A connector for connecting an impeller to a shaft. The impeller has a shaft-side hub extension H with a central recess. The connector is inserted into the recess to frictionally connect an outwardly facing surface 14 of the connector with a radially inner surface of the hub extension. The connector has a threaded portion 12 which screws onto a corresponding threaded portion 7 of the shaft. The connector has an abutment surface 21 which engages a corresponding abutment surface 4 of the shaft when the thread portions are screwed together. The abutment surfaces are inclined from the radial direction such that, when the abutment surfaces engage as the thread portions are screwed together, the outwardly facing surface of the connector is urged radially outwardly to increase the strength of the frictional connection with the radially inner surface of the hub extension.
CONNECTOR

Field of the Invention

The present invention relates to a connector for connecting an impeller to a shaft, and in particular, but not exclusively, for connecting an impeller of a turbocharger to a turbocharger shaft.

Background of the Invention

Turbocharger impellers are typically made of aluminium alloys to provide low rotational inertia with reasonable strength at a commercially-acceptable cost. Attachment of the impeller to the steel turbocharger shaft is achieved in various ways. For example, because of the relative weakness of aluminium and the small diameter of the shaft, one option is to provide the impeller with a steel insert containing a screw-threaded socket which can be threaded on to the shaft. This arrangement can take a higher torque than a connection in which the shaft is directly threaded into the aluminium body (the torque is proportional to the power transmitted across the joint, and so the impeller can be used at a higher pressure ratio than one in which there is a direct threaded connection).

Typically, such an insert is fitted into the impeller by shrink fitting; the aluminium body of the impeller is heated to expand the bore which is to receive the steel insert, while the insert is cooled, for example using liquid nitrogen, before being inserted into the bore. The resultant interference connection is restricted by the temperature to which the aluminium can be heated before its material properties are affected, and by the temperature to which the steel can be cooled.

While the arrangement described can perform satisfactorily, a problem can arise during cycling of the turbocharger from rest to full load. As the turbocharger starts to spin, the joint is affected by centrifugal forces, whereby the aluminium grows outwards away from the steel insert. This reduces the interference force between the insert and the impeller, and due to design constraints it has been found that this reduction tends to be greater at one end of the insert than at the other. Consequently, the insert is gripped more firmly at one of its ends than at the other. The turbocharger then starts to heat up, and because of the different thermal coefficients of expansion of the aluminium alloy and the steel, the aluminium grows axially more than the steel, causing the two metals to slide over each other, except at the
location where the impeller still grips the insert firmly. On shutdown, the centrifugal stresses are removed, but the thermal stresses remain for some minutes as the turbocharger cools. In this process, the point of grip of the impeller on the insert changes from one end to the other, and as the turbocharger cools, the insert "walks" along the impeller.

In certain very cyclic conditions (for example fast ferry applications in high ambient temperatures), it has been observed that the insert can move so far along the impeller that turbocharger failure can occur. Although the effect can be mitigated to some degree by increasing the original interference between the components, for the reasons mentioned above this solution is limited, and it is therefore desirable to achieve a design which ensures that the point of grip remains at the same location during the operating cycles, rather than shifting from one end of the insert to the other.

Accordingly, EP1394387 proposes an outer steel constraining ring which reinforces the frictional contact between aluminium impeller and the insert. Since the ring does not expand as much as the impeller body as the turbocharger heats up, the point of grip between the impeller and the insert remains within the axial extent of the ring during the whole operating cycle of the turbocharger, thereby preventing the tendency of the impeller to "walk" along the insert. As a consequence, the operating life of the turbocharger can be considerably extended in comparison with the conventional turbocharger without the constraining ring.

However, the assembly of such a joint is relatively complex. First the insert and impeller bore are manufactured to tight tolerances. Then typically the insert is cooled and the impeller heated, and the insert is placed within the impeller bore at a hub extension of the impeller. As the insert warms up and the impeller cools, a shrink fit joint is formed, but because of the non-axisymmetrical shape of the impeller, some distortion occurs within the impeller. Generally, the outer surface of the impeller hub extension must therefore be reground to be axisymmetric so that it will be suitable for the outer joint with the constraining ring. A further ring may then be shrunk onto a flange portion of the insert to prevent the constraining ring from coming off the impeller.

