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Naval thrust bearings

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SYNOPSIS

Marine thrust bearings have been developed for naval use from the earliest days of screw propulsion, through multi-collar thrust blocks to the present generations of tilting pad bearings. Following the introduction of the Michell thrust bearing to marine applications in the years around the First World War, there was a long period of relative stability in bearing technology. During this time there were few design changes of major interest. In the past 20 years, however, a much wider range of choices have become available. Bearing casings, although retaining similar internal arrangements, are now designed to suit different shipboard machinery layouts. The increasing requirement for submersible vessels to operate continuously at depth at very slow speeds, has led to methods for enhancing the load carrying capacity of bearings in a situation which is unfavourable for hydrodynamic lubrication. Lubrication systems themselves have been developed with self-contained thrust bearings becoming a realistic choice in some cases. Possible future bearing developments include the use of active magnetic bearings to absorb at least part of normal thrust loadings.

HISTORICAL

The nineteenth century pioneers of screw propulsion quickly discovered that there must be adequate provision within the hull of a vessel to absorb the reaction of the propeller thrust. John Bourne's book on the screw propeller, published in 1852, gives considerable attention to various thrust devices. Figure 1 shows the arrangements in the single screw vessel, HMS *Ajax*. To quote the author: 'The thrust of the screw is received upon a cast iron upright applied to the end of the shaft for that purpose'.[1] Notice that the astern thrust is taken at the end of the shaft aft of the propeller, where best practice was to fit a disc with lignum vitae segments. Such simple bearings on the ends of propeller shafts were soon found to be inadequate and were replaced by multi-collar thrust blocks, in either enclosed or open horseshoe form as shown in Fig 2. These multi-collar systems formed the new standard until the advent of single collar, tilting pad thrust blocks during the First World War.

The horseshoe type of multi-collar thrust with provision for independent adjustment of the shoes was a fine piece of engineering. However as speeds and powers advanced, the multi-collar thrust found it increasingly difficult to accommodate the heavier loads it was called upon to bear. The solution was to provide more and more load bearing surface until, in the case of at least one merchant liner, no less than 22 collars were required in the design. As we now know the conditions for hydrodynamic lubrication were far from ideal and continual adjustment was necessary to ensure an even distribution of load between the collars. Power losses were considerable, with enormous amounts of heat being generated at the bearings. Continuous wear of the bearing elements ensured that frequent replacement was essential.

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The introduction to marine use, at about the turn of the century, of the direct drive steam turbine temporarily eased the situation. In these turbines practically all the thrust was balanced by steam pressure on a dummy piston. However with the later development of geared turbine propulsion systems around 1912, thrust block problems re-appeared in aggravated form. According to J H Gibson,[1] marine engineers of the day were 'at their wits' end' for a solution until it was realised that the remedy was at hand in the form of the single collar, tilting pad thrust bearing which we know today.

A G M Michell had taken out patents covering his tilting thrust pad invention in 1905. In the same year his solution to Reynolds' equation which forms the basis of the invention was published in a German mathematical journal.[2] The first published description in this country of a Michell bearing was given by G B Woodruff in a lecture to the Institute of Marine Engineers in October 1908.[3] The discussion which followed

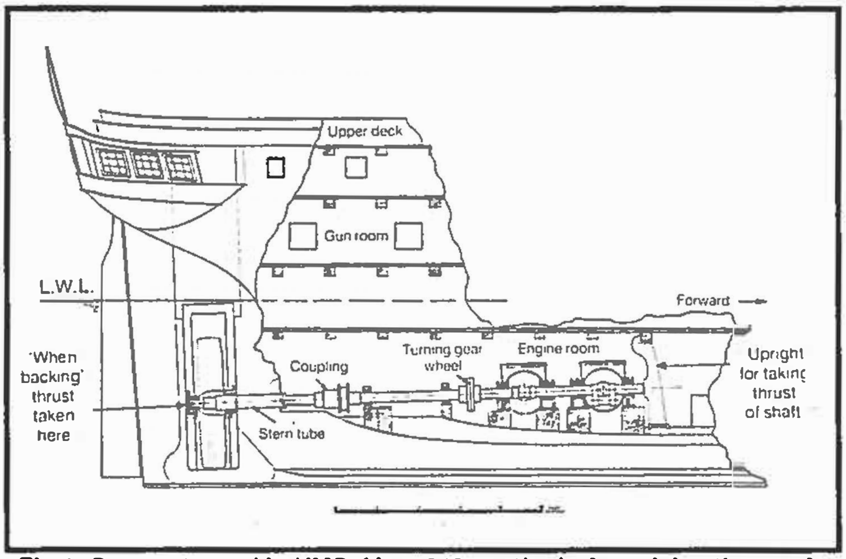

Fig 1: Screw steamship HMS *Ajax* 1848; method of receiving thrust of screw propeller in either direction

effort of the time. As an example, no less than 280 destroyers were launched from British Yards during the First World War.[5]

Figure 4 gives a good idea of the state of the art for naval thrust bearings by the end of the First World War. The shaft is carried by two journal bearings incorporated in the casing. The casing is foot mounted and split on the horizontal centre line. The lower half is in one piece; the upper half in three pieces to allow independent access to the journals. The tilting thrust pads have spherical pivots acting on hardened inserts set in massive retaining rings which are themselves spherically seated. The spherical pivots did not provide entirely satisfactory results,[1] and were soon abandoned in favour of line pivots which are still in use for most present day applications.

