POD Propulsion

Where is the Problem?

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Azimuthal thrusters in ship propulsion have existed for many years in various forms. Its main feature is to combine the propulsive function to that of steering with the advantage of getting rid of the rudder, ensuring steering and manoeuvrability of the ship by the slewing motion of the propeller (rotation in the horizontal plane).

Elimination of the rudder is not the only positive aspect of azimuth thrusters. The far greater manoeuvrability provided, allows to steer large ships in confined spaces without the help of tugs and, with an adequate number of units, the possibility of dynamic positioning of the vessel.

POD is one type of azimuth propulsion consisting of an integrated electric motor / propeller unit mounted on the same shaft, installed in a gondola under the stern of the ship. The gondola revolves around a vertical axis suitably orienting the propeller so as to control the direction of motion. Typical of the evolved POD propulsion is that the propeller pulls the ship as opposed to the conventional, less efficient pushing action.

Installations of PODs of ever-increasing power were initially adopted for icebreakers, merchant vessels operating in icebound areas and navy ships. The break-through in the cruise industry initiated with Carnival's first installation on the "Elation" in 1998 rapidly increasing from 6 MW to 25 MW per unit, the largest number of high-power installations regarding cruise ships.

The largest number of electric podded propulsion units of high power output was supplied by two main competitors: Rolls-Royce's with the "Mermaid" and ABB with the "Azipod".

Unfortunately, the results of practical experience have quickly wetted the initial enthusiasm and interest of owners who, especially in high-power installations, found themselves unexpectedly faced with serious engine damages forcing emergency dry docking for repairs, with consequent interruption of cruises, programme cancellations and ships put out of service for at least two weeks. The frequency of such disruptions caused a temporary drop in the number of new installations, especially on cruise ships, but this trend has recently reversed by Royal Caribbean Cruise Line ordering in April 2012 four Azipod ® units to be installed on two ships currently under construction in Germany.

Figure 1

What made RCCL to regain confidence in the POD propulsion?

Put in simple words a POD consists in an electric motor enclosed in a watertight torpedo-like fuselage called gondola, with the rotor shaft directly coupled to a propeller. The shaft is supported by roller bearings. The gondola is positioned under the stern of the ship. (Figure 1 - Figure 2)

