The proposed invention relates to electrical submersible pumps used for hydrocarbons production from oil wells. The pump stage operational life increases by enhancement of stage abrasion and erosion wear properties. The indicated goal is achieved by
constructing the flow area of a submersible pump stage from separate segments manufactured from wear resistant material. Segments are retained in the stage construction through compression fit rings. Sleeve from plastically deformable material is installed between hub and segments and between ring and segments; segments side interference is constructed in form of chevron type face labyrinth seal; gasket with radial beams is placed between segments and hub and the beams quantity is equal to the segments quantity; bushing from wear resistant material is press fit into the diffuser hub.
Abstract

The proposed invention relates to electrical submersible pumps used for hydrocarbons production from oil wells. The pump stage operational life increases by enhancement of stage abrasion and erosion wear properties. The indicated goal is achieved by constructing the flow area of a submersible pump stage from separate segments manufactured from wear resistant material. Segments are retained in the stage construction through compression fit rings. Sleeve from plastically deformable material is installed between hub and segments and between ring and segments; segments side interference is constructed in form of chevron type face labyrinth seal; gasket with radial beams is placed between segments and hub and the beams quantity is equal to the segments quantity; bushing from wear resistant material is press fit into the diffuser hub.
Electrical Submersible Pump Stage Construction

The proposed invention relates to electrical submersible pumps used for hydrocarbons production from oil wells. Pump construction includes a stack of stages placed inside a housing. Each stage includes a stationary diffuser and a rotating impeller. Abrasive solids are present in the production flow in forms of formation rock or proppant grains. Formation solids average concentration in the production flow is 200 mg/liter. In the case of heavy oil production this number can be much higher. Proppant flow back grains concentration in the production flow can reach concentrations as high as 1 g/liter right after fracturing. Production flow speed inside the pump stage for most applications is around 15 m/sec. This high speed causes the stage geometry erosion wear. Solids being trapped inside the stage small gaps between spinning and stationary components cause the stage material abrasion wear as well. As a result pump efficiency decreases. Stages wear also leads to the increase of journal bearings dynamic loads. Accelerated radial bearings wear causes pump premature failure.

There are several known technical solutions (analogs) in existence. One of these patents proposes the implementation of iron and boride carbides layers through stage flow area (USA patent № 19830120). Carbide/boride layers are wear resistant materials. The disadvantage of this technology is surface roughness increase. Consequentially the stage hydraulic characteristics (head and efficiency) are reduced. Diffusion coating technology with wear resistant materials can be used as well. However, due to the limited coating thickness (for diffusion process) eventually it will be worn out with time exposing the base material.

The closest technical solution (prototype 1) to the proposed is a turbodrill stage being described in Russian patent № 2244090. Turbodrill is a hydraulic machine used for well drilling. Turbodrill construction comprises a stack of axial type stages
(rotor plus stator). A stack of rotors is retained on a turbodrill shaft and a stator stack is retained inside a housing. Working fluid circulated from the surface spins the turbodrill shaft with bit attached. According to this patent the turbodrill stage flow area is fabricated from ceramic using the injection molding process. Flow area is retained to metal hub and outside ring through a press fit connection. The presented construction of the turbodrill stage is wear resistant and maintains good operation characteristics for a long time. Stage disadvantage is the technological complexity of the complete flow area molding from ceramic material.

The above mentioned disadvantage has been resolved in the construction of a turbodrill stage proposed by Russian company "Techbur" (prototype 2). In this design the stage flow area is constructed of separate ceramic segments. Each segment consists of a blade and attached surface. Special filler (epoxy type glue) is used for segments connection to each other and press fit ring retains all segments around the hub. Filler is used as well for gaps filling between the blades. Separate segments manufacturing is much easier process. Filler erosion wear in blade gaps is a disadvantage of this construction. As a result the stage operational parameters will be reduced once the filler starts wearing out.

The goal of the proposed invention is pump stage operational life increase by enhancement of stage abrasion and erosion wear properties. The indicated goal is achieved by constructing the flow area of a submersible pump stage from separate segments manufactured from wear resistant material. Segments are retained in the stage construction through compression fit rings.

According to an aspect of the present invention, there is provided an electrical submersible pump stage including an impeller and a diffuser, each comprising a hub, blades and an outside ring wherein: a stage flow area is constructed from separate segments manufactured from wear resistant material, and segments retention to the hub is achieved by means of external compression fit rings.

Examples of embodiments of the present invention will now be described with reference to the drawings, in which:

FIG. 1 shows a section view of a pump according to an embodiment of the invention;
FIG. 2 shows a cross-section on line A-A of FIG. 1;
FIG. 3 shows the construction of a pump impeller;
FIG. 4 shows the construction of a pump impeller with deformable sleeves;
FIG. 5 shows a separate impeller segment design;
FIG. 6 shows a side connection between segments;
FIG. 7 shows an impeller hub construction with a sealing gasket;
FIG. 8 shows a design of an impeller cap;
FIG. 9 shows a diffuser construction;
FIG. 10 shows a design of a separate diffuser segment;
FIG. 11 shows a diffuser design with a deformable sleeve; and
FIG. 12 shows a detailed view of part of a pump section.

An embodiment of an electrical Submersible Pump according to the proposed design (Fig.1) comprises the following main components: a housing 1, a shaft 2, journal bearings 3, diffusers 4, compressed inside the housing 1 between a head 5 and a base 6. Impellers 7 have been compressed on the shaft 2 by means of a nut 8. Torque is transmitted from the shaft 2 to the impeller 7 by means of a rectangular key 9 (Fig.2).