**Summary of the Invention**

It would be desirable to provide a connection between an impeller and a shaft which is simpler to install, but one that can transmit high torques and can prevent or reduce any tendency of the impeller to "walk".
Accordingly, in a first aspect the present invention provides a connector for connecting an impeller to a shaft, in particular for connecting an impeller of a turbocharger to a turbocharger shaft, the impeller having a shaft-side hub extension with a central recess, wherein:

the connector is inserted into the recess to frictionally connect an outwardly facing surface of the connector with a radially inner surface of the hub extension;

the connector has a threaded portion carrying a thread which screws onto a corresponding threaded portion of the shaft,

the connector has an abutment surface which engages a corresponding abutment surface of the shaft when the thread portions are screwed together, thereby tightening the threads to provide a rotationally fixed connection between the impeller and the shaft; and

the abutment surfaces are inclined from the radial direction such that, when the abutment surfaces are mutually engaged as the thread portions are screwed together, the outwardly facing surface of the connector is urged radially outwardly to increase the strength of the frictional connection with the radially inner surface of the hub extension.

By increasing the strength of the frictional connection with the radially inner surface of the hub extension, the point of maximum grip between the impeller and the connector can be forced to remain substantially stationary, even when the impeller and the connector experience differential thermal distortions. In this way the problem of impeller "walking" can be overcome. In addition, regrinding of the hub extension can also be avoided after fitting of the connector, as it is usually unnecessary to fit a constraining ring of the type described in EP1394387 to the hub extension.

A second aspect of the invention provides an impeller having a shaft-side hub extension with a central recess and fitted with a connector according to the first aspect, the connector being frictionally connected at an outwardly facing surface with a radially inner surface of the hub extension.

A third aspect of the invention provides the impeller fitted with a connector of the second aspect, which impeller is connected to a shaft having a corresponding threaded section, the thread of the threaded portion of the connector screwing onto the corresponding threaded portion of the shaft.

A fourth aspect of the invention provides a turbocharger having the connected impeller and shaft of the third aspect.
Optional features of the invention will now be set out. These are applicable singly or in any combination with any aspect of the invention.

The abutment surfaces can be inclined at an angle to the radial direction of 30° or more, and preferably 40° or more. The abutment surfaces can be inclined at an angle to the radial direction of 80° or less, and preferably 60° or less.

The abutment surface of the connector may be arranged such that the shaft-side end of the outwardly facing surface of the connector is urged radially outwardly. In this way, the point of maximum grip between the impeller and the connector can be located at the shaft-side end of the hub extension.

The central recess may be a blind hole (i.e. with an end surface). Thus, the impeller may not have a through-hole extending from one side to another of the impeller.

The outwardly facing surface of the connector may be approximately cylindrically shaped. The radially inner surface of the shaft-side hub extension of the impeller which frictionally connects with the outwardly facing surface may be correspondingly approximately cylindrical.

The frictional connection between the connector and the hub extension can be achieved by e.g. press fitting or shrink fitting.

The threads carried by the threaded portion of the connector may be protected by a helicoil formation fitted to the connector. As the material of the connector may be less strong than the material of the shaft, the helicoil formation can thereby prevent damage to the threads of the connector.

The threaded portion of the connector is typically within the central recess. In this way, an axially compact arrangement can be achieved.

Preferably, the frictional connection between the outwardly facing surface of the connector and the radially inner surface of the hub extension transmits, in use, substantially all of the torque between the shaft and the impeller.

The connector (which provides the outwardly facing surface and the threaded portion) can be formed as a unitary body.
The connector may be formed of a material having a greater strength than the material of the impeller. For example, the shaft can be formed of steel (e.g. a high strength steel), the impeller can be formed of aluminium alloy, and the connector can also be formed of steel (e.g. a high strength steel).

