exists at partial capacity through each 180º arc, forces F1 and F2 are approximately equal and opposite, thereby producing little, if any, radial force on the shaft and bearings.

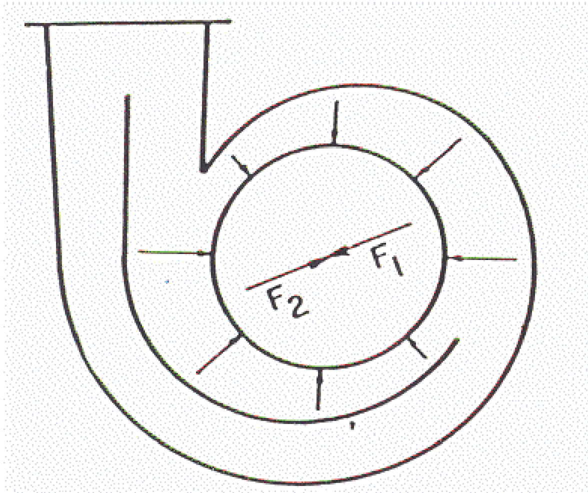

Fig.1.5 Radial reactions in double-volute pump

Axial Thrust in Single-Stage Pumps

The pressures generated by a centrifugal pump exert forces on both its stationary and rotating parts. The design of these parts balances some of these forces, but separate means may be required to counter-balance others. Axial hydraulic thrust is the summation of unbalanced impeller forces acting in the axial direction. As reliable large-capacity thrust bearings are not readily available, axial thrust in single-stage pumps remains a problem only in larger units.

Theoretically, a double-suction impeller is in hydraulic axial balance with the pressures on one side equal to, and counter-balancing the pressures on, the other *(Fig 2.1).* In practice, this balance may not be achieved for the following reasons:

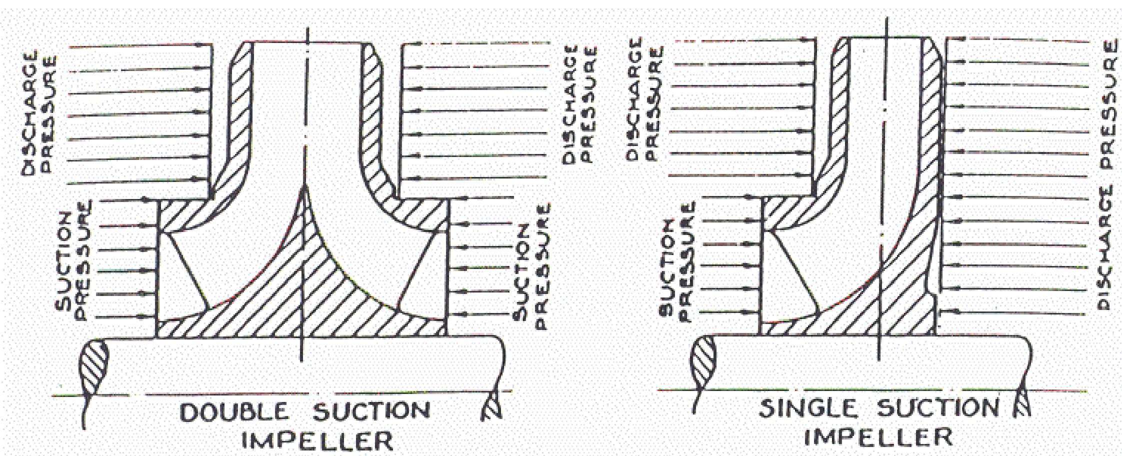

Fig. 2.1 Origin of pressure acting on impeller shrouds to produce axial thrust

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The suction passages to the two suction eyes may not provide equal or uniform flows to the two sides.

1. External conditions such as an elbow being too close to the pump suction nozzle may cause unequal flows to the suction eyes.
2. The two sides of the discharge casing may not be symmetrical, or the impeller may be located off-centre. These conditions will alter the flow characteristics between the impeller shrouds and casing, causing unequal pressures on the shrouds.
3. Unequal leakage through the two leakage joints will tend to upset the balance.

Combined, these factors create definite axial unbalance. To compensate for this, all centrifugal pumps, even those with double-suction impellers, incorporate thrust bearings.

The ordinary single-suction radial-flow impeller with the shaft passing through the impeller eye *(Fig 2.1)* is subject to axial thrust because a portion of the front wall is exposed to suction pressure, thus exposing relatively more back wall surface to discharge pressure. If the discharge chamber pressure were uniform over the entire impeller surface, the axial force acting towards the suction would be equal to the product of the net pressure generated by the impeller and the unbalanced annular area.

Actually, pressure on the two single-suction impeller walls is not uniform. The liquid trapped between the impeller shrouds and casing walls is in rotation and the pressure at the impeller periphery is appreciably higher than at the impeller hub. Although we need not be concerned with the theoretical calculations for this pressure variation, *(Fig 2.2)* describes it qualitatively. Generally speaking, axial thrust towards the impeller suction is about 20% to 30% less than the product of the net pressure and the unbalanced area.