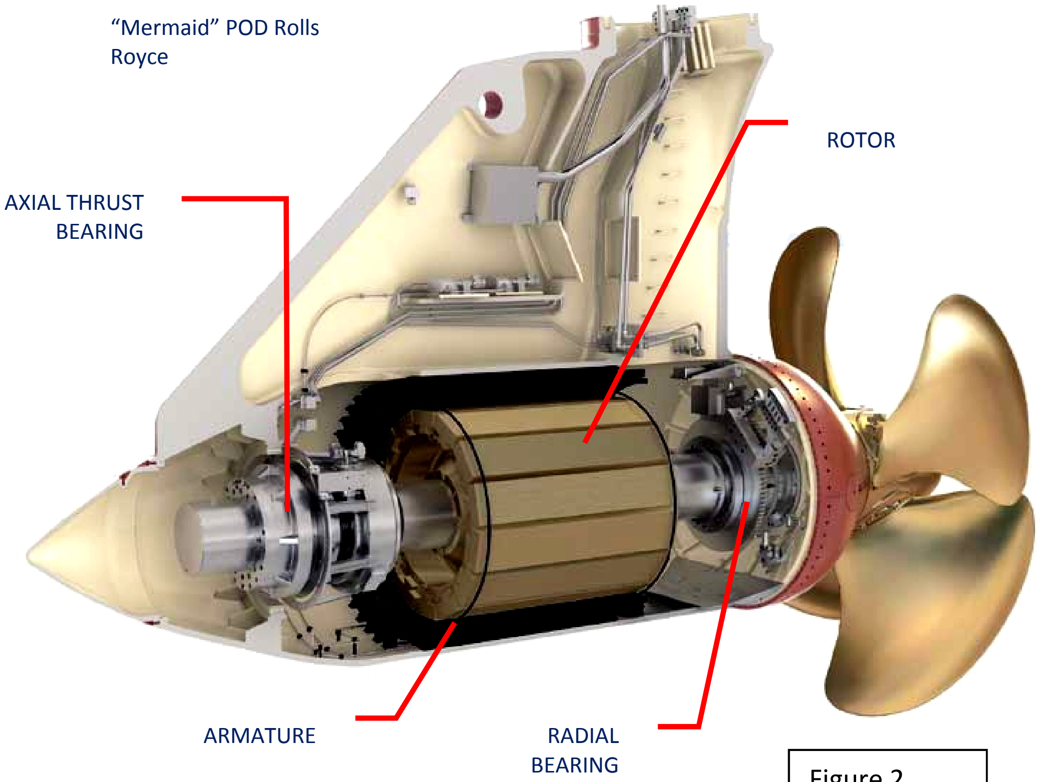

Figure 2

In this article is featured a specific issue of kinematic / geometric nature and how and how it has been addressed There have been other problems of electrical and mechanical origin affecting the performance of PODs; however bearing failure is perhaps that occurred most frequently and with the most relevant economical impact.
The vital organs of the propulsion system are the electric motor, and the radial bearing(s) (support) and axial bearings (thrust), which must ensure durability and reliability in all operating conditions.

AXIAL THRUST BEARING Figure 3

RADIAL BEARING Figure 4

Bearings may be arranged in two different configurations:

The one consists of two radial roller bearings supporting the shaft placed respectively in front of and behind the electric motor (A - B) and two spherical thrust bearings (C - D), located at the opposite end of the propeller also called non-driving end; the radial bearing B is interposed between the thrust bearings.

It is extremely important that the two thrust bearings are placed at a distance from each other such that their centres coincide at the same point of spherical oscillation. The term "spherical bearing" indicates that the track-way on which the rollers orbit is not a conical surface (rectilinear generatrix) but is spherical (i.e. the generatrix is an arc of a circle).

The radial bearings support the vertical loads of the electric motor, shaft, propeller whilst the thrust bearings support the thrust of the propeller, in the forward motion and in reverse respectively.

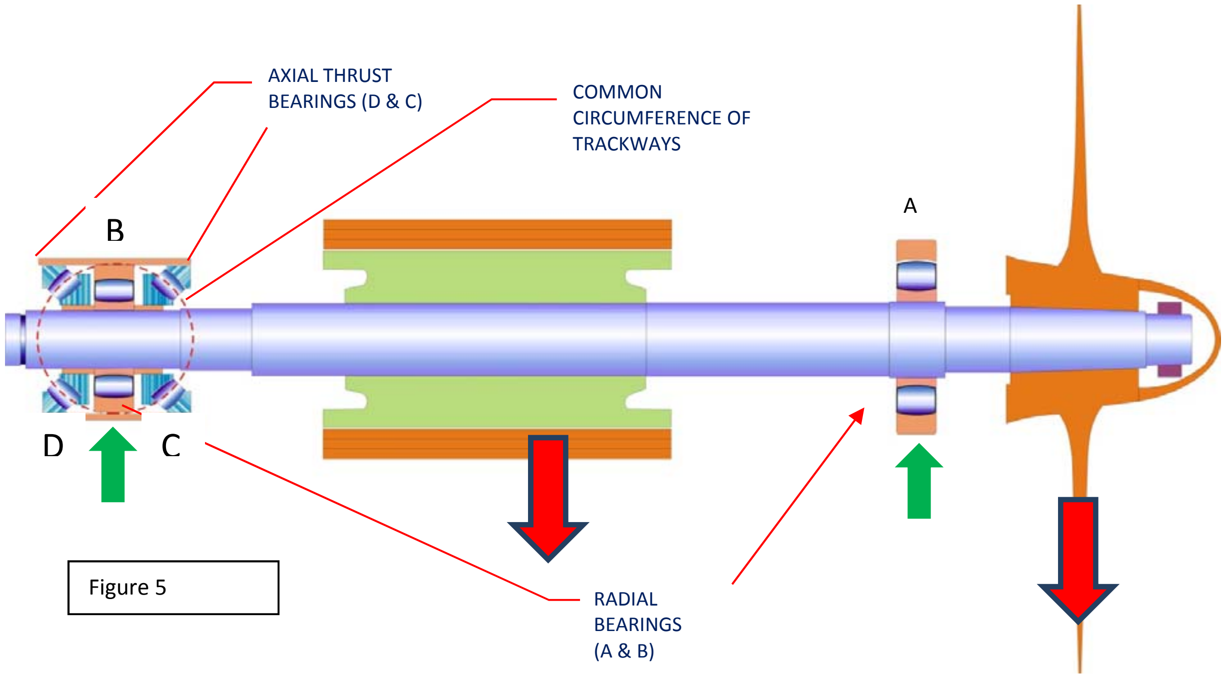

Figure 5

The other configuration consists of a radial roller bearing supporting the shaft, placed between the electric motor and the propeller (driving end) and two axial spherical thrust bearings, placed at the non-driving end in contact one of another.

