NI-RESIST IRON FOR PROPELLERS

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The requirements of a propeller material vary with the size of the propeller and the type of vessel to which it is to be fitted. For a large ocean-going vessel, which is steaming for thousands of hours each year, the propeller efficiency i. e. its ability to convert engine power into useful forward thrust, is very important and to achieve a high efficiency the propeller must be machined into a complex shape held to very close dimensional tolerances. To retain these tolerances over years of service in seawater, propeller materials of high strength and corrosion resistance are used. Also, as the design and manufacture of such propellers represent a large proportion of the total cost the use of relatively expensive materials such as aluminium bronzes can readily be justified.

For smaller propellers, such as are used on inshore fishing-vessels, where the hours in service each year are relatively low, the achievement of high efficiency by a costly machining operation may not be justified and it is often possible to use the propeller in the unmachined condition. For such propellers expensive propeller alloys may not be necessary and materials such as grey cast iron and high strength brasses are commonly used. One material which has found increasing use in Europe in recent years for propellers on harbour craft, tugs and fishing vessels, is Ni-Resist iron and the purpose of this article is to discuss the merits of this material for such propellers.

Ni-Resist Irons

Ni-Resist is the name applied to a group of alloy irons to which a sufficient amount of alloying element (mainly nickel) has been added to produce an austenitic matrix. Because of the alloy content and the austenitic matrix, Ni-Resist irons exhibit much better corrosion resistance and toughness than do ordinary cast irons.

Like unalloyed cast iron the Ni-Resist irons can be made with either flake or spheroidal graphite and for propellers, the spheroidal form is normally used as this gives much improved strength and ductility. Tables 1 and 2 give the composition and properties of three types of S. G. Ni-Resist iron. For comparison the same information is included for a widely used high tensile brass propeller alloy.

An examination of the data in these tables shows that the mechanical properties of the Ni-Resist irons and high tensile brass propeller alloy are very similar and this would suggest that any one of the three irons considered could be used for propeller manufacture. However, marine propellers are always liable to be exposed to mechanical damage, for example, by striking floating objects or harbour walls, hence it is desirable to choose an alloy with good toughness, to withstand such impacts and high ductility, so that damaged blades can be straightened. For this reason, Ni-Resist Iron type D2-C is normally chosen for propeller manufacture. A propeller made in this alloy has been successfully repaired by straightening and welding after suffering severe mechanical damage in service on a fishing trawler.

Casting Properties

The complex shape required in a propeller is most economically obtained by casting. Thus any propeller material should have good casting properties.

Ni-Resist Type D2-C has good castability but its shrinkage is higher than that of ordinary grey cast iron and feeding arrangements must be adequate to produce sound castings. The contraction allowance is about $\frac{3''}{16}$ per foot (1.56 cms/metre) and wherever possible the principle of controlled directional solidification should be applied to ensure good feeding. Fortunately the shape of a propeller is ideal from this point of view and solidification is usually arranged to commence at the blade tips, progress towards the blade roots with final solidification in the propeller boss above which a large feeder head is positioned.

Corrosion Resistance

A propeller spends most of its life immersed in the sea but as it moves through the water at relatively high velocities when in use, the corrosion resistance in fast flowing, as well as in static, seawater must be considered.

The high alloy content of the Ni-Resist irons improves their corrosion resistance in seawater so that, in general, their corrosion behaviour is more akin to that of copper-base alloys than that of ordinary cast irons.

Thus an ordinary grey iron would show a corrosion rate in seawater of about 0.006 i. p. y. (0.15 mm. p. y.) whereas the value for austenitic iron would be about 0.001-0.002 i. p. y. (0.025-0.050mm. p. y.).

In flowing seawater also, the Ni-Resist irons show improved corrosion resistance over ordinary grey irons. In a test at the Harbour Island Corrosion Laboratory of International Nickel Inc., a manganese bronze alloy corresponding to the specification given in Table I showed a corrosion rate in seawater of 0.055 in/year (1.37 mm/year) at 27 f. p. s. The corresponding figure for Ni-Resist Type D2-C was 0.024 in/year (0.50 mm/year) and for ordinary grey iron 0.176 in/year (4.4 mm/year). Thus Ni-Resist Type D2-C could be expected to perform at least as well as high tensile brass and much better than grey cast iron in propeller applications.