The impeller design is explained in Fig.3 and Fig.4. The impeller includes a hub 10, separate segments 11 located around the hub, a cap 12 and an external ring 13. The cap 12 and ring 13 connection with the segments 11 is press fit. There is a key slot 14 on the hub 10. The segment configuration (Fig.5) includes a blade 15 and adjusting surfaces 16 and 17. A cylindrical extrusion 18 adjoins surface 16. The geometry configuration 19 of the segment surface 16 matches the hub configuration 21 through their contact area (Fig.3). The geometry configuration 20 of the segment surface 17 matches the configuration 22 of cap 12 through the contact area (Fig.3). The segments 11 are retained in the impeller through
compression load from the cap 12 and the ring 13. Friction force generated in the connections is sufficient enough for retaining impeller components as one monolithic unit and for torque transmission from the shaft. The segments 11 are fabricated from wear resistant material with minimum Knoop hardness 500 units. Ceramic and carbides based materials can be used for the segment material.

The impeller assembly (Fig.3) is performed in the following way. Segments 11 are positioned around the hub 10. The ring 13 is heated up to a fixed temperature. The heating temperature value is determined based on the compression fit load and depends on the coefficient of ring thermal expansion. Once heated up the ring 13 is placed over the extrusions 18 of the segments 11 (Fig.5). The ring 13 cools down compressing the segments 11 and squeezing them against the hub 10. At the next step the cap 12 is heated up to the fixed temperature and placed over segments. After cooling, the cap tightly squeezes the segments and presses them against the hub. In the proposed impeller construction, the segments retention occurs from both ends. This way the construction robustness has been achieved.

In order to achieve reliable retention of the segments and to eliminate the chances of some segments being loose due to differences in dimensional tolerances, one of the proposed construction versions of the design includes thin sleeves manufactured from deformable material (Fig.4). A first sleeve 23 is installed between the segment 11 and the cap 12. A second sleeve 24 is installed between the ring 13 and the segment 11. Under squeezing load the sleeves are plastically deformed and the load is distributed uniformly through all impeller segments. Copper or material with similar properties can be used for sleeves manufacturing.

A labyrinth type face seal 25 (Fig.5 and Fig.6) fabricated at the sides of the segments is another version of the stage construction. The face seal prevents produced fluid contact with hub and cap surfaces. The face seal is constructed in the form of a chevron connection between male and female features at the segment sides.

In order to block fluid recirculation under the segments, a certain impeller design version is proposed. Concentric groove 26 (Fig.7) with adjusting radial slots 27 in a quantity equal to the segments quantity is implemented on the hub surface. An elastomer seal 27A is shown in Fig.7. Due to cap 12 heating during impeller
assembly the elastomer seal can not be placed in a contact area between the cap and segment. Soft deformable material can be placed in cap slots 28 (Fig.8).

A diffuser construction is shown in Fig.9. The diffuser consists of a hub 29, segments 30, an external skirt 31 press fit over the segments 30 and an internal bushing 32. The bushing 32 is press fit in the hub 29. The diffuser single segment construction geometry is shown in Fig.10. The segment consists of a blade 33 and adjusting surfaces 34 and 35. The contact surface configuration of the adjusting surface 35 matches the geometry of the outside surface of hub 29. The contact surface configuration of the adjusting surface 34 matches the configuration of skirt 31 inner surface. Segments 30 and bushing 32 are manufactured from wear resistant material with min Knoop hardness 500. Ceramic or carbide based materials should be used for segments and bushing fabricating.

The diffuser assembly is performed in the following order. The bushing 32 is pressed in the hub 29. The segments 30 are positioned around the hub 29. The skirt 31 is heated up to a fixed temperature. The heating temperature value is determined based on the compression fit load and depends on the coefficient of skirt thermal expansion. Skirt 31 is placed over segments 30 (Fig.9). Cooling down the skirt tightly squeezes the segments and presses them against the hub.

A chevron type face seal 36 is constructed at the diffuser segment sides (Fig.10) and prevents hub and skirt surfaces erosion wear. The diffuser face seal configuration is identical to that of the impeller described above.

In order to achieve diffuser segments reliable retention and to eliminate the chances of some segments being loose due to differences in dimensional tolerances one of the proposed versions of the design includes a thin deformable sleeve 37 placed between segments and skirt (Fig.11).

In order to block fluid recirculation under the diffuser segments a deformable seal can be used. The seal design is identical to impeller seal 27 and placed between the hub and segments.
A fragment of pumps section with proposed stages is shown in Fig.12. The diffusers 4 stack is compressed inside the housing 1. Impellers 7 with spacers 38 are compressed on the shaft 2. The spacer is fabricated from abrasion resistant material. Ceramic or carbide based materials should be used for spacer manufacturing. Spacer 38 and bushing 32 comprises a pump journal bearing. The proposed pump section design is suited for production of hydrocarbons with high content of abrasive solids. The stage flow area is erosion resistant due to the proper material implementation. Each pump stage has a wear resistant journal bearing to prevent stage abrasion wear.
CLAIMS:

1. An electrical submersible pump stage including an impeller and a diffuser, each comprising a hub, blades and an outside ring wherein: a stage flow area is constructed from separate segments manufactured from wear resistant material, and segments retention to the hub is achieved by means of external compression fit rings.

2. The stage of claim 1 wherein a sleeve from plastically deformable material is installed between the hub and the segments and between the ring and the segments.

3. The stage of claim 1 or 2 wherein a segments side interference is constructed in a form of a chevron type face labyrinth seal.

4. The stage of any one of claims 1 to 3, wherein a gasket with radial beams is placed between the segments and the hub and the number of beams is equal to the number of segments.

5. The stage of any one of claims 1 to 4, wherein a bushing from wear resistant material is press fit into the diffuser hub.