However, the connector may be formed of a material having a coefficient of thermal expansion which is greater than the coefficient of thermal expansion of the material of the shaft. In this way, the differential thermal forces which encourage the impeller to "walk" can be reduced. The connector may be formed of a material having a lower coefficient of thermal expansion than the material of the impeller. For example, the shaft may be formed of steel having a coefficient of thermal expansion of about 11x10^{-6}/K, and the impeller may be formed of aluminium alloy having a coefficient of thermal expansion of about 22.7x10^{-6}/K. The connector can then be formed, for example, of magnesium alloy, bronze, brass or stainless steel. Preferably the connector is formed of a material that is resistant to galling with the shaft. Generally, a value for the coefficient of thermal expansion of the connector that is equal to or close to that of the impeller is preferred for reducing the differential thermal forces which encourage the impeller to "walk". Therefore, preferably the value of \((\alpha_c - \alpha_s)/(\alpha_i - \alpha_s)\) is greater than 0.2, and more preferably greater than 0.3 or 0.4, where \(\alpha_c\) is the coefficient of thermal expansion of the connector, \(\alpha_i\) is the coefficient of thermal expansion of the impeller, and \(\alpha_s\) is the coefficient of thermal expansion of the shaft.

However, a risk of a coefficient of thermal expansion of the connector which is much greater than that of the shaft is that the resultant stretching of the shaft at high temperatures could lead to shaft breakage. Therefore, at least for typical materials for the impeller and shaft (such as respectively aluminium alloy and steel), preferably the value of \((\alpha_c - \alpha_s)/(\alpha_i - \alpha_s)\) is less than 0.9, and more preferably less than 0.8 or 0.7. However, this does not exclude that the value of \((\alpha_c - \alpha_s)/(\alpha_i - \alpha_s)\) can be equal to or greater than 1. In particular, if the value of \((\alpha_i - \alpha_s)\) is reduced, then higher values of \((\alpha_c - \alpha_s)/(\alpha_i - \alpha_s)\) can be adopted without risk of shaft breakage. Thus one option is to form the impeller of a material having a relatively low coefficient of thermal expansion, such as a metal matrix composite having an aluminium alloy matrix and silicon carbide particulate reinforcement which, depending on the volume of silicon carbide, typically has a coefficient of thermal expansion in the range of from 14-17x10^{-6}/K. In such cases, a relatively high coefficient of thermal expansion for the connector not only can reduce any tendency of the impeller to "walk", but also can assist with the
production of a shrink fitted frictional connection between the connector and the hub extension.

Indeed, more generally, the impeller may be formed from a metal matrix composite having an aluminium alloy matrix and silicon carbide particulate reinforcement. By forming the impeller from such a metal matrix composite, significant material properties of the impeller can be improved. For example, the impeller can be made stiffer, which allows thinner vanes to be machined into the impeller since the natural frequencies of these vanes will be comparatively high. The thinner vanes are then more suitable for high Mach number flows. Also, the strength of the impeller can be increased, it can be made more resistant to ageing at high temperatures, and it can have improved fatigue resistance. In addition, the coefficient of thermal expansion of the impeller can be decreased, thereby reducing the differential thermal forces which encourage the impeller to "walk".

Rather than forming the connector as a unitary body, the connector may have a first subcomponent and a second subcomponent, wherein:

- the first subcomponent has a first sleeve portion which is coaxial with the hub extension, and the second subcomponent has a second sleeve portion which is sandwiched between the first sleeve portion and the hub extension, such that the second sleeve portion is frictionally connected on one side with the first sleeve portion and on the opposing side provides the outwardly facing surface which is frictionally connected with the radially inner surface of the hub extension;
- the first subcomponent provides the threaded portion of the connector and the abutment surface of the connector; and
- the impeller and the first subcomponent are formed of respective materials having different coefficients of thermal expansion, and the second subcomponent is formed of a material having a coefficient of thermal expansion which is intermediate the coefficients of thermal expansion of the impeller and the first subcomponent. The two subcomponents can be fixed together to form the connector, e.g. by press fitting or shrink fitting, before the connector is fitted to the impeller. By forming the second subcomponent from a material having an intermediate coefficient of thermal expansion, the differential thermal forces which encourage the impeller to "walk" along the insert can be spread across two interfaces, further reducing any tendency of the impeller to "walk". Preferably, the frictional connection between the sleeve portions transmits, in use, substantially all of the torque between the shaft and the impeller. The first subcomponent may be formed of a material having a greater strength than
the material of the impeller. The first subcomponent may be formed of a material having a lower coefficient of thermal expansion than the material of the impeller. For example, the first subcomponent can be formed of steel, and the impeller can be formed of aluminium alloy. The second component can then be formed, for example, of stainless steel, bronze or brass.