Special Corrosion Considerations

Grey cast iron is prone to graphitisation when subjected to corrosion in seawater, particularly if it is warm. This type of attack may leave the alloy with an uncorroded appearance but scraping the affected area with a knife will reveal that the iron has been changed to a fairly soft corrosion product which consists mainly of graphite, silica and iron oxides. The rate of attack in the affected area may be many times higher than the corrosion rate normally observed on cast iron in seawater. Ni-Resist irons do not form this graphitic layer to the same extent, because of their inherent corrosion resistance, and even when coupled to samples of iron covered with a graphitic layer the corrosion of the Ni-Resist is not accelerated.

Graphitisation is akin to dezincification, a form of selective attack to which copper-zinc alloys are prone. The manganese bronze alloys used for propellers may suffer from dezincification and blades have been known to fail from this cause.

Stress corrosion

Some copper-base propeller alloys when stressed and exposed to seawater will crack under the conjoint action of the stress and corrosion The normal working stresses are not high enough to cause this type of cracking but residual stresses in the alloy produced by weld repairs or cold straightening to fair blades are and manganese bronze propeller alloys must be stress relieved after such processes in order to avoid stress corrosion cracking. Ni-Resist irons are not susceptible to stress corrosion cracking in seawater.

Galvanic Corrosion

The relatively high potential between bronze and steel can give rise to corrosion around the stern of a ship. The corrosion is concentrated in areas where the paint film has been damaged and usually takes the form of deep pitting. Ni-Resist irons, although they are more noble than carbon steel or ordinary grey iron are less noble than bronzes, hence when coupled to these materials the risk of severe corrosion is reduced.

Economics of Using Ni-Resist Type D2-C for Small Propellers

As the cost of the material represents only a part of the cost of a propeller, and as variations in the price of copper over the last few years have been large and frequent, it is not possible to give any precise price reduction for a Ni-Resist propeller compared with a bronze one. However, the main reason for the use of Ni-Resist propellers in Europe is their lower cost together with the fact that the price of Ni-Resist has been much more stable than that of bronze. The current world shortage of nickel has limited extensive use of Ni-Resist for propellers and this might prove to be a limitation in India also. However, this shortage is likely to be only temporary so that an increased usage of Ni-Resist for propellers will be seen over the next few years. The maximum size made so far is 2½ tons finished weight but at least one manufacturer is offering to supply propellers up to 10 tons weight.

TABLE I

	S. G. Ni-Resist Irons			High Tensile Brass	
	Type D-2 Aus 202-A	Type D-2B Aus 202-B	Type D-2C Aus 203	BSS 1400 HTB 1-C	
Carbon	3.00% Max	3.00% Max	2.90% Max	Cu	55% Min
Silicon	1.75-3.00%	1.75-3.00%	2.0-3.0%	Zinc	Remainder
Manganese	0.7-1.0%	0.70-1.00%	1.8-2.4%	Iron	0.50-2.0%
Phosphorus	0.08% Max	0.08% Max	0.08% Max	Manganese	3.0% Max
Nickel	18.0-22.0%	18.0-22.0%	21.0-24.0%	Tin	1.5% Max
Chromium	1.74-2.50%	2.75-4.0%	0.50% Max	Aluminium	2.5% Max

TABLE II

	Type D-2 Aus 202-A	Type D-2B Aus 202-B	Type D-2C Aus 203	BSS 1400 HTB 1-C
U. T. S.	24–30	26–31	24–29	30.0 min^{m}
Tons p. s. i. (Kg/sq mm)	(38–47)	(41–49)	(38–46)	(47.2)
0.2% Proof Stress	14–16	14.5–16.5	13.5–15.5	12.0 min^{m}
Tons p. s. i. (Kg/sq mm)	(22–25)	(23–26)	(21–24)	(19.0)
Elongation % on 2″	8–20	7–15	20–40	20% min^{m}
Specific Gravity	7.41	7.45	7.41	8.25
Modulus of Elasticity	16.5–18.5	16.5–19	15	15.5
lbs/sq in x 10^6 (Kg/sq mm x 10^3)	(11.6–13.0)	(11.6–13.4)	(10.5)	(11.0)
Charpy V-Notch	12.0	10.0	28.0	18.0
At Room Temperature				
ft. lbf. (Kg metres/sq cm)	(2.075)	(1.73)	(4.84)	(3.1)