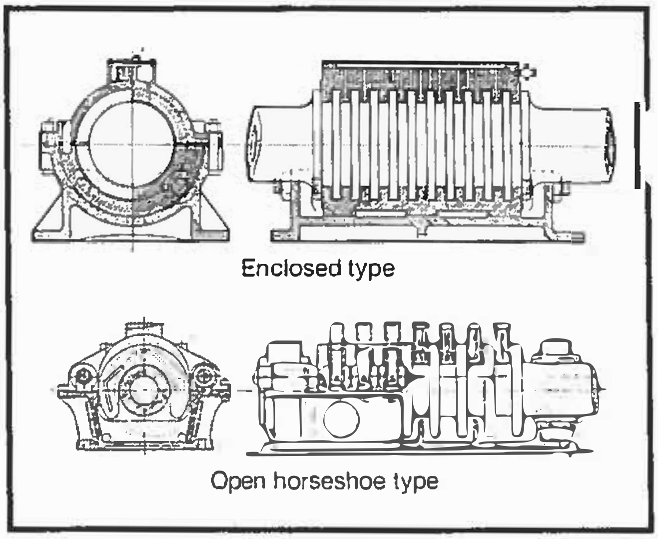

Fig 2: Multi-collar thrust blocks

Woodruff's lecture is recorded and gives some idea of the enormous scepticism with which marine engineers approached the revolutionary idea of replacing large, satisfying, multi-collar thrust blocks with what must have seemed a ridiculously small single collar device.

All the early Michell bearings applications were for industrial rather than marine use. Figure 3, reproduced from Woodruff's 1908 Institute of Marine Engineers lecture, is of a centrifugal pump fitted with a Michell thrust bearing in 1907 as part of the Murray River hydro-electric scheme. Some experimental work was started by C A Parsons in the early part of 1912 with a view to testing the suitability of a tilting pad thrust bearing for marine use.[4] Such was the success of these experiments, and of the first vessels incorporating Michell thrust blocks launched in 1913 and 1914, that the new bearings were soon adopted wholeheartedly and universally. The first ship of the Royal Navy fitted with tilting pad bearings ran her trials in August 1914. During the First World War Michell bearings were fitted to propulsion machinery totalling 10M shaft hp, a figure which reflects the massive shipbuilding

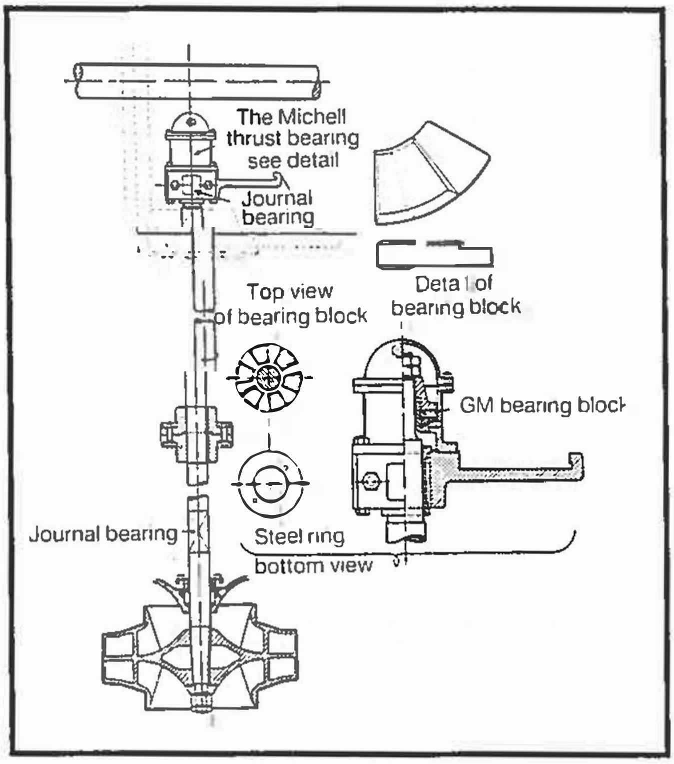

Fig 3: Michell vertical thrust bearing for a centrifugal pump installed at Cohuna on the Murray River, Victoria, 1907