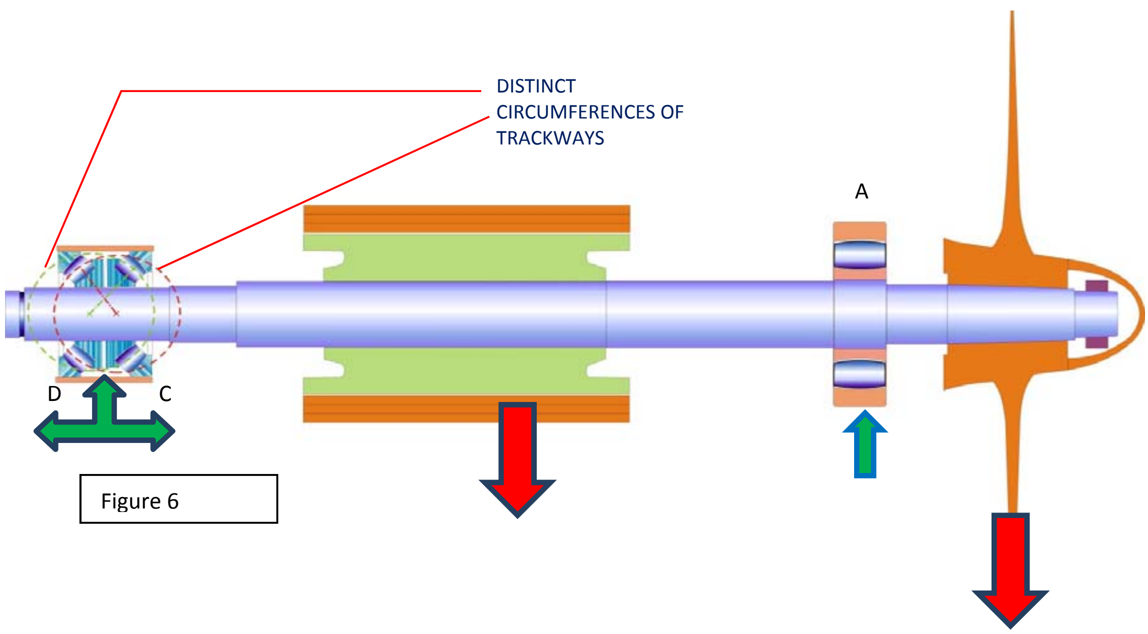

Figure 6

In this case there is no radial bearing B, and radial bearings C and D accomplish the dual function of supporting the vertical loads and the thrust. The main feature of this configuration is that while in the former one the centres of oscillation of the three bearings B - C - D coincide in the same circumference centre, in the latter configuration, the centres of oscillation of the two bearings C - D are set apart.

The majority of problems that have plagued the POD bearings arise from this overlooked design flaw.

It should be appreciated that the shaft of the complex electric motor – propeller is not perfectly rigid and has a certain degree of flexibility. Thus due to the weight of the electric motor and the propeller it bends between the supports. Moreover, because of uneven thrust exerted on the propeller, the plane of rotation of the same oscillates continually causing wobbling, and this oscillation is transmitted to the shaft and consequently to the bearings.

