Comparative properties of propeller alloys

Introduction

The requirements of a propeller material are many and vary with the size of the propeller and the type of vessel. It must be capable of being cast into a complex shape held to close tolerances, it must be strong and tough, have high resistance to corrosion and erosion. During its lifetime almost every propeller is damaged in one way or another and requires to be repaired. Good weldability without adverse side effects is, therefore, a desirable feature of a propeller material.

This paper highlights a range of propeller alloys including various properties and offers comments based on extensive knowledge and experience of Stone Marine Propulsion.

Mechanical Properties

Typical mechanical pr0perties are given in the table below a variety of materials. These values quoted relate to cast bars of relatively small section, and it should be appreciated that these properties will not necessarily be obtained in actual propellers castings. The properties of these materials in the form of propellers will vary throughout the propeller as the section thickness of the casting changes. In general, the properties of blade edges should not be greatly different from those given in the table, but in heavier sections the proof stress, tensile strength, impact value and hardness will almost certainly be less than those indicated and, in general, the heavier the propeller the lower these values will be. Proof stress and tensile strength of material from blade roots of large pr0pellers may only be 60 — 70% of the values quoted in the table.

There is a wide variety of stainless steels, but one of the most common for propellers is l3% chromium martensitic steel which depends for its properties on heat-treatment. The austenitic 18% chromium 8% nickel steel has also been used in service, but more usually for fresh water applications. The duplex ferritic austenitic stainless steel has been developed more recently and experience of this steel is limited. All the steel have high elastic modulus. The martensitic and duplex steels both have high proof stress and tensile strength, but the austenitic has lower strength; however, it has very high ductility and impact strength.

The mechanical properties of mild steel are only slightly better than those of manganese bronze, although the elastic modulus is much higher.

Grey cast iron is a weak brittle material but the austenitic cast iron has properties which are similar to manganese bronze.

The mechanical properties of plastic materials are poor when compared to metals and, in particular, their elastic moduli are very low. Fibre reinforcement may be used in the case of plastic materials but in general this, while improving the mechanical properties, is usually detrimental to the cavitation erosion resistance.

Fatigue Resistance

Fatigue strength is one of the most important properties of a propeller material, particularly when contemplating the use of propellers for high powered or fast vessels, where fluctuating stresses can be very high.

Extensive investigations of the fatigue characteristics of propeller alloys over a range of conditions have been performed by Stone Manganese Marine.

The corrosion fatigue strength is quite markedly influenced by the mass effect of the casting, and specimens taken from large marine propellers are likely to have fatigue strengths about 25% lower than those of test bar material. The endurance value is also very dependent on the operating mean stress and mean stresses of the order of 60MPa can reduce the fatigue strengths of specimens by 20% or more. The table below gives the corrosion fatigue strengths of test bar materials tested at zero mean stress. These values relate to Wohler tests at 3000rpm in 3% salt solution on 9.5mm diameter specimens. The results of individual usually show a marked degree of inconsistency, and the values given are averages.

It is emphasized that the data is for comparison purposes only and should not be used in design calculations, as tests which relate much more closely to the conditions under which propellers operate are necessary for this purpose.

Material	Stress at l0 reversals MPa
Manganese Bronze	84
Nikalium	141
Novoston	124
Superston 70	122
Martensitic Stainless steel, 77 13% chromium	77
Sonoston	73
Austenitic stainless steel. 18% chromium. nickel 10%	117
Low Carbon Steel	35

Resistance to cavitation erosion

The propeller designer strives to avoid blade forms that induce cavitation. Due to high wake variations, however, it is virtually impossible, with some types of vessels to avoid this phenomenon throughout the complete revolution of each blade, and erosion is a possible outcome. Cavitation erosion is also frequently the result of damage to the leading edge of a propeller blade.

The severity of the attack is, of course dependent on the inherent resistance of the material to such a form of attack. Cavitation of consistent intensity can be produced conveniently on the surfaces of test specimens in the laboratory by causing the Specimens to vibrate at high speed in a test liquid by means of a magnetostriction device, in this way various materials can be tested and compared at any selected intensity of cavitation. The results of a series of tests in 3% salt solution are given in the table below.

It will be seen that comparisons of conventional propeller materials offer good resistance to this type of attack.

Material	Loss rate mm^3 / hour
Nikalium	1.1
Superston seventy	1.4
Martensitic Stainless steel — 13% chromium	2.6
Austenitic Stainless steel with Molybdenum	3.0
Manganese bronze	3.2
Sonoston	5.6
Low carbon steel	7.1
Grey cast iron	15

All tests performed on a magnetostriction device operating at 20KHz and peak-to-peak vibration of 51microns, in 3% sodium chloride solution at 25°C.

Damping capacity

This property can be defined in several ways and is very dependent on stress levels. At the levels of stress which can cause vibration noise in propellers, however, the conventional materials have specific damping capacities of much less than one per cent. Flake graphite cast iron has a specific clamping capacity of about |0 per cent. Sonoston has a specific damping capacity of IE to 30 per cent.

Repair

Propellers are constantly exposed to damage, and good reparability is an essential requirement of the materials used.

Nikalium, Novoston, Superston seventy and Manganese Bronze can all be welded satisfactorily by skilled personnel using approved methods and are sufficiently malleable at moderately high temperatures to allow straightening to be carried out easily.

Sonoston propellers are not repaired so easily, and need to be dealt with by personnel who are familiar with the alloy.

Steels are relatively easy to weld and straighten, but cast irons are not.

Regardless of material, high residual stresses will be left after welding, and these can reduce the fatigue strengths of propeller blades considerably. In addition to this, the fatigue strength and corrosion resistance of the heat affected zone maybe greatly inferior to those of the original cast material. Heat treatment after welding is therefore desirable in most cases, and essential in some. Post weld heat treatment in the case of stainless steels or by straightening high at" temperatures must be employed than the copper base alloys.

The MIG or TIG processes are preferred for welding.

For best results it is strongly advised to employ the services of suitably trained and qualified engineers for the repair of propellers manufactured in any material.

Physical Properties

Material	0.2% Proof Stress Mpa	Tensile Strength Mpa	Elongation %	Modulus of elasticity Gpa	Izod Impact Value J/cm2	Brinell Hardness Number	Specific gravity
Manganese Bronze	200	510	28	107	30	145	8.2
Nikalium	270	680	27	124	34	175	7.6
Novoston	305	685	30	117	50	185	7.4
Superston Seventy	345	725	27	117	50	190	7.4
Sonoston	285	565	25	77	50	150	7.1
13% Chromium Stainless Steel	450	680	20	200	39	220	7.8
Austenitic Stainless Steel	265	565	45	195	115	130	8.0
Low Carbon Steel	250	450	26	200	42	130	7.9
Grey Cast Iron	-	235	-	105	-	200	7.1
Austenitic SG Cast Iron	235	435	42	105	47	150	7.1