Correspondence - Propulsors

QE class propeller & rudder design

Warship Technology has received the following letter from Dr Graham Patience, Managing Director of Stone Marine Propulsion, regarding the article in the October 2009 issue of *Warship Technology* 'Propeller and rudder designs for the QE class carriers' and the use on the Queen Elizabeth (QE) class of built-up propellers.

Sir,

I have read with some interest the feature in the October edition on the propeller and rudder design for the QE class carriers, which I understand to be based upon a paper presented at the June 2009 Warship Conference in the UK.

My interest is in the fact that, like the Type 45 propellers, the new aircraft carrier is to be fitted with built-up propellers. This is a subject upon which I have previously expressed my views and my opinion has not changed. If anything, it has hardened. The utilisation of this out-dated concept on what will be the future capital ships of the Royal Navy appears to confirm that the Navy is condemned to this type of propulsion for the foreseeable future – a prospect which no doubt will be viewed with some commercial satisfaction by those who promote it, but not by any self-respecting propeller specialist.

We have already been subjected to the unconvincing justification of built-up propellers as reducing through-life costs, despite the necessity for continuous and regular monitoring – inspection and replacement – of blades, hubs, holes and bolts, all of which add risk and cost to what should be kept as a simple product. But the subject article goes even further, making some effort to justify the adoption of built-up propellers on the grounds of slotting, pitch compensation, manufacturing accuracy and the adoption of stainless steels – none of which stand up to proper scrutiny.

As a critical component of any ship, the propeller has to convert propulsive power into thrust to provide the required mobility. In doing so it is subject to cyclic forces and hence susceptible to fatigue. It has to withstand erosive and corrosive attack; operate for 24 hours a day as required; occupies a vulnerable position and because of difficulty of access, it is subject to long intervals between servicing. Yet it is expected to operate efficiently and reliably with acceptable noise and vibration properties. The practical engineering approach to these conflicting requirements must be the knowledgeable application of simplicity – not to unnecessarily complicate the issue with an increasing number of smaller components and over-sophisticated attachment systems. Such a concept appears even more essential for the military configuration unless there are quite clear military advantages to be gained – which for built-up propellers there are not.

In reading the paper I was immediately struck by the comparison between military and commercial design practices. The authors point out that the operating requirements for the new carriers result in a design that must be recognised as challenging. For a military application this may indeed be the case but they fail to point out that in the commercial world, such challenges have become commonplace. So much so that the commercial designer now copes with single-shaft transmissions of up to 80MW – twice the level the authors find challenging – and has in fact provided solutions for this power level that have proven eminently successful in service.

The modern large containership is rarely configured with a shaft power as low as the 40MW of the new carriers and, whilst commercial design objectives do not place as high an emphasis on cavitation inception as in the military world, the requirements for acceptable cavitation and excitation behaviour at the highest efficiency are no less stringent.

The commercial design problem is exacerbated by the fact that the ships are single screw – the propeller does not enjoy the predominantly uniform open water characteristics of twin-screw flow. It has to operate within the boundary layer of the hull with its far greater variations in wake. The reader may draw his own conclusions as to which is the more challenging design case.

But what really struck me was the comparison to be made between the new class of carriers and its namesake in the commercial world – the *QE2*. The similarities of the design requirements are close. *QE2* was initially configured at 55,000shp per shaft (40.6MW) on a twin-screw arrangement. It too had a high ship speed and, as a high profile passenger vessel, strict performance requirements. But because of different shaft revolutions, the *QE2* propellers had a smaller diameter of 19ft (5.79m).

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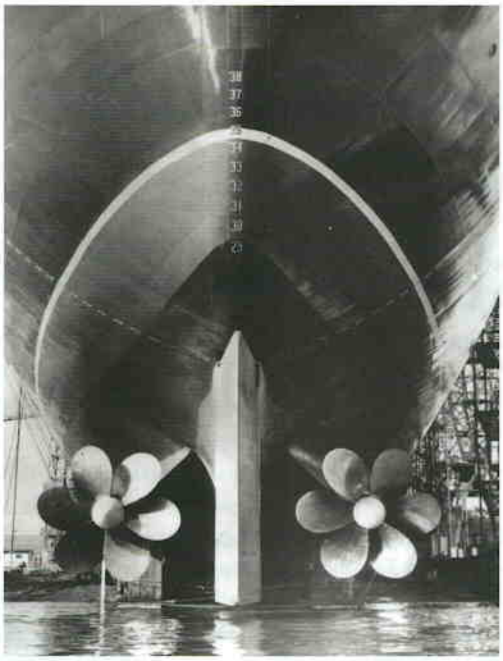
This, in the author's terms, increased its design difficulty from a Density Factor of 1112 for the QE carriers to a Factor of 1540 for the *QE2*, some 40% higher.

The *QE2* propellers were designed in the 1960s, nearly 45 years ago. They were designed against the background of computers limited to 1k (yes, just one); no wake surveys; cavitation tests were in open water; there was no CFD (computational fluid dynamics); finite element techniques were just a dream; and large numbers of blade design alternatives were out of the question. As far as analysis went, the only patches we had were those on the elbows of our jackets.

Despite all that we got it right. The propellers – they were fixed-pitch monobloc propellers – were highly successful. They operated day in and day out for nearly 17 years, providing the required performance with acceptable noise and vibration until the ship was re-engined and fitted with CPPs (controllable pitch propellers) and vane wheels. It is worth pointing out that the latter demonstrated a good example of the consequences of added complication and risk since it is a matter of record that the vane wheels failed during the sea trials; the blade design had to be changed to resolve a tip vortex problem; and root erosion was a severe problem for even single Atlantic crossings.



The *QE2* propellers, not long after they had been fitted.

Yet, other than polishing and dressing out the occasional minor edge damage, the original fixed-pitch propellers didn't need any major maintenance. They didn't need any pitch adjustment or any other of the so-called benefits of the built-up propeller. They just worked, and worked very well – a testament to the knowledge and judgement and experience of the designers of the day.

That is not to denigrate modern design methodology. The development of computers and mathematical treatments of what is a very complex flow interaction are most welcome and nowadays readily available to the designer. Rather, it gives support to the practice of design by engineers with a more complete understanding of their product and its operation than that provided by the generation of numbers extruded from a 'black box' which have little meaning without the experience and understanding required for their interpretation and application.

For interest I include a picture of the *QE2* propellers, which was taken not long after they had been fitted. Perhaps the modern military designer would look at this and, in the context of the new QE class, draw attention to the low level of skew and the high number of blades – and pronounce that in accordance with the modern doctrine they would have been much better if they had been designed as built-up.

Well, would they? No, of course not. Built-up propellers were killed off in the 1930s. They were overtaken by technology and replaced by the more efficient, simpler, cheaper, lower maintenance, lower risk, fixed-pitch propeller. The present resurgence in built-up propellers should be recognised for what it is – a needless over-complication – and as a consequence would be better buried alongside its predecessor.

Yours faithfully
Dr Graham Patience
Managing Director
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