SCOOP-TRIMMED HYDRAULIC TURBOCOUPLING


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ABSTRACT OF THE DISCLOSURE

A scoop-trimmed hydraulic turbocoupling has a second, quick-emptying scoop which is forced into the ring of liquid in the scoop chamber to effect abnormally rapid emptying of the coupling when a detector detects abnormal operation conditions, for example, pulling-out of a synchronous element applying the full load, coupling or seizure of the driven load, requiring disconnection of the coupling drive more quickly than can be effected by the normal trimming scoop.

This invention relates to scoop trimmed hydraulic turbocouplings and to power transmission systems in which drive is transmitted through scoop-trimmed hydraulic turbocouplings.

Scoop-trimmed hydraulic turbocouplings comprise vaned impeller and runner elements which together define a toroidal working circuit for the working fluid and a casing which rotates with the impeller and extends around the runner to form a scoop chamber into which extends a movable trimming scoop. The scoop chamber is in communication with the working circuit and the scoop trims off the liquid from the scoop chamber and thereby from the working circuit. Liquid is conveyed from the scoop to a reservoir, and is returned from the reservoir to the working circuit at a steady rate by a pump. In many cases a cooler for the liquid is suitably located in the flow path. The radial position of the scoop in the scoop chamber determines the radial depth of liquid in the scoop chamber and thereby the quantity of liquid in the working circuit. This in turn determines the torque transmitted by the coupling.

Thus the transmitted torque, and hence the transmitted power can be adjusted by adjusting the position of the scoop in the scoop chamber.

Scoop-trimmed hydraulic turbocouplings can thus be conveniently incorporated in power transmission systems for use where the transmitted torque is to be controllable. This enables the speed of a driven machine to be controlled and also enables the driving machine, for example an electric motor, to be quickly run up to its operating speed and load torque.

Adjustment of the scoop position, and hence the transmitted torque is often affected automatically by a servo-mechanism in response to changes in operating conditions. In order to prevent “hunting” of the servo-mechanism due to overshooting as a result of too rapid adjustment of the scoop, the speed of movement of the scoop is deliberately kept low. Thus the trimming scoop may take ten or even twenty seconds to move through its full range of movement.

A scoop-trimmed turbocoupling according to the present invention includes a second movable scoop constructed as a quick-emptying scoop and acting means for moving the quick-emptying scoop to empty the scoop chamber and thereby the working circuit in response to a signal from a detector for detecting an abnormal operating condition necessitating rapid reduction in the torque transmitted by the coupling.

The size of the outer diameter of the trimming scoop is restricted by the other parts of the coupling. Accordingly, the wall thickness and thereby the mechanical strength of the tube can only be increased at the expense of reducing the bore of the trimming scoop. This in turn would increase the flow velocities in the trimming scoop, leading to the possibility of turbulence and surging which may be reflected back into the working circuit to upset the steady transmission of torque. It is thus in general not considered feasible to construct a satisfactory trimming scoop which can also be used for rapid emptying of the coupling by being forced deeply into the rotating ring of liquid in the scoop chamber.

The quick-emptying scoop acts independently of the trimming scoop and can therefore be designed for optimum performance in removing liquid from the scoop chamber and working circuit. Thus whereas the trimming scoop may take 10 or 20 seconds to complete its travel, the quick-emptying scoop may complete 90% of its travel from the “working-circuit full” to the “working-circuit empty” positions in four seconds so that in this time interval the torque transmitted by the coupling may drop to no more than a quarter of the full load value.

The quick-emptying scoop may remain stationary during normal operation of the coupling and of the trimming scoop with its scooping orifice just clear of the circuit full position.

Alternatively, the quick-emptying scoop and its actuating means may move with the trimming scoop during normal operation, with the scooping orifice of the quick-emptying scoop retracted relative to the trimming scoop so as to lie a short distance outside the radial level of liquid determined by the scooping orifice of the trimming scoop. The quick-emptying scoop then has less far to move if its operation becomes necessary in the partially filled condition of the working circuit.

Both the trimming scoop and the quick-emptying scoop may be of different designs best suited for the purposes they have to fulfil. Thus the trimming scoop tube mouth and section may be sized specifically to give good regulation with minimum aeration of the liquid, whilst the quick-emptying scoop tube would be constructed specifically for very rapid emptying.

Advantageously, a diverter valve may be included in the supply conduit from the pump to the working circuit. The diverter valve is operated simultaneously with movement of the quick-emptying scoop and may for example, be mechanically linked to it. When operated, the diverter valve diverts the pump output away from the working circuit, conveniently back into the reservoir. The speed of operation of the quick-emptying scoop can thereby be increased since the normally continuous supply of working liquid to the working circuit is cut off.

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

FIG. 1 is a perspective view with parts cut away of a scoop-trimmed coupling in accordance with the invention;
FIG. 2 is a side elevational view of the coupling shown in FIG. 1, the upper part of the figure being shown in vertical axial section;
FIG. 3 is a diagrammatic cross sectional view on the line III—III of FIG. 2 showing a modified form of scoop operating gear in the normal operating condition; and
FIG. 4 is a view corresponding to FIG. 3 showing the quick-emptying scoop in its operational position for rapidly emptying the coupling under emergency conditions.

