June 23, 1964 R. L. SMIRL 3,137,915

HYDRODYNAMIC COUPLING

Original Filed May 27, 1955 2 Sheets-Sheet 1

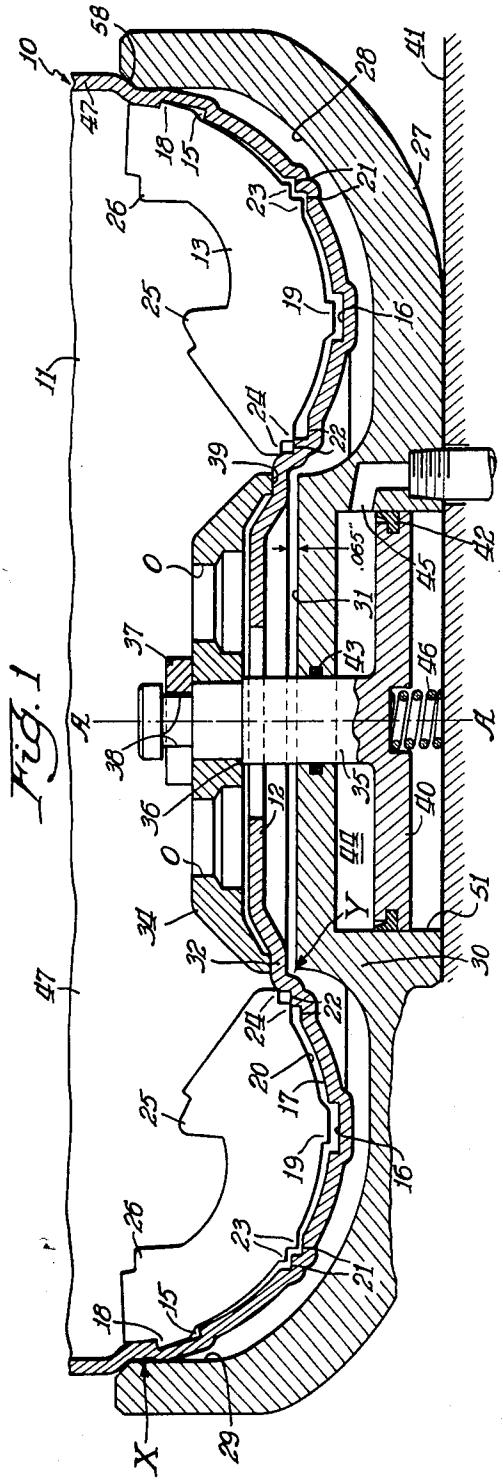


Fig. 1

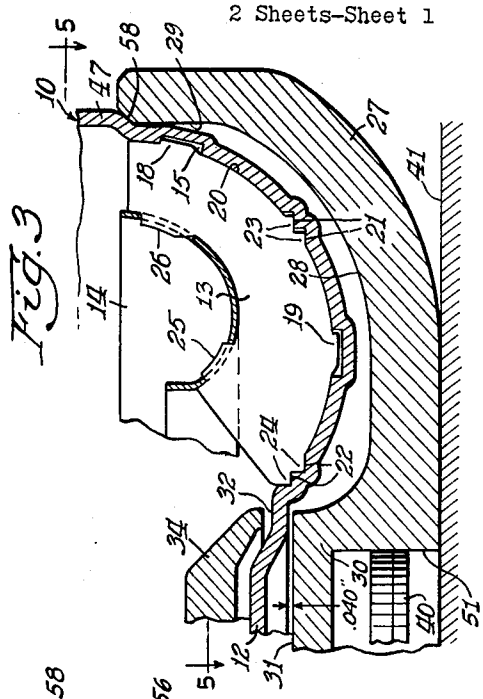


Fig. 3

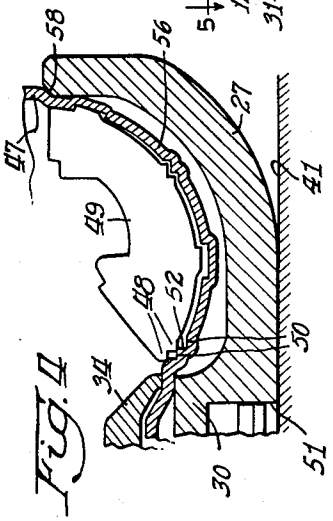


Fig. 4

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Fig. 2

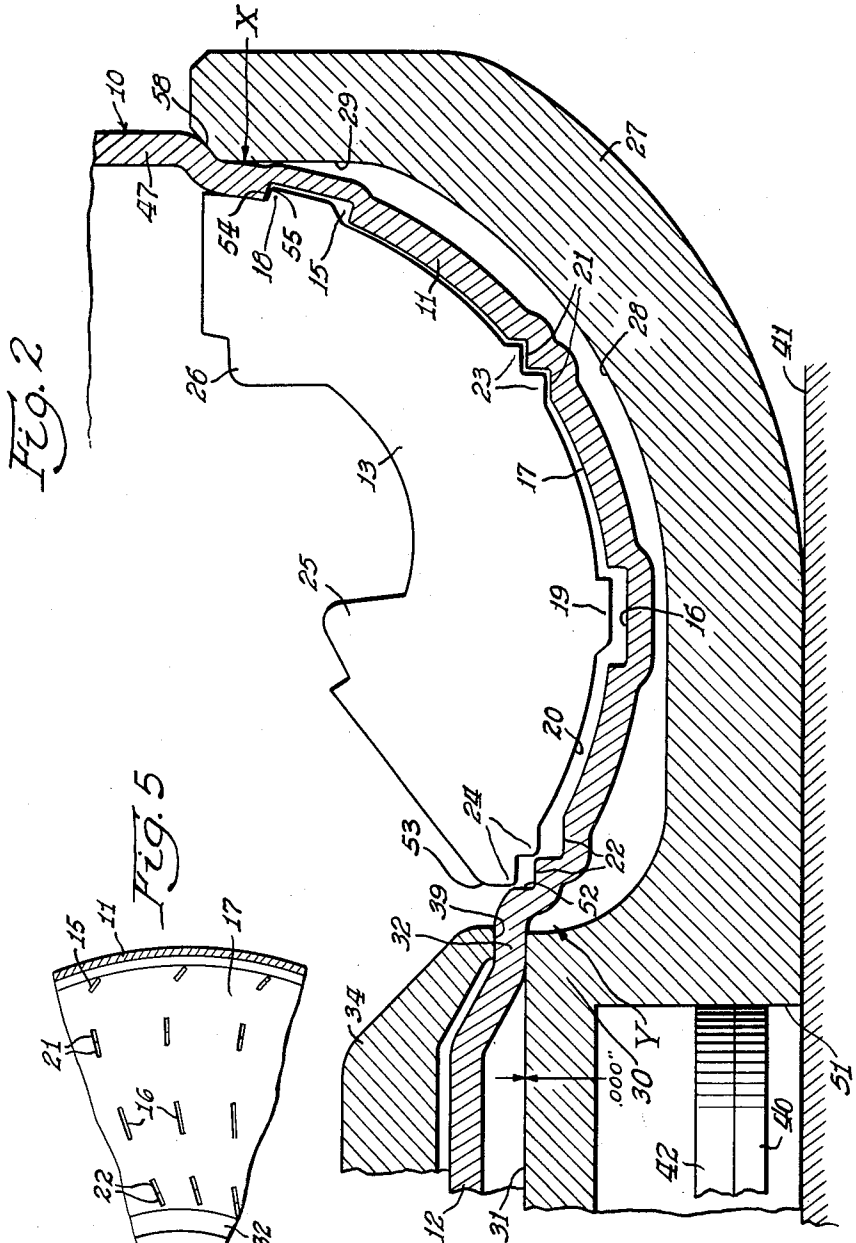


Fig. 5

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3,137,915

HYDRODYNAMIC COUPLING

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Original application May 27, 1955, Ser. No. 511,591, now Patent No. 2,948,226, dated Aug. 9, 1960. Divided and this application Dec. 23, 1959, Ser. No. 861,563

8 Claims. (Cl. 29—23.5)

This invention relates to hydrodynamic coupling devices and more particularly to vaned elements of such devices and a method and apparatus of fabricating or assembling the same.

This application is a division of applicant's Patent 2,948,226, dated August 9, 1960.

In prior vaned hydrodynamic coupling elements, the vanes have been assembled with their supporting members, such as semi-toroidal shells or housings, by positioning the vanes in the housing separately and welding the vanes individually or collectively to the housing; or by clinching over tabs on the vanes extending through slots in the housing; or flexing each vane to position its tabs within slots in the housing and releasing the flexed vane to engage the edges of the slot, followed by a tab clinching or vane-staking operation to insure retention of the vanes in the housing. Any of these arrangements require expensive equipment and consumption of considerable time and labor to assemble the vanes and housing.

It has been observed that, in the use of such vaned coupling elements with the progressively higher engine speed now conventionally the trend in automotive vehicles, the vanes must not only be mechanically interlocked with the shell, but the vane and shell assembly must be subjected to a brazing operation to insure the vanes are retained in the shell. These multiple assembly operations are necessary due to the hydrodynamic pressure forces acting on the semi-toroidal shell and tending to distort the shell by sufficiently axially deflecting or "ballooning" the shell to disrupt the vanes disposition with respect to the shell and loosening or dislodging the vanes from the shell. Axial deflection of the shell of these vaned elements also presents a problem to the correct operation of the hydrodynamic coupling device as the impeller thereof is usually provided with a hub sleeve connected to the gears of a pump furnishing oil under pressure to the device and maintaining the oil under pressure in the device for satisfactory performance of the device, and an undesirable amount of axial deflection of the impeller shell causes the pump gears to jam.