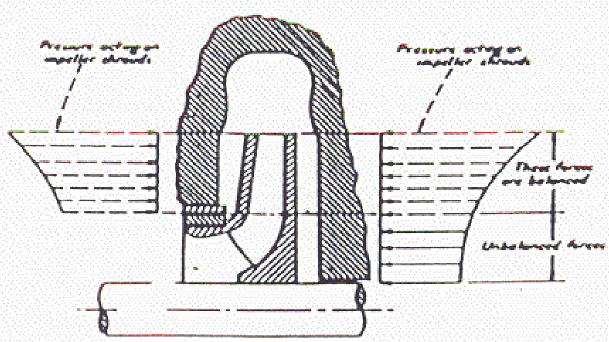

Fig.2.2 **Actual pressure distribution on front and back shrouds of single-suction impeller with shaft through impeller eye**

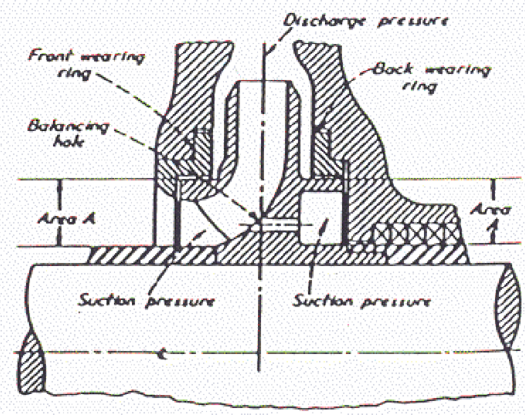

Fig.2.3 **Balancing axial thrust of single-suction impeller with wearing ring on the back and balancing holes**

To eliminate the axial thrust of a single-suction impeller, a pump can be provided with both front and back wearing rings. To equalise thrust area, the inner diameter of both rings is made the same *(Fig 2.3).* Pressure approximately equal to the suction pressure is maintained in a chamber located on the impeller side of the back wearing ring by drilling so-called balancing holes through the impeller. Leakage past the back wearing ring is returned into the suction area through these holes.

However, with large single-stage suction pumps, balancing holes are considered undesirable because leakage back to the impeller suction opposes the main flow, creating disturbances. In such pumps, a piped connection to the pump suction replaces the balancing holes.

Another way to eliminate or reduce axial thrust in single-suction is by use of pump-out vanes on the back shroud. The effect of these vanes is to reduce the pressure acting on the back shroud of the impeller *(Fig 2.4).* This design, however, is generally used only in pumps handling gritty liquids where it keeps the clearance space between the impeller back shroud and the casing free of foreign matter.

So far, the discussion of the axial thrust has been limited to single-suction impellers with a shaft passing through the impeller eye and located in pumps with two stuffing boxes, one on either side of the impeller. In these pumps, suction pressure magnitude does not affect the resulting axial thrust. On the other hand, axial forces acting on an overhung impeller with a single stuffing box *(Fig 2.5)* are definitely affected by suction pressure.

In addition to the unbalanced force found in a single-suction, two-box design *(Fig 2.2)* there is an axial force equivalent to the product of the shaft area through the stuffing box and the difference between suction and atmospheric pressure. This force acts towards the impeller suction when the suction pressure is less than the atmospheric, or in the opposite direction, when it is higher than the atmospheric.

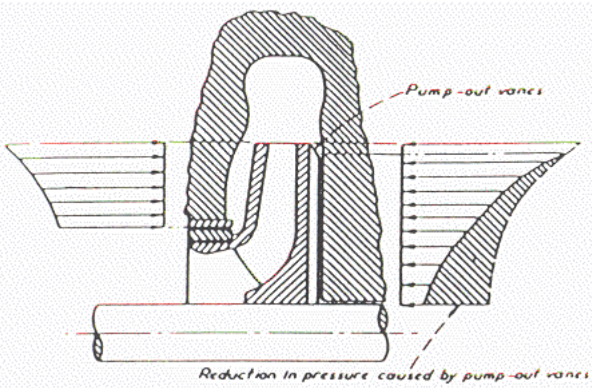

Fig.2.4 Reducing axial thrust of single-suction impeller with pump-out vanes

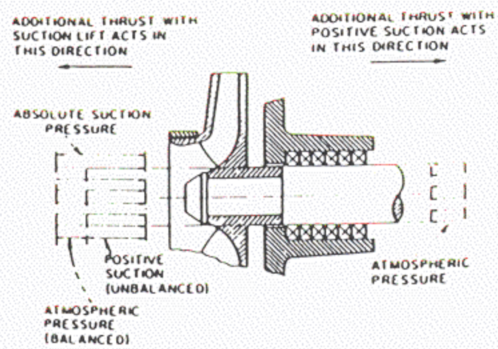

Fig.2.5 Axial thrust problem with single-suction overhung impeller and single stuffing box

When an overhung impeller pump handles a suction lift, the additional axial force is very low. For example; if the shaft diameter through the stuffing box is 2" (area = 3.14 sq.in) and if the suction lift is 20ft of water (absolute pressure – 6.06 psia), the axial force caused by the overhung impeller and acting towards the suction will be only 27lb.

On the other hand, if the suction pressure is 100 psi, the force will be 314lb and acts in the opposite direction. Therefore, as the same pump may be applied for many conditions of service over a wide range of suction pressures, the thrust bearing of pumps with single-suction overhung impellers must be arranged to take thrust in either direction. They must also be selected with sufficient thrust capacity to counteract forces set up under the maximum suction pressure established as a limit for that particular pump.