The connector and/or the impeller may have one or more centring portions having respective engagement surfaces which engage with one or more corresponding centring portions of the shaft, the threaded portion of the connector and the centring portions of the connector and/or the impeller being distributed along the impeller axis. The thread surface of the connector and the engagement surfaces of the connector and/or the impeller can face radially inwardly, and the respective diameters on the shaft of the thread and the engagement surfaces can then decrease towards the impeller.

Generally the impeller has a casing, and the connector and/or the hub extension can then form a seal with a section of the casing. For example, the seal can include a sealing ring, which may be carried by the casing section and which may be received by a corresponding circumferential recess formed on an outer surface of the connector and/or the hub extension. The sealing ring may have one or more annular grooves on its radially inner face, and the recess may have corresponding circumferential ribs which are received in the grooves. Another option is for the seal to include a labyrinth seal, with formations on facing surfaces of the casing section and the connector and/or the hub extension forming the labyrinth.

The connector may be formed with or may carry a circumferential oil thrower formation at its radially outer surface.

Further optional features of the invention are set out below.

**Brief Description of the Drawings**

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a sectional elevation through a turbocharger impeller joined to a shaft by a connector in accordance with an embodiment of the invention;
Figure 2 is a close-up schematic view of a seal between a section of a casing of the impeller of Figure 1 and a hub extension of the impeller;

Figure 3 is a close-up schematic view of a seal between a section of a casing of an impeller and a sleeve portion of a further embodiment of the connector;

Figure 4 shows schematically a sectional elevation of a further embodiment of the connector; and

Figure 5 shows a sectional elevation of a further embodiment of the connector which is similar to the embodiment of Figure 1 except that the connector is formed from a first subcomponent and a second subcomponent.

**Detailed Description and Further Optional Features of the Invention**

Referring first to Figure 1, an aluminium alloy impeller 1 is fitted on to a steel turbocharger shaft 2 by means of a connector 3. The alloy of which the impeller is made (known in the U.S.A. by the designation "2618A") has a relatively high strength for use up to a temperature of about 200°C, having a composition of aluminium with about 2.5wt.% copper and smaller amounts of magnesium, iron and nickel.

The alloy of the impeller 1 has a coefficient of thermal expansion of about 22.7×10⁻⁶/K, and the steel of the shaft 2 has a coefficient of thermal expansion of about 11×10⁻⁶/K. The material of the connector 3 can be medium carbon steel such as EN8, which also has a coefficient of thermal expansion of about 11×10⁻⁶/K. Alternatively, however, the material of the connector 3 may have a coefficient of thermal expansion such that the value of \((\alpha_c - \alpha_s)/(\alpha_i - \alpha_s)\) is greater than 0.2, and more preferably greater than 0.3 or 0.4. For example, the connector 3 may be made of magnesium alloy (coefficient of thermal expansion of about 26×10⁻⁶/K), bronze (coefficient of thermal expansion typically of about 18×10⁻⁶/K, although as high as 20-21×10⁻⁶/K for manganese-bronze), brass (coefficient of thermal expansion of about 18.7×10⁻⁶/K) or stainless steel (coefficient of thermal expansion of in the range of 16-17.3×10⁻⁶/K). Such alloys can also be resistant to galling with the steel of the shaft 2. Advantageously, by forming the connector 3 from a material having a coefficient of thermal expansion greater than the material of the shaft, the differential thermal forces acting across the frictional connection (discussed below) between the connector 3 and the impeller
1 can be reduced relative to a connector formed from the a material having the same coefficient of thermal expansion as that of the shaft.

The connector 3 is of cup-like shape and has an outer surface 14 for connecting to the impeller 1, a threaded portion 12 with a threaded bore 11 forming the base of the cup, and a flange portion 8 around the mouth of the cup.