The primary object of the invention is to provide an apparatus for making an improved hydrodynamic coupling element and method of making the same in which the coupling element comprises a hollow shell preferably in the form of a substantially semi-toroidal stamping of sheet metal, such as steel, and a plurality of vanes, preferably of sheet metal, such as steel, having portions interengageable with portions of the shell to provide a mechanical interlock with the shell, the invention being particularly characterized by the shell being flexed by pressure sufficient to expand the shell within its elastic limit to provide a considerable contractive force of the shell, when the pressure is released, affording a preloading of the shell to firmly engage the vane portions with the shell portions, and, as the vanes are disposed radially of the shell and in annular array within the shell, the vanes have a rigidity capable of withstanding the contractive force of the preloaded shell without bending or distorting the original shapes of the vanes. Since the shell has sufficient yield strength to carry the hydrodynamic forces unaided, it is possible to preload the shell sufficiently, within its elastic limit, to take advantage of the stiffness

of the vanes in the assembly to reduce axial deflection of the shell to a negligible quantity and to insure the vanes being securely held by the shell at high engine speeds, for example, such as 4000 r.p.m.

Another object of the present invention is to simplify the construction and arrangement of a hydrodynamic coupling element, and to provide an improved method of assembling the respective parts thereof.

Another object of the invention is to provide an improved hydrodynamic coupling element and method of assembling the same in which a semi-toroidal sheet steel housing has slots therein and is capable of expanding to receive projections on the vanes in the slots and contracting to engage the projections with the housing with sufficient force to positively interlock and securely hold the vanes in the housing.

It is a further object of the invention to provide an improved hydrodynamic coupling element and method of assembling the same which may include a hollow housing of any metal capable of expanding and contracting to position vanes of sheet metal, or cast metal, having portions thereof fitted into recesses in the housing and engaging the housing edges defining the recesses.

A further object of the invention is to provide an improved hydrodynamic coupling element and method of assembly thereof in which a hollow flexible housing is provided with a semi-toroidal surface having slots therein and tabs on the vanes extend from the arcuate margins thereof, which margins are of less curvature than the surface of the housing, the housing being flexed to expand the same to decrease the curvature of the surface thereof to permit engagement of the arcuate margins of the vanes and positioning of the vane tabs in the housing slots, the shell then being allowed to contract to forcibly engage the vane edges with the housing slot edges and to continue to exert a contractive force to hold the vanes and housing in assembly.

A further object of the invention is to provide a new hydrodynamic coupling element assembly apparatus for placing and securing the vanes and housing together.

Additional objects, aims and advantages of the invention will be apparent to persons skilled in the art from a consideration of the construction and assembly of the hydrodynamic coupling element and its method of assembly and apparatus for assembling as contemplated in the within description, and in the accompanying drawing in which:

FIG. 1 is an axial sectional view of a hydrodynamic coupling element and the preferred form of apparatus, such as a press, for connecting a plurality of vanes to the hollow shell of the element, and illustrating the shell and vanes being positioned for assembly in the press and prior to the assembling operation;

FIG. 2 is a fragmentary axial sectional view showing the press completely closed; and

FIG. 3 is a fragmentary axial sectional view showing the press open, and the vanes and shell in assembled condition;

FIG. 4 is a view similar to FIG. 2 illustrating the press in closed position and in use with a shell shallower than that shown in FIG. 1; and

FIG. 5 is a fragmentary sectional plan view of the impeller taken along line 5—5 of FIG. 3 and having the vanes and core ring removed; the view is representative for both embodiments of the disclosed invention.

The drawings are to be understood as being more or less of a schematic character for the purpose of disclosing typical or preferred forms of the improvements which are contemplated herein, and in these drawings like reference characters identify the same parts in the different views.

Referring to the drawings, the improved hydraulic torque converter vaned element is generally indicated at

10 and comprises a semi-toroidal annular shell or housing 11 which may be stamped sheet metal and capable of expanding and contracting. The shell has its radially inner periphery defined by a flat hub portion 12 for piloting the element on a shaft, or the like, for rotation about its axis indicated by the line A—A in FIG. 1. The shell 11 is provided with a plurality of vanes 13 positioned within the semi-toroidal shell 11 and connected to the shell and a core ring 14 of semi-toroidal shape, as shown more particularly in FIG. 3, to provide the hydraulic torque converter vaned element. The vaned element 10 is in its preferred embodiment illustrated as an impeller of a hydraulic torque converter, which in conventional practice, also includes a turbine and a stator for providing a closed toroidal circuit for the circulation of fluid through the impeller, turbine, and stator, the vanes of the impeller, turbine, and stator having curvatures designed to provide infinitely variable torque ratios from the stall condition and to the coupling range of the torque converter, when the stator is held stationary, as it is well-known in the hydraulic torque converter art.