Apart from minor developments, the configuration shown in Fig 4 remained relatively unaltered for naval vessels for something like 50 years. In the last 20 years, however, there have been a number of important developments in bearing design. The reasons for these developments are various. They include increasing sophistication in calculation and computing techniques giving more reliable predictions of bearing performance; the increasing need for bearings to economise on space and weight, particularly in submarines; improved manufacturing techniques; and changes in bearing operational requirements. The purpose of the rest of this paper is to highlight some of the major recent trends in naval thrust bearing design

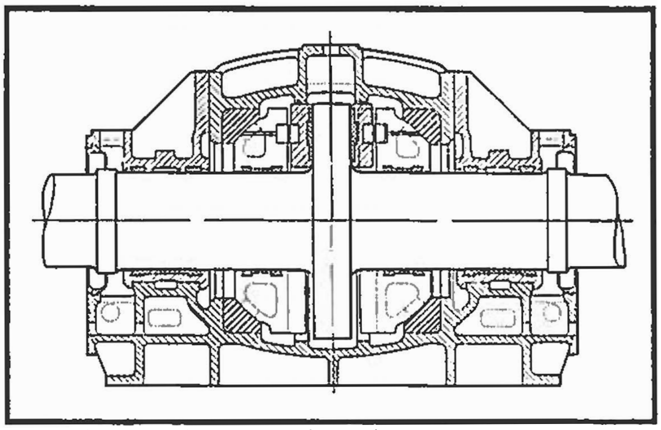

Fig 4: Typical naval thrust bearing about 1918

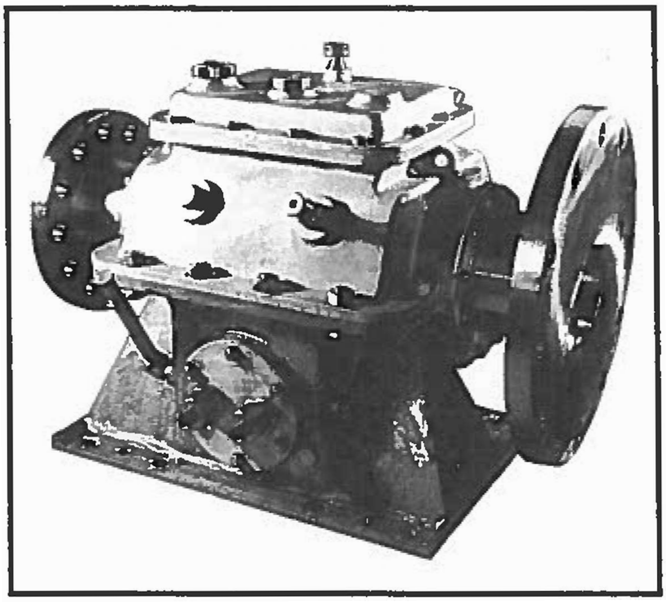

Fig 5: Hunt class minesweeper thrust block, 1970

for vessels currently afloat and for some of those coming into service in the next decade or so.

BEARING STRUCTURES

The thrust bearing designed in the early 1970s for the Hunt class of minesweepers (Fig 5) can be traced back to the immediate post First World War era. The casing is cast although the materials, having regard for the nature of the vessel, are gunmetal for the lower half and aluminium for the upper half respectively. Internally the double thrust arrangement with journals fore and aft of the collar is very similar to that of the bearing shown in Fig 4 although on a much smaller scale. By contrast, Fig 6 is a photograph of the thrust block supplied for the light aircraft carrier HMS *Invincible*, and her sister ships. Internally the double thrust arrangement is as in earlier bearings although in this case the overall design is made simpler by the shaft being supported by journal bearings which are sited separately from the thrust block. The most serious major development embodied by the bearing shown in Fig 6 is the switch from a cast casing to one which is fabricated. This change, made possible by modern welding and non-destructive testing techniques, is reckoned to provide in excess of a 20% weight advantage compared with a casting of comparable strength.

The casing structure is built around three concentric cylinders. An outer cylinder spans the length of the bearing while two shorter, smaller diameter ones cover the seal areas at each end. A series of ribs radiate from the inner cylinders to the outer skin. This arrangement shown in diagrammatic form in Fig 7 has proved immensely strong and has been widely used for subsequent freestanding naval thrust bearings. The same basic structure is used, for example, for thrust blocks installed in the Dutch Walrus and HMS *Upholder* classes of diesel-electric powered submarines. In a modified and slightly simpler form the casing structure has been employed in the USS *Avenger* class of mine counter measure vessels and in the US Navy TAO-187 class of fleet replenishment ships. Further variants of the same arrangement have been supplied for the current UK and French strategic submarine building programmes.

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