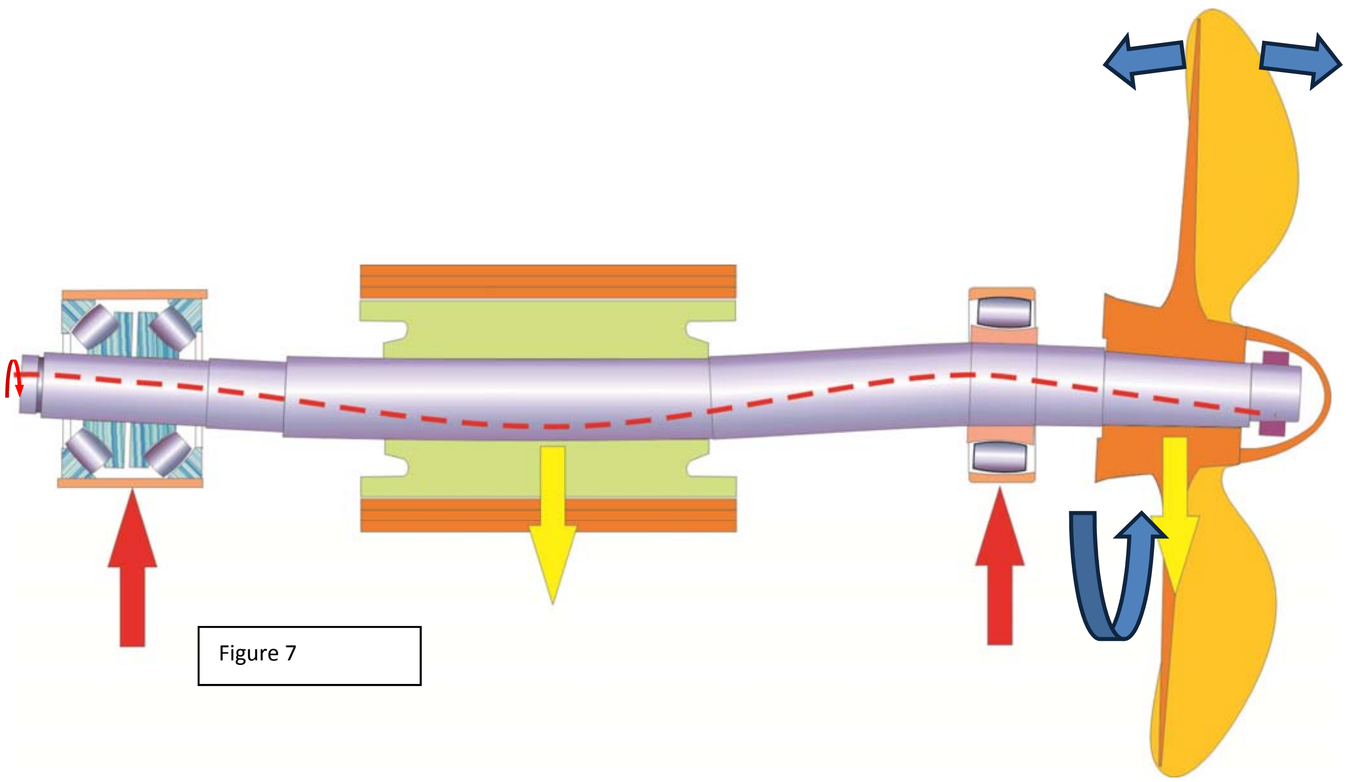

Figure 7

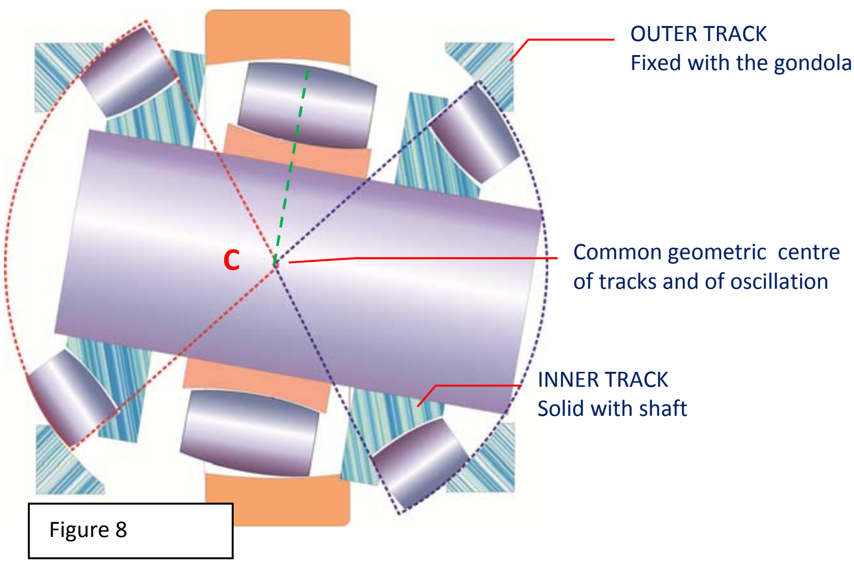

Figure 8

Due to the bending of the geometrical axis of shaft and the oscillation transmitted by the propeller, the shaft does not rotate centred on its geometrical axis, but it rotates eccentrically to it with a precession movement or whirling.

The inner races of the bearings are fixed with the shaft and they follow its movements and oscillations.