FIG. 3 illustrates the shell, vanes and core ring in assembly, the shell 11 being provided with radially spaced elongate openings, recesses, or slots 15 and 16 in its semi-toroidal inner surface 17 respectively receiving tabs 18 and 19 formed on the arcuate outer edges or margins 20 of the vanes, the shell being further provided with a plurality of radially spaced sets of V-shaped openings, recesses, or notches 21 and 22, with one set of notches 21 being disposed between the slots 15 and 16, and the other set of notches 22 being disposed radially inwardly of the slot 16, these sets of notches 21 and 22 receiving pairs of V-shaped tabs and teeth 23 and 24 respectively on the arcuate outer margin 20 of the vane.

A feature of the present invention resides in the shell 11 being composed of a metal capable, when stamped into the form of the shell, to flex sufficiently to expand and contact; the semi-toroidal surface of the shell being formed with a curvature greater (the term greater curvature is used throughout to mean greater deviation from a straight line) than the curvature of the arcuate outer margin or edge of each vane and, accordingly, the radius of curvature of the shell surface being less than that of the vane edges; and the vanes being rigid in an axial direction and being restrained laterally by tabs engaging slots in the shell 11 and core ring 14. It will be apparent that the free curvature of the shell and the spacing between the outer slot 15 and inner slots 22 may be controlled to provide an interference or pre-loaded fit with the vanes. Furthermore, it is contemplated that pressure be applied to the shell to cause it to expand sufficiently to decrease the curvature of the semi-toroidal surface thereof to permit the alignment and positioning of the vane tabs in the notches and slots in the shell, and the positioning of the core ring 14 over the tabs 25 and 26 and thereafter to remove the pressure to allow the shell to contract to engage the outer arcuate margin of each vane with the semi-toroidal surface of the shell and to tightly engage the vane tabs with the edge of the slots and interlock and securely hold the vanes in the housing.

More particularly and referring to the drawing, the shell 11 may be a sheet steel stamping having a thickness permitting flexing of the shell in the region X—Y when its outer periphery is held against axial movement and its hub 12 is moved axially by the application of force to the hub to expand the shell and to cause the curvature of the semi-toroidal surface 17 to be decreased to less than the curvature of the arcuate margins 20 of the vanes 13, i.e., the radius of curvature of the surface 17 is increased to be greater than the radius of curvature of the arcuate margins of the vanes 13. Therefore use of the term "greater curvature" is defined to mean greater deviation from a straight line or mathematically may be represented by an increasing value of $1/R$, R being the radius of curvature. Prior to applying force to the hub 12 of the

shell, the vanes may be inserted in the shell and held in the shell, which may be by any suitable slotted locating plate receiving the vanes, with the vane tabs 18 positioned in the slots 15 of the shell and it will be noted that, in FIG. 1, the curvature of the surface 17 of the shell radially spaces the notches and slots in relation to the tabs 23, 19 and 24 on the vanes to prevent entry of the tabs in the notches 21 and 22 and slot 16 and also the surface 17 of the shell is spaced from the outer margins 20 of the vanes. However, as the shell is expanded, the decreased curvature of the surface 17 of the shell allows the tabs to be inserted in the notches 21 and 22 and slot 16, and to engage the surface 17 with the arcuate margins 20 of the vanes. Upon the removal of pressure on the hub 12 of the shell, the shell contracts to force the vane tabs, and particularly the tabs 18, 23 and 24, into engagement with the edges of the notches and slot 15 in the shell to hold the vanes and shell in assembly and to prevent movement of the vanes axially and radially of the shell. More particularly, the remote edges or sides (side 53 of teeth 24 and side 55 of tab 18) are forced into tight engagement with the remote sides or edges (side 54 of notch 15 and side 52 of slot 22) by the removal of pressure. Upon assembly of the shell and vanes as described, the core ring 14 is positioned on the inner arcuate margins of the vanes with the tabs 25 and 26 extending therefrom positioned in slots in the core ring, the vane tabs 25 and 26 being bent over to engage the inner surface of the core ring to complete the assembly of the impeller.