The shaft 2 is formed at its end with an abutment surface 4 inclined from the radial direction at an angle \( \alpha \) of from 30° to 80° (preferably of from 40° to 60°), the abutment surface 4 surrounding a cylindrical centring portion 5, and a screw-threaded portion 7 of further reduced diameter extending from the end of the centring portion. The connector 3 is inserted into a blind central recess formed in the hub extension H, with the outer surface 14 of the connector 3 frictionally connected to the radially inner surface of the hub extension H. The flange portion 8 of the connector 3 engages against a shaft-side end face 9 of the hub extension H to determine the relative axial positions of the connector 3 and the hub extension H. An abutment surface 21 formed by the other side of the flange portion 8 is correspondingly inclined from the radial direction at the angle \( \alpha \) and is engaged by the abutment surface 4 on the shaft 2. The centring portion 5 of the shaft is received in a corresponding centring portion 10 of the connector in a close, but not tight, fit. The threaded bore 11 engages on the screw-threaded portion 7 of the shaft. The threaded portion 12 has a small clearance from the end of the recess.

The connector 3 is fitted on to the hub extension H by cooling the connector 3 to cause it to shrink and by heating the impeller to cause the hub extension H to expand, and then inserting the connector 3 into the central recess of the hub extension H until the flange portion 8 contacts the end face 9 of the hub extension H. On returning from their thermal excursions, the connector 3 and hub extension H frictionally grip across the outer surface 14 of the connector 3 and the radially inner surface of the hub extension H. The outer surface 14 extends over and thereby frictionally contacts most of the axial length of the hub extension H.

The outer diameter of the flange portion 8 is provided with an oil capture/thrower ring R, which in this embodiment of the invention is machined into the flange portion 8. Another option, however, is to form the ring R as a separate component.
As shown better in Figure 2, a section 15 of the impeller casing and the outer surface of the hub extension H are in close proximity to help provide a rotating oil and pressure seal between the impeller 1 and the casing. To improve the seal, the hub extension H has a recess 13 on its outer surface which is bounded at one end by the flange portion 8 of the first component of the connector and which receives a sealing ring 16 carried by the casing section 15. To reduce wear between the sealing ring 16 and the hub extension H, the casing section 15 has a small abutment surface 20 on the shaft side (right hand in Figure 1) of the seal ring 16 and against which the sealing ring 16 rests. To provide enhanced sealing, the sealing ring 16 has annular grooves 18 on its radially inner face, and the recess has corresponding circumferential ribs 17 which are received in the grooves, as described in EP A 1130220. Alternatively, however, the sealing ring can be a plain ring (i.e. without grooves) received in a plain recess (i.e. without ribs). The sealing ring 16 co-operates with the casing section 15 and serves to retain lubricating oil to the shaft side of the assembly and compressed air to the impeller side of the assembly (left hand in Figure 1). The compressed air is contained between the body of the impeller 1, the hub extension H with its sealing ring 16, and the impeller casing, within which the impeller assembly is mounted for rotation on overhung bearings (not shown).

After the connector 3 is fitted on to the hub extension H, the screw-threaded portion 7 of the shaft 2 is screwed onto the threaded portion 12 of the connector 3, the respective centring portions 5, 10 ensuring the shaft aligns with the axis of the impeller. The threads are screwed until the opposing abutment surfaces 4, 21 of the shaft 2 and the flange portion 8 come into abutment, which causes the threads to tighten and provides a rotationally fixed connection between the impeller 1 and the shaft 2.

In addition, however, the inclination of the abutment surfaces from the radial direction urges the connector 3 radially outwardly so that the shaft-side end of its outer surface 14 more strongly grips the radially inner surface of the hub extension H. The point of maximum grip between the impeller 1 and the connector 3 is thus forced to be at the shaft-side end of the joint. Advantageously, as the impeller is operated, the point of maximum grip remains at the shaft-side end, so that, although the impeller 1 and the connector 3 expand at different rates, on cooling they return to their original positions. In this way, "walking" of the impeller 1 can be avoided, which allows the impeller 1 to be driven by a higher torque and therefore increases the maximum pressure ratio of the impeller 1.
Also, by containing the threaded connection between the connector 3 and the shaft 2 in the central recess of the hub extension H, an axially compact arrangement is achieved. The frictional connection between the connector 3 and the impeller transmits, in use, substantially all of the torque between the shaft 2 and the impeller 1. Further, as there is no need to fit a constraining ring of the type described in EP1394387 to the hub extension H, regrinding operations can be avoided during fitting of the connector 3.

If there is any tendency for the impeller 1 to "walk", advantageously this can be monitored by measuring the size of the gap that would open up between the flange portion 8 and the end face 9. For this reason, it is preferred that the flange portion 8 and the end face 9 determine the relative axial positions of the connector 3 and the hub extension H. Alternative pairs of facing features that could be configured to abut each and thereby determine the relative axial positions (such as the threaded portion 12 and the end of the recess) are less amenable to inspection.