The bearing outer races are solid with the structure of the gondola and are therefore steady. To accommodate the relative movements, bearing rollers are barrel-shaped and tracks on which the rollers ride have spherical surfaces. That feature will allow for the small oscillations generated on the shaft. This relative freedom of movement is achieved only if the centres of oscillation of the three bearings coincide as in the case illustrated in Figure 5. Looking at their arrangement, it is noted that the centres of the circumference of the two thrust bearings overlap. This allows the set of two thrust bearings to oscillate in synchrony. (Figure 8).

Quite different is the case illustrated in Figure 6. Indeed, because of the displacement of the centres of oscillation of the two thrust bearings, the tilting of one counters the other. As a result the rollers exert abnormally high pressure on the surface of the track, and in installations of large power output the resulting stress may be extremely high, in excess of the yield limit of the steel, with consequent flaking and breakage of the track.

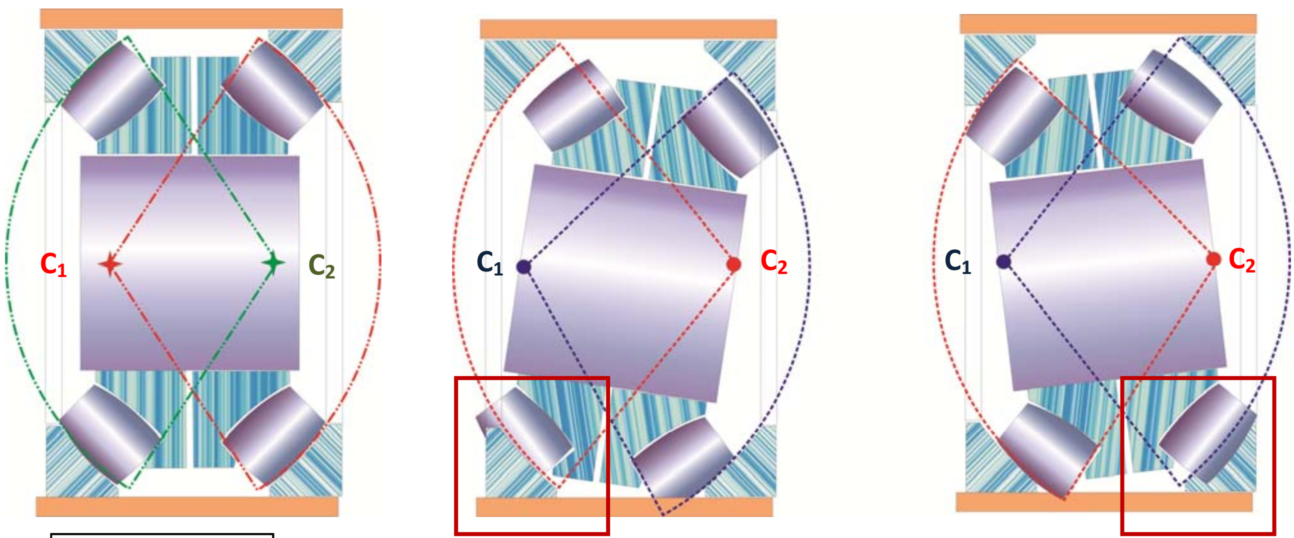

Figure 9

The metal fragments produced by this failure are carried within the bearing, leading rather sooner than later the catastrophic destruction of the bearing.

The kinematic mechanism described above may be simplified as in figure 9 where it is shown how the rollers in the course of the oscillations interfere geometrically with the surface of the track. Such interference in fact generated enormous elasto-plastic tensions.

To simplify the concept you may imagine a seesaw which is a board pivoted in the middle (fulcrum) in this configuration, the system of constraints is isostatic. Imagine instead the same seesaw with two fulcrums; it obviously cannot oscillate. This second configuration produces a hyper-static system, which in mechanical design it is crucial to avoid because it generically leads to large constraint forces and internal stresses which can cause distortion and failure.