The housing 11 and vanes 13 are assembled by the apparatus and in the manner shown in FIGS. 1, 2 and 3. The apparatus employed for fixing the vanes in the housing comprises an arrangement whereby the vane tabs 18 are positioned in the slots 15 to dispose the vanes in proper radial array and equidistantly spaced from each other and the hub 12 of the shell is then forced downwardly and along the axis A—A of rotation of the vaned element to cause the curvature of the surface 17 of the shell to decrease so that the remaining tabs of the vanes may be inserted within the notches and slot 16 in the shell, the pressure on the hub 12 of the shell then being removed to allow movement outwardly and upwardly of the shell 11, along the axis of the shell to provide forces in the shell attempting to return the surface 17 of the shell to its initial curvature but being restrained by the tabs tightly engaging the ends of the slots and notches in the shell and securely holding the vanes in the shell.

More particularly, the apparatus for assembling the vanes with the shell comprises a press having an annular bed plate 27 mounted on a stationary support 41 and provided with an inner semi-toroidal surface 28 of substantially less curvature than the curvature of the shell 11 and terminating at the inner peripheral cylindrical surface 29 at the upper radially outer margin of the bed plate. The radially inner hub 30 of the bed plate is provided with a top flat surface 31 for engagement with a complementary flat surface on an offset portion 32 of the hub 12 of the shell 11, connecting the hub 12 with the semi-toroidal portion of the shell. The pressure member of the press comprises an annular thrust plate 34 located centrally of the bed plate and supported on a rod 35 positioned for movement downward along an axis corresponding to the axis of the bed plate and the shell, the rod extending through an axial opening in the plate 34 and having a shoulder 36 engaging the edge of the opening in the plate. The plate is held tightly against the shoulder by a C-shaped washer 37 received within an annular groove 38 in the rod 35. This assembly of the plate 34, rod 35 and washer 37 causes the plate 34 to move axially on movement of the rod 35. The plate 34 has a cup-like portion provided by a downwardly extending flange having a flat surface 39 engageable with the offset portion 32 of the hub 12 of the shell 11.

The plate 34 may be provided with a plurality of openings O for positioning the plate on the rod and for re-

moving the plate from the rod on withdrawing the washer from the rod.

The thrust plate 34 is movable axially of the bed plate 27 and the shell 11 by a piston 40 located within a cavity 51 in the bed plate and connected to the rod 35. The piston 40 is provided with a lip type seal 42 engaging the cylindrical side wall of the cavity and the rod 35 is surrounded by and engaged with a seal ring 43 to prevent the escape of fluid under pressure in the chamber 44 defined by the piston 40 and the side and top walls of the cavity formed in the bed plate 27 upon fluid under pressure flowing into the chamber through a port 45 connected to a pump (not shown) for actuating the piston 40 downwardly to engage the thrust plate 34 with the shell 11. At this time, a spring 46, having one end received within the piston 40 and its other end seated on the support 41, is compressed by the piston and, upon the pressure of the fluid being relieved in the chamber 44, the spring will be effective to move the piston 40 and thereby the plate 34 upwardly away from the shell.

As will be seen from an inspection of FIG. 1, the shell 11 is received within the bed plate 27 and is provided with an outer cylindrical portion 47 connected to the semi-toroidal portion of the shell and being formed to provide a shoulder 58 engaging the upper edge of the bed plate to position the axis of the shell in alignment with the axis of the bed plate. Thus, it will be seen from inspection of FIG. 1 that the shell 11 only engages the upper edge of the bed plate 27, the hub 12 of the shell being spaced from the bed plate and the thrust plate 34 being positioned above and spaced from the hub 12 of the shell 11. The vanes 13 are then inserted in the shell and placed in radial array about the semi-toroidal surface 17 with the tabs 18 positioned within the slots 15 of the shell and the radially inner end of the vane defining the end tab 24 being positioned in point contact with the portion of the hub defining the radially innermost notch 22 of the shell. It will be apparent that, as the slots 15 are elongate and only of sufficient width to accommodate the tabs 18, the tabs 18 will be held in the slots 15 to maintain the vanes in the shell in the position shown in FIG. 1. Referring to FIG. 1, the shell hub 12 and the bed plate hub 30 are axially spaced apart, for example, a distance of .065 inch. Referring to FIG. 2, upon movement of thrust plate 34 downwardly, the surface 39 of the flanged portion of the thrust plate will engage the adjacent surface of the hub of the shell 11 and move the hub of the shell downwardly to engage the surface 31 of the bed plate 27. As the engagement at 58 of the shell 11 with a bed plate 27 prevents downward movement of the outer peripheral edge of the shell 11, the semi-toroidal portion of the shell will move downwardly to cause deformation or expansion of the shell in the region X–Y to thereby decrease the curvature of the inner surface 17 of the shell to the curvature of the adjacent arcuate margins of the vanes, so that the blades may be moved downwardly, from the position shown in FIG. 2 so as to position the tabs within the slots and notches in the shell as shown in FIG. 3. When the thrust plate is raised clear of the shell as shown in FIG. 3, the flexed shell will attempt to contract to regain its original shape as shown in FIG. 1, but will be prevented from doing so by the vanes having their tabs received within and engaging the edges of the slots and notches in the shell. This will be obvious from inspection of FIGS. 1 and 3 wherein the shell in its unflexed state, as shown in FIG. 1 has .065 inch clearance between the bottom of the hub of the shell and the top of the hub of the bed plate 27, and in the assembly of FIG. 3, the shell, in attempting to regain its normally unflexed condition, will be prevented by the vanes and remain flexed as indicated by the clearance of .040 inch between the hubs of the shell and bed plate.

