INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

Propelling the boating world

The propeller shaft may be the most important component of any motorized vessel. It drives the propeller, hour after hour, day after day. Molybdenum provides improved strength and corrosion resistance in several high-performance stainless steel grades used in demanding shaft applications.

The propeller shaft is a critical component of any motorized vessel. It must withstand high stresses when transmitting the motor's power to the propeller, as well as any impact should the propeller strike an object. It must also resist corrosion in marine environments. Today's vessels use a variety of highly sophisticated propulsion systems and a range of advanced shaft materials, depending on the vessel's operating conditions. Stainless steels are the most common shaft materials, available in several grades.

Shaft design

The primary considerations in shaft design are the selection of the correct shaft diameter and shaft material, given the power of the vessel and the rotational speed of the shaft. The shafts of large, slow-moving cargo vessels turn at only a few hundred revolutions per minute (rpm) but the motors are very powerful so they need shafts up to 1 meter in diameter. At the other end of the range, small fishing boats with electric motors may have a shaft of only 1 centimeter in diameter. For fast patrol boats or yachts, where shafts turn at several thousand rpm, larger diameters are necessary. Suppliers to the pleasure-boat and workboat industries commonly stock sizes in the range of 2 to 18 centimeters.

Manufacturing

Good shaft performance requires precision and attention to detail during manufacturing. Fatigue resistance is of primary importance. This requires good straightness to minimize vibrational stresses and defect-free surfaces to minimize stress concentrations. The steel mill must deliver a shaft to the fabricator that not only is straight but also low in residual stresses that might otherwise cause the shaft to change shape during machining. Fabricators must produce good roundness, a precise diameter and taper for mounting the propeller, and keyways free of sharp corners which increase stresses. The finished shaft must have low residual stresses. Only such a shaft can withstand fatigue over the many hours of cyclic stress during its life.

Material choices

Common shaft materials range from carbon steels to very high-performance molybdenum-containing stainless steels. Each material serves specific needs over the broad spectrum of boating applications.

The waters where the vessel operates and the vessel's pattern of use play an important role in specifying a shaft material. Carbon steel shafts, fitted with sleeves and frequently covered in fiberglass to protect them from corrosion, are routinely used in large ocean-crossing vessels because they are cost effective and size, weight and agility are less important. On the other side of the range, sporty pleasure yachts, which can be docked for long periods of time in corrosive, polluted waters, require high-strength shafts with maximum corrosion resistance, i.e. molybdenum-containing duplex or austenitic stainless steels. Thanks to their high strength, these steels permit reductions of shaft, support, and seal dimensions that simultaneously reduce weight and drag, improving vessel performance and efficiency. It is important to note, that despite their good corrosion resistance, most of these grades are not sufficiently resistant to seawater, so they need to be cathodically protected with sacrificial anodes.

The fabrication of boat shafts requires large, sophisticated machinery to maintain the tight tolerances necessary. © Schaffran Propeller + Service GmbH

Duplex stainless steels, like the workhorse 2205 grade containing 3% molybdenum, not only deliver high strength and corrosion resistance, they also resist abrasion and erosion at high flow rates. Because of these advantages, European companies increasingly select duplex stainless steel propeller shafts and almost every commercial and pleasure boat built in Australia uses them. Duplex grades are particularly useful where high acceleration and heavy-duty operation is expected, such as in coast guard vessels and mega yachts. ›

The “Richard Dixon” is from the latest model series of fast response cutters operated by the US Coast Guard. Each boat uses two large alloy 22 propeller shafts. © US Coast Guard, Mark Bamey

Typical properties of steel and stainless steel boat shafting alloys

Name	1018 Steel	Type 316	Alloy 2205	Alloy 2507	Alloy 19	Alloy 22	Alloy 17-4PH
Type	Carbon Steel	Austenitic	Duplex	Duplex	Austenitic	Austenitic	Martensitic
Typical yield strength (MPa)	220	290	500	550	860	860	860
Cr	–	16.0–18.0	22.0–23.0	24.0–26.0	18.0–20.0	20.5–23.5	15.0–17.5
Ni	–	10.0–14.0	4.5–6.5	6.0–8.0	8–10.5	11.5–13.5	3.0–5.0
Mo	–	2.0–3.0	3.0–3.5	3.0–5.0	–	1.5–3.0	–
N	–	–	0.14–0.20	0.24–0.32	0.20–0.30	0.20–0.40	–
Toughness	moderate	good	moderate	moderate	good	good	moderate
Corrosion resistance	low	moderate	good	excellent	moderate	good	minimal
Cost	low	moderate	moderate	high	moderate	high	moderate
Typical application	Ships and large commercial boats; shafts require protective sleeves	General purpose, light duty, brackish and fresh waters	Pleasure boats, premium and large yacht applications, commercial and workboats	High-end luxury yachts	General purpose yacht applications	Premium and large yacht applications, commercial and workboats	Commercial boats and wetted shafts in outboard and stern drive applications

When low drag is important, higher strength nitrogen-alloyed austenitic grades, such as alloy 22 with a minimum of 1.5% molybdenum, are used to reduce the required shaft size. One disadvantage of this material in shipbuilding is that it is very tough to machine. An alloy 22 shaft may take twice as long as the same job in duplex stainless steel. It is sometimes described as the material of choice for high-horsepower and special-purpose military vessels. North America as a whole is taking this design approach, with high-strength, austenitic grades dominating high-end and severe shaft applications.

Both types of stainless steels have very good shafting properties, so it is interesting to contemplate why usage patterns vary around the world. The key is probably availability. High-nitrogen austenitic grades were developed in North America decades ago, where they have become a de facto standard. Duplex stainless steels are generally not available from stock there. Conversely, duplex stainless steels have been developed in Europe and are to date the most popular in that region, so their availability is good and they are more dominant.

Alternate materials are available to fit specific circumstances. The molybdenum-free martensitic stainless steel 17-4PH performs well for workboats and fishing boats in corrosive bay and river waters because their near-continuous operation keeps shafts clean from fouling and they have good strength and toughness. ›

Boat shafts require precise machining of the taper where the propeller is attached.
© Clements Engineering

This work boat has two 90 millimeter diameter 2205 duplex stainless steel shafts. It is designed to bring crews to offshore wind farms. © Clements Engineering

Fresh water yachts, which are docked much of the time, require a corrosion resistant material such as molybdenum-containing Type 316 stainless steel, because deposits can build up during inactive times, leading to crevice corrosion in lower grades. In this case sacrificial anodes are not necessary.

Summary

Molybdenum plays an important role in recreational, commercial, civil and military boat and ship design by improving the strength and corrosion resistance of high-performance propeller shafts used for these vessels. Molybdenum-containing high-strength austenitic and duplex stainless steel grades deliver the strength, toughness and corrosion resistance necessary for a good propeller shaft. These alloys allow many kinds of vessels to operate efficiently, safely and reliably the world over. (Alenka Kosmac, Curtis Kovach)