Figure 10

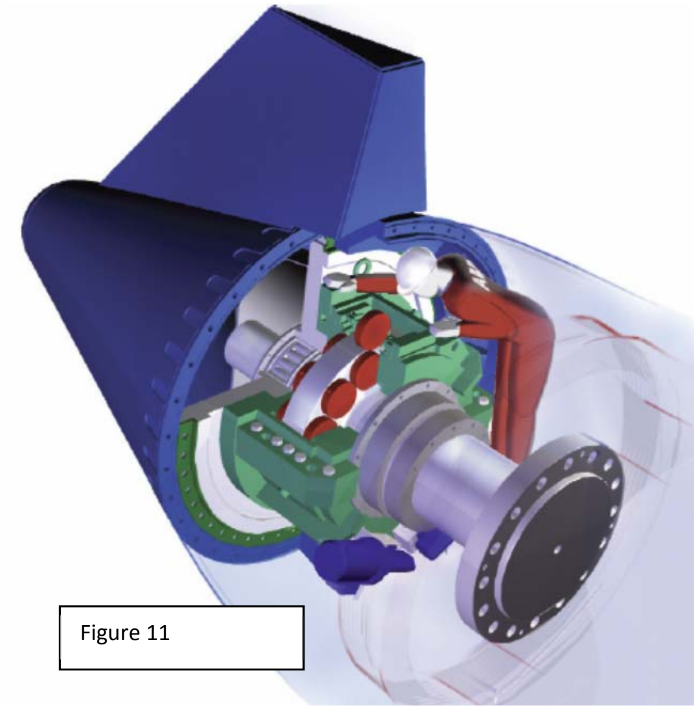

Figure 11

The new generation of PODs that will be installed on the RCCL ships, in view of improving the reliability of the system, have thrust roller bearings replaced with Mitchell-type traditional thrust bearing, consisting of a flange integral with the shaft, on which act the thrust pads. Figures 11-12

Before being adopted, this new “old-times” system has long been extensively tested on a full scale prototype, applying loads in the order of magnitude as those in service, with satisfactory results of reliability and durability.

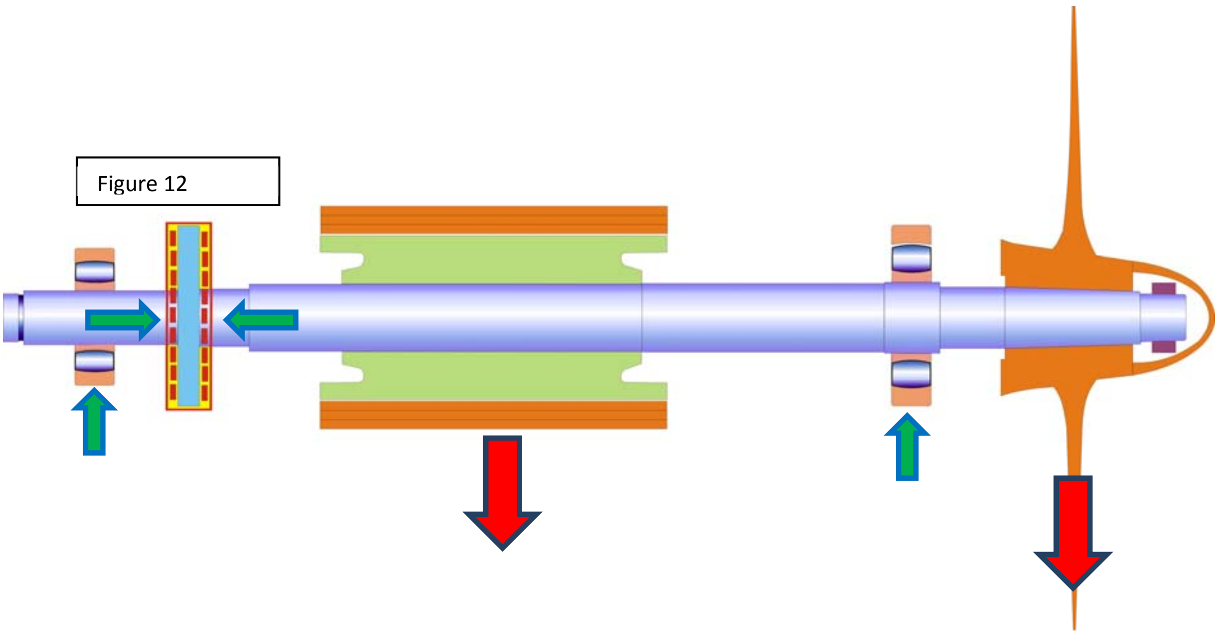

Figure 12

Although there are other drawbacks that have not been dealt with in this short note, which are the subject of study and improvement on the part of manufacturers the prospects of a rebirth of POD propulsion are bright. It is perhaps too early to claim victory, but it is fair to acknowledge that significant progress have been made in the reliability of the POD system.

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