It will be noted that the stamped sheet metal or steel vanes of a hydraulic torque converter element are provided with accurately calculated and formed shapes to obtain controlled directional flow of fluid through the vaned passages of the element and determining the torque-multiplying characteristics of the hydraulic torque converter. These shapes of the vanes are critical and in the assembly with the shell, it is imperative they be maintained as close as possible to their predetermined stamped form for obtaining the desired torque-multiplying characteristics thereof as any variations in the curvatures of the vanes will produce entirely different torque-multiplying characteristics of the vanes. Due to this factor, the vanes in the present invention are sufficiently rigid to prevent bending or deformation in the assembly with the shell and core ring and are firmly fixed and positively held against movement or displacement. For this purpose, the vanes are firmly interlocked with the shell, when the assembly is completed, by a built-in preload or stress trapped between the vane tabs and the shell. This advantageous feature minimizes deflections of the shell in operation due to hydrostatic and centrifugal pressures. With the built-in preload, a force greater than the pre-stressed load has to be applied before any appreciable deflection takes place in operation, whereas in prior methods of assembly with the shell not being under any pre-load or stress, the shell begins deflecting with small hydraulic pressures.

After assembling the vanes with the shell as described, the vane tabs 25 and 26, as shown in FIG. 3, are inserted within the slots of the core ring and the tabs are then bent over to engage inner surface of the core ring to complete the assembly of the impeller, the thrust plate then being raised from the assembled vaned element 10.

FIG. 4 illustrates a modification of the invention wherein the shell 56 is formed shallower than the shell 11 in FIGS. 1, 2 and 3 to obtain the greatest preloading, without exceeding the elastic limit, of the shell and the amount of stretch or expansion for assembly purposes is limited to a point leaving a slight interference at the V-shaped tabs 48 of the vanes 49 with the edges of the notches 50 in the shell 56. More particularly, and referring to FIG. 4, the shell is flexed by the apparatus and the vanes 49 are placed in position in the shell 56, as shown in FIG. 4, and with the tabs 48 of the vanes engaging the edges of the notches 50 and the vanes are then rapped by a mallet at their inner ends to snap them over the interference provided by the edges of the notches. After the core ring is installed on the vanes in the manner previously described, the load on the shell by the apparatus is released and a very tightly preload assembly results.

It is within the contemplation of the present invention that the vanes can be of the cast aluminum type having different thicknesses throughout the vane, instead of the uniform thickness of sheet metal vanes. Also, the shell should be made of a resilient metal and preferably sheet steel, which has the ability to be flexed or deformed and to attempt to return to its normal shape, or to "spring back," upon release of pressure by the apparatus to place the vanes in engagement with the shell with sufficient preload or stress to positively interlock the vanes with the shell.

It will be apparent from the foregoing description that a vaned element of a hydrodynamic coupling device, designed and assembled in conformance with the invention, has the advantageous characteristic of providing a significant reduction in axial deflection, or "ballooning" of a shell over prior prefabricated and assembled vaned elements, and which feature is of paramount importance in contributing a vane and shell assembly capable of withstanding the hydrodynamic fluid forces resulting in the operation of engines at the high speeds now current in automotive vehicles.

In actual and comparative tests of vaned assemblies, a cast aluminum shell and sheet steel vanes mechanically interlocked therewith and in which the shell was provided with 68 deep external ribs or fins for maximum rigidity

of the shell, the shell had greater axial deflection at 4500 r.p.m. than a preloaded steel assembly with only a 5/32" thickness of the shell. While brazing a mechanically interlocked vane, shell and core ring assembly is of value in maintaining the vane and core ring assembly in contact with the shell during high speed operation, a distinction between the concept of stiffness as opposed to strength will help visualize how preloading the vane and shell assembly can given the same effect of brazing up to the speed where the preloading force is cancelled by the hydrodynamic fluid forces. Since the steel shell has sufficient yield strength to carry the forces unaided, it is possible to preload sufficiently, within the elastic limit of the shell, to take advantage of the stiffness of the vane and core ring assembly. For example, if a certain brazed vaned element assembly has .015" deflection at 4000 r.p.m. and if a similar shell, core ring and vane assembly in which the vanes are flexed to engage slots in an unflexed steel shell and are then fixed to the shell by deforming edges of the slots in the shell to stake the vanes in the shell, shows a deflection of .050" at the same speed, the forming the shell of the present invention to give .050" preload in its assembled condition will prevent the shell from moving out of contact with the vane and core ring assembly, and at 4000 r.p.m. only .015" to .020" deflecton is found.

