “Why is optical better than a laser, the latter being my alignment tool of choice?” Chris was quick to give lasers their due, but he pointed out several advantages to using an optical scope over a laser, explaining, “A laser alignment system uses similar principals—optical targets creating a line; however, the level of accuracy is lower. A laser spot is projected onto a target or surface like a transmission flange center fastener. In larger yachts the stretch distance between laser and optic may be 20 feet or more, which creates a laser spot up to 1/8-inch in size. The human eye struggles to see the center of a dancing laser spot. As a result, error rates of .050 to .100 of an inch (comparatively

and how I could focus on different targets up the scope’s line of sight (each target representing a bearing location, you can’t do that with a laser), I was sold. This is the ultimate in assessing the precision of a running gear installation. Of course there’s more to it than this. You can read the description of the process in its entirety on Straight Line’s website at <http://highseasyachtservice.com/technical-articles/optical-scope-alignment-the-basics>.

Interestingly, there’s still a place for lasers at Straight Line in running gear alignment. When a vessel is hauled, particularly a fiberglass or wooden one, it distorts. It’s a natural state of affairs and it doesn’t *necessarily* mean there’s anything wrong with it. The problem is that it’s nearly impossible to haul and block a boat and know whether it has hogged (the bow and stern are drooping) or sagged (the center of the hull is sagging). In either case, if the alignment is carried out with the vessel in a shape that it won’t be in when launched, then the alignment, no matter how precise, will be flawed. That’s where a trio of lasers comes in. Chris’ team can “deck sight” a boat using lasers that enable them to reproduce the floating shape of the vessel when it’s blocked.



## STRAIGHT LINE DOES NOT LIVE BY ALIGNMENT ALONE

At this point, you might believe that all Straight Line does is check shaft alignment, and you'd be forgiven for coming to this conclusion because I've yet to mention their other specialties. In addition to carrying out alignments, the folks at Straight Line also remove, install, and lap props; repair and replace stabilizer fin bearings and seals; replace and balance motor mounts (did you know motor mount loads need to be balanced?); and install and service torsional dampeners.

In addition to their crack optical alignment crew, Straight Line has an equally crack machine shop crew. These two aspects of the program are more than symbiotic; one cannot survive without the other. No matter how well aligned a shaft may be with its bearings, if the manner in which the shaft mates to the engine is flawed in any way, the shaft and engine as a unit will not yield the ultra-precision that is necessary and the standard for Straight Line. Toward that end, the machine shop's repertoire includes shaft straightening for those up to 6 inches diameter and 35 feet long; coupling repair and fabrication; cutting of shaft tapers, coupling bores, and keyways (keyways cut by Straight Line on all shafts over 2 inches include a stress dissipating "spoon" design); coupling pilot repair and replacement (this is an often overlooked aspect

Top left: Spooned keyways are designed to distribute loads and minimize stress risers. Left: The burnishing indicates that this propeller shaft taper has been lapped. Lapping provides a customized fit between a propeller or coupling and shaft. Above: Chris Brown holds cutless bearing mandrels used to support bearings while they are machined.

of alignment, the fit of the shaft coupling's recess to the transmission coupling's protrusion); and strut and rudder repair.

While in the tool crib I noticed a series of curious-looking mandrels, so I inquired as to their purpose. "Those are cutless bearing jigs." Huh, what are they used for? Cutless bearings are typically made up of a metallic shell and rubber-like liner. The shell slides into a strut or shaft log bore with just a little effort, what's referred to as a light interference fit. In practice, however, this often isn't the case, one or the other needs to be cut or modified. That in and of itself isn't groundbreaking technology, when the bearing shell is designated as the one to be cut, it's placed in a lathe and some of its material, usually on the order of a few thousandths of an inch, is removed. However, if the bearing is chucked into the lathe without any support, it can distort. The cutting will often compensate for the distortion, making the shell perfectly round once again, until it's removed from the chuck, whereupon it will often be oval-shaped. The jig supports the bearing and prevents it from distorting during this process. That represents fine attention to detail.

## DETAILS, DETAILS

A few of the small, yet valuable, touches I noted while poking around the shop spoke volumes about




Straight Line's commitment to excellence. They include lapping couplings to shafts, dry fitting complete shaft assemblies in the shop for precision, checking and then stamping the parts to ensure that they are reassembled in precisely the same orientation, and the use of torque wrenches and grade 8 fasteners, where called for, for all running gear assemblies.

When I nodded approvingly at the mention of the torque wrench, Chris intoned, "We always use torque wrenches and thread locking compound, even on cutless bearing set screws. If you overtighten those, the shafts will sing." In fact, they go so far as to dimple the cutless bearing shell where the set screw lands, to reduce the pressure that's necessary. Loose or loosening fasteners simply aren't tolerated in this shop. It's the machinists' equivalent of the Bushido Code—all fasteners shall remain as they were installed, period. Finally, sea trials are mandatory for all Straight Line completed projects.

Next, Chris took me on a whirlwind tour of some of the projects they were currently working on, from classic wooden commuters and sailing catamarans to modern, super yachts and trawlers. Chris commented that 20 percent of Straight Line's work is on new boats. With the yard tour finished, it was time for me to leave Straight Line. It was an enjoyable and enlightening

sojourn through the world of precision running gear repair. As I was preparing this article and peppering Chris with still more questions, he excitedly shared with me a new graphic representation program he developed for detailing and recording the alignment and measurements on any boat. The visual nature resonated with me and I voiced my approval. He also indicated that he was very close to obtaining ABS approval for shaft weld repairs. The standard is quite rigorous; however, he's confident his team has the requisite skill set to meet the requirements.

As I mentioned at the outset of this article, alignment is often overlooked or simply given cursory attention at best. The next time your vessel is hauled, have a close look at the shaft and bearings. Turn the shaft, if you can. If your feet come off the ground, well, you know the rest of the story. If you find you have a persistent running gear or vibration problem that no one else seems to be able to figure out, consider giving the folks at Straight Line Marine a call. I suspect there isn't too much they haven't seen, or fixed, when it comes to running gear. 

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*Steve owns and operates Steve D'Antonio Marine Consulting ([www.stevedmarine.com](http://www.stevedmarine.com)), providing consulting services to boat buyers, owners, and the marine industry.*



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