Figure 3 is a close-up schematic view of a seal between a section of a casing of an impeller and the flange portion 8 of a further embodiment of the connector 3. In this case, instead of a seal formed by a sealing ring, the hub extension H and flange portion 8 on one side and the casing section 15 on the other side have engaging surfaces 19 carrying respective sets of machined grooves which interlock to form a labyrinth seal.

An option is to form the impeller 1 from a metal matrix composite having an aluminium alloy matrix and silicon carbide particulate reinforcement. For example, the composite can be an AMC Xfine™ composite based on an AA2124 or AA6061 aluminium alloy system reinforced with up to 30% by volume of silicon carbide particulate, and available from Aerospace Metal Composites of Farnborough, UK. Such a composite may have a coefficient of thermal expansion of 14-17x10⁻⁶/K. In comparison with an impeller formed of unreinforced aluminium alloy, the differential thermal forces acting between the impeller and the connector can thus be substantially reduced, further reducing the tendency of the impeller 1 to "walk" off the connector 3. The volume average particle diameter of the particulate reinforcement may be 2 microns or less to improve the machinability of the composite.

Figure 4 shows schematically a sectional elevation of a further embodiment of the connector 3. This embodiment is similar to the embodiment of Figure 1 except that the shaft 2 has two centring portions 5a, 5b, and the connector has two corresponding centring portions 10a, 10b. The threaded portions 7, 12 of the shaft 2 and the connector are located axially
between the engaging pairs of centring portions such that, on each of the shaft 2 and the
connector 3, the respective diameters of the threaded portions and the centring portions
decrease towards the impeller.

Figure 5 shows a sectional elevation of a further embodiment of the connector. This
embodiment is similar to the embodiment of Figure 1 except that the connector is formed
from a first subcomponent and a second subcomponent.

The first subcomponent is of cup-like shape and has a first sleeve portion 23 forming the wall
of the cup, a threaded portion 12 with a threaded bore 11 forming the base of the cup, and a
flange portion 8 with an inclined abutment surface 21 around the mouth of the cup. The
second subcomponent is a cylindrical second sleeve portion 24. To form the connector, the
second sleeve portion 24 is shrink fitted onto the first sleeve portion 23 such that the two
sleeve portions 23, 24 are coaxial and frictionally connected, with the second sleeve portion
24 covering the outer surface of the first sleeve portion 23.

The first subcomponent is formed of a medium carbon steel such as EN8. The second
subcomponent is formed of a material, such as stainless steel, bronze or brass, having a
coefficient of thermal expansion which is intermediate the coefficients of thermal expansion
of the aluminium alloy impeller 1 and the first subcomponent.

The connector 3 is fitted on to the hub extension H in the same way as the connector of
Figure 1, the outer surface 14 of the second sleeve portion 24 frictionally connecting to the
radially inner surface of the hub extension H. Likewise, after the connector 3 is fitted on to
the hub extension H, a screw-threaded portion 7 of the shaft 2 is screwed onto the threaded
portion 12 of the connector, the respective centring portions 5, 10 of the shaft 2 and the
connector 3 ensuring the shaft 2 aligns with the axis of the impeller 1. The threads are
screwed until the opposing inclined abutment surfaces 4, 21 of the shaft 2 and the flange
portion 8 come into abutment, which causes the threads to tighten and provides a rotationally
fixed connection between the impeller 1 and the shaft 2, and which also urges the connector
3 radially outwardly so that the shaft-side end of the outer surface 14 more strongly grips the
radially inner surface of the hub extension H.

Advantageously, however, by forming the second subcomponent from a material having an
intermediate coefficient of thermal expansion, the differential thermal forces acting across
each frictional connection can be reduced, whereby the tendency for the impeller 1 to “walk” can be further reduced.

While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given this disclosure. For example, in embodiments such as that of Figure 4, instead of the connector having a centring portion 10a, the impeller may have a centring portion at the base of the recess that engages with the centring portion 5b of the shaft. In another example, particularly if the shaft 1 is formed of stronger material than the connector 3, the threads carried by the threaded portion 12 of the connector 3 may be protected by a helicoil formation to prevent damage to the threads of the connector 3.

Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the invention.

All references referred to above are hereby incorporated by reference.
CLAIMS

1. A connector (3) for connecting an impeller (1) to a shaft (2), the impeller having a shaft-side hub extension (H) with a central recess wherein:
   the connector is inserted into the recess to frictionally connect an outwardly facing surface (14) of the connector with a radially inner surface of the hub extension;
   the connector has a threaded portion (12) carrying a thread which screws onto a corresponding threaded portion (7) of the shaft;
   the connector has an abutment surface (21) which engages a corresponding abutment surface (4) of the shaft when the thread portions are screwed together, thereby tightening the threads to provide a rotationally fixed connection between the impeller and the shaft; and
   the abutment surfaces are inclined from the radial direction such that, when the abutment surfaces are mutually engaged as the thread portions are screwed together, the outwardly facing surface of the connector is urged radially outwardly to increase the strength of the frictional connection with the radially inner surface of the hub extension.

2. A connector according to claim 1, wherein the abutment surfaces are inclined at an angle (α) to the radial direction of 30° or more.

3. A connector according to claim 1 or 2, wherein the abutment surfaces are inclined at an angle (α) to the radial direction of 80° or less.

4. A connector according to any one of the previous claims, wherein the abutment surface of the connector is arranged such that the shaft-side end of the outwardly facing surface of the connector is urged radially outwardly.

5. A connector according to any one of the previous claims, wherein the central recess is a blind hole.

6. A connector according to any one of the previous claims, wherein the frictional connection between the outwardly facing surface of the connector and the radially inner surface of the hub extension transmits, in use, substantially all of the torque between the shaft and the impeller.

7. A connector according to any one of the previous claims, wherein the threaded portion of the connector is within the central recess.
8. A connector according to any one of the previous claims, wherein the connector is formed of a material having a coefficient of thermal expansion which is greater than the coefficient of thermal expansion of the material of the shaft.

9. A connector according to any one claims 1 to 7 which has a first subcomponent and a second subcomponent, wherein:

- the first subcomponent has a first sleeve portion (23) which is coaxial with the hub extension, and the second subcomponent has a second sleeve portion (24) which is sandwiched between the first sleeve portion and the hub extension, such that the second sleeve portion is frictionally connected on one side with the first sleeve portion and on the opposing side provides the outwardly facing surface which is frictionally connected with the radially inner surface of the hub extension;

- the first subcomponent provides the threaded portion of the connector and the abutment surface of the connector; and

- the impeller and the first subcomponent are formed of respective materials having different coefficients of thermal expansion, and the second subcomponent is formed of a material having a coefficient of thermal expansion which is intermediate the coefficients of thermal expansion of the impeller and the first subcomponent.

10. A connector according to any one of the previous claims, wherein the connector and/or the impeller has one or more centring portions (10; 10a, 10b) having respective engagement surfaces which engage with one or more corresponding centring portions (5; 5a, 5b) of the shaft, the threaded portion of the connector and the centring portions of the connector and/or the impeller being distributed along the impeller axis.

11. A connector according to any one of the previous claims, wherein the impeller has a casing and the connector and/or the hub extension forms a seal with a section (15) of the casing.

12. A connector according to any one of the previous claims, wherein the connector is formed with or carries a circumferential oil thrower formation (R) at its radially outer surface.

13. An impeller having a shaft-side hub extension with a central recess and fitted with a connector according to any one of the previous claims, the connector being frictionally connected at an outwardly facing surface with a radially inner surface of the hub extension.
14. The impeller fitted with a connector of claim 13, which impeller is connected to a shaft having a corresponding threaded section, the thread of the threaded portion of the connector screwing onto the corresponding threaded portion of the shaft.

15. A turbocharger having the connected impeller and shaft of 14.
**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

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<th>Category</th>
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<th>Identity of document and passage or figure of particular relevance</th>
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<td>US4915589 A&lt;br&gt;(Elektroschmelzwerk Kempten GmbH): See inclined abutment surfaces of coupling elements 15, 16 in figure 2 in particular.</td>
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**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:

- F01D; F04D

The following online and other databases have been used in the preparation of this search report:

- EPDOC, WPI, Selected full-text databases

**International Classification:**

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