In prior vaned elements, the vanes are flexed to engage seats or slots in a shell and this assembly method is not easy to apply to flat or substantially flat vanes. However, it has been determined that a vane and shell assembly, produced by practicing the present invention is equally effective with either flat or curved vanes and provides better deflection characteristics with flat vanes than with curved vanes.

It will be apparent to those skilled in the art that the invention is also applicable to vaned elements of the fluid coupling of non-torque converting type and it is intended that the expression "hydrodynamic coupling device" in the claims covers vaned elements of the torque converting and non-torque converting type.

It is to be understood that the expressions "openings" and "recesses" in the claims are intended to define slots or notches.

While this invention has been described in detail in its present preferred form or embodiment, it will be apparent to persons skilled in the art, after understanding the improvements, that various changes and modifications may be made therein without departing from the spirit or scope thereof. It is therefore aimed in the appended claims to cover all such changes and modifications.

I claim:

1. In a method of making a vaned element of a hydrodynamic coupling device, the steps comprising forming a hollow shell of flexible material having a substantially semi-toroidal portion with an inner surface and having an axis; forming radially spaced sets of circumferentially spaced recesses in said surface of said shell; forming a plurality of vanes each having an arcuate margin with a curvature greater than the curvature of said surface of said shell and having spaced first and second tabs on said margin thereof; and connecting said vanes to the shell by holding the radially outer periphery of semi-toroidal portion of said shell against movement while applying pressure to the radially inner periphery of said semi-toroidal portion of said shell to move the latter periphery in a direction parallel to said axis of said shell to expand said shell and thereby decrease the curvature of said surface of said shell to less than the curvature of said arcuate margins of said vanes; positioning the tabs of said vanes in said recesses in said shell; and releasing the pressure on said radially inner portion of said shell to allow the flexed shell to contract to engage the sides of the tabs on each vane with the corresponding remote edges of the recesses and to engage said surface of said shell with said margin of each vane.

2. In a method of making a vaned element of a hydrodynamic coupling device, the steps comprising forming a hollow shell of flexible material having an inner substantially semi-toroidal surface; providing radially spaced sets of circumferentially spaced recesses in said surface of said shell; forming a plurality of vanes each having an arcuate margin with a curvature less than the curvature of said surface of said shell and having spaced first and second tabs on said margin thereof, the linear distance between the edges of the recesses of each set remote from each other being less than that between the edges of the tabs on each vane remote from each other; and connecting said vanes to the shell by holding the radially outer portion of said shell against movement while applying pressure to the radially inner portion of said shell to expand said shell and thereby decrease the curvature of said surface of said shell to less than the curvature of said arcuate margins of said vanes; positioning the tabs of said vanes in said recesses in said shell; and releasing the pressure on said radially inner portion of said shell to allow the flexed shell to contract to engage the vane tabs with the edges of the recesses remote from each other and to engage said surface of said shell with said margin of each vane.

3. In a method of making a vaned element of a hydrodynamic coupling device, the steps comprising forming a hollow annular, semi-toroidal shell of flexible material; forming a plurality of vanes; forming spaced portions in both said shell and vanes in a manner to facilitate connection of said shell portions to said vane portions, the spaced portions on said vanes being spaced farther apart than the spaced portions of said shell; applying pressure to said shell to flex and expand said shell; inserting the vanes in said shell; and releasing the pressure on said shell to contract said shell to engage said connecting portions of said shell and vanes.

4. In an apparatus for assembling a substantially semi-toroidal flexible shell symmetrical about an axis thereof to a plurality of vanes having arcuate outer margins with curvatures less than the curvature of the inner surface of the shell, a hollow holder receiving the shell and having a substantially circular rim portion engageable with the outer surface of the shell adjacent the outer periphery of the shell to hold the latter against movement in at least one direction, and a central portion adjacent to but axially spaced from the inner periphery of the shell; a pressure member; means for supporting the pressure member axially of the rim portion of the holder for axial movement and into engagement with the inner periphery of the shell to move the inner periphery of the shell opposite in direction to said one direction into engagement with the central portion of the holder to flex and expand the shell and thereby decrease the curvature of the inner surface of the shell to less than that of the vane margins for insertion of the vanes in the shell to partially contact the arcuate margins of the vanes with the inner surface of the shell, movement of the pressure member away from the inner periphery of the shell allowing contraction of the flexed shell to correspond the curvature of the inner surface of the shell to that of the arcuate margins of the vanes to engage the arcuate margins of the vanes with the inner surface of the shell.

5. In an apparatus for assembling a substantially semi-toroidal shell of flexible material having radially spaced sets of circumferentially spaced recesses in the inner surface thereof with a plurality of vanes having arcuate outer margins with curvatures less than the curvature of the inner surface of the shell and having spaced tabs on the outer margins spaced apart a greater distance than the recesses of the shell, a hollow holder receiving the shell and having a substantially circular rim portion engageable with the outer surface of the shell adjacent the outer periphery of the shell, and a central portion adjacent to but axially spaced from the inner periphery of the shell; a pressure member; means for supporting the pressure member axially of the rim portion of the holder and for axial movement into engagement with the inner periphery

of the shell to move the inner periphery of the shell into engagement with the central portion of the holder to flex and expand the shell and thereby decrease the curvature of the inner surface of the shell to less than that of the vane margins for insertion of the vanes in the shell with arcuate margins of the vanes partially contacting the inner surface of the shell and to position the vane tabs in the shell recesses, movement of the pressure member away from the inner periphery of the shell allowing contraction of the flexed shell to correspond the curvature of the inner surface of the shell to that of the arcuate margins of the vanes to engage the arcuate margins of the vanes with the inner surface of the shell and to forcibly engage the vane tabs with edges of the recesses of the shell.

6. In an apparatus for assembling a substantially semi-toroidal shell of flexible material having an inner surface with radially spaced sets of circumferentially spaced recesses therein and a plurality of vanes having arcuate outer margins each having a curvature less than the curvature of the inner surface of the shell and having spaced tabs on the outer margins spaced apart a greater distance than the recesses of the shell, a hollow holder receiving the shell and having a substantially circular rim portion engageable with the outer surfaces of the shell adjacent the outer periphery of the shell, and a pressure member disposed axially of the rim portion of the shell and adjacent the inner periphery of the shell so that upon relative axial movement of the holder and pressure member toward each other, the inner periphery of the shell will be moved in an axial direction relative to the outer periphery of the shell to flex and expand the shell and thereby decrease the curvature of the inner surface of the shell to less than that of the vane margins to enable insertion of the vanes in the shell while permitting the arcuate margins of the vanes to partially contact the inner surface of the shell permitting the vane tabs to be positioned in the shell recesses, release of the pressure member away from the inner periphery of the shell allowing contraction of the flexed shell and permitting the curvature of the inner surface to correspond with that of the arcuate margins of the vanes and permitting the recesses of the shell to forcibly engage the vane tabs.

7. In a method of making a vaned element of a hydrodynamic coupling device, the steps comprising forming a hollow annular shell of flexible material having a substantially semi-toroidal inner surface providing radially spaced sets of circumferentially spaced slots in said surface of said shell; forming a plurality of vanes each having an outer arcuate margin with a curvature less than the curvature of said surface of said shell; and

spaced first and second tabs on said margin, the linear distance between the ends of the slots of each set remote from each other being less than that between the ends of the tabs on each vane remote from each other; and connecting each vane to the shell, by inserting the tab of a vane in the slot of one set to engage said tab with one of the said remote ends of said slots, holding the radially outer portion of said shell against movement while applying pressure to the radially inner portion of said shell to expand said shell and thereby decrease the curvature of said surface of said shell to less than the arcuate curvature of said vane margins; rotating the vane inwardly toward and into the shell to position the second tab of the vane in engagement with the edge of a slot of the second set; applying force to the second tab of the vane to snap the tab over the edge and into said second set slot; and releasing the pressure on said shell to engage the second tab with the other of said remote ends of said slots, and to induce reaction forces in the shell by the engaged slot ends to seat the outer margin of the vane against said surface of the shell and to hold the vane in assembly with the shell.

8. In a method of making a vaned element of a hydrodynamic coupling device, the steps comprising forming a hollow annular, semi-toroidal shell of flexible material; forming circumferentially spaced recesses in radially spaced sets in the inner surface of said shell; forming a plurality of vanes each having an arcuate margin with spaced first and second tabs, the radial distance between the ends of the recesses of each set remote from each other being less than that between the edges of the tabs on each vane remote from each other; and connecting each vane to the shell, by applying pressure to said shell to flex and expand said shell; positioning the first tabs of each vane in one recess of a set and the second tab in engagement with the inner surface of the shell adjacent one edge of the other recess of the set; applying force to the vanes to snap the second tab over the edge of said other recess and into said other recess; and releasing the pressure on said shell to engage said tabs with ends of said recesses of said shell.

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