The scoop-trimmed hydraulic turbocoupling shown in
FIGS. 1 and 2 follow conventional practice in that it comprises a base 1, the interior of which forms a sump for the working liquid and on which is mounted a housing 2 supporting in a spherical bearing 3 co-axial input and output shafts 4 and 5, the input and output shafts being located relative to each other by a bearing 6. Secured to the input shaft 4 is a impeller casing 7 carrying the impeller element 8 and a scoop chamber 9. A runner element 10 is secured to the output shaft 5. The impeller 8 is also mounted on an impeller sleeve 11 which is rotatably supported by the spherical bearing 3. The impeller and runner elements 8 and 10 are a series of vanes and toger define a toroidal working circuit W for the working liquid of the coupling.

The working circuit W is in free communication with the interior of the scoop chamber 9 through the gap between the impeller and runner elements 8 and 10 at their radial outer peripheries.

Oil for filling the working circuit W is delivered by a motor driven pump 12 from which the oil passes through a cooler 13 and a diverter valve 14 to an inlet pipe 15 which delivers oil to the working circuit through internal passages 16 within the housing 2.

A trimming scoop tube 17 is slidably mounted in the housing 2 and extends into the scoop chamber 9. The free end of the scoop tube 17 is formed with a scooping orifice 18 which dips into the annulus of oil in the scoop chamber 9 and trims off oil into the scoop tube 17. At its other end the scoop tube 17 is formed with an orifice 19 through which the oil passes through an elbow 20 to a cylindrical de-erator chamber 21 which it enters tangentially to form a rotating oil film on the wall thereof. From the lower end of the chamber 21 the oil drops into the pump in the base 1.

The scoop tube 17 can be moved between its various operating positions by a hydraulic or pneumatic actuator 22, the range of movement of which is sufficient to move the scoop between one end position in which the scoop chamber 9 and working circuit W are empty and substantially no torque is transmitted and the other end position in which the working circuit W and scoop chamber 9 are full. Moreover the actuator 22 enables the scoop tube 17 to be held in any desired intermediate position corresponding to the desired partial filling of the working circuit W.

The actuator 22 is controlled by appropriate control gear which is conventional in the art and the precise nature of which is determined by the installation in which the coupling is used. In general the speed of movement of the scoop tube 17 will be kept low in order to avoid hunting and overshooting of the control systems and thus of the transmitted torque.

The coupling shown in FIGS. 1 and 2 differs from conventional practice in that it includes a second, quick-emptying scoop tube 23 which is parallel to the scoop tube 17 but mounted on the opposite side of the coupling axis. The external diameter of the quick-emptying scoop tube 23 may be the same as that of the scoop tube 17 but as clearly shown in FIG. 2 its wall thickness is greater, thereby imparting greater rigidity. The quick-emptying scoop tube 23 terminates in a scooping orifice 24 which is larger than the orifice 18. The scoop tube 23 is normally located so that its scooping orifice 24 lies radially inwards of the annulus of oil in the scoop chamber 9 so that under normal operating conditions there is no flow through the quick-emptying scoop tube 23 in any position of the control scoop tube 17. However, the quick-emptying scoop tube 25 can be forced further into the scoop chamber 9 under emergency conditions by an actuator 25 which is arranged to operate much more rapidly than the actuator 22. The greater rigidity of the scoop tube 23 enables it to withstand the forces imposed on it by this operation while its large scooping orifice 24 empties the working circuit W and scoop chamber 9 very rapidly.

The pressure supply to the actuator 25 is also applied to a conduit 26 to actuate the diverter valve 14 to divert the flow from the cooler 13 directly back into the sump through a conduit 27, thereby diverting the flow from the coupling inlet 15.

The relative orifice sizes and wall thicknesses of the control and quick-emptying scoop tubes 17 and 23 are shown by way of comparison in phantom outline in FIG. 2.

FIGS. 3 and 4 illustrate an alternative arrangement for operating the scoop tubes 17 and 23. In this arrangement the quick-emptying scoop tube 23 moves with the control scoop tube 17 but is positioned so that its orifice 24 is slightly nearer to the coupling axis than the control scoop orifice 18 so that no liquid enters the orifice 24. Thus when an emergency occurs requiring the working circuit to be rapidly emptied, the scoop tube 23 only has to move a small distance for its orifice to enter the annulus of liquid in the chamber 9.

For this purpose the scoop tube 17 carries an arm 27' which in turn carries a lost motion device 28 which operates with a flange 29 on the quick-emptying scoop 23. The lost motion device 28 provides two abutments 30 and 31. A spring 32 of sufficient stiffness to move the quick-emptying scoop 23 under normal conditions is positioned between the abutment 31 and the flange 29.

The actuator 25' for the quick-emptying scoop is normally empty of fluid but is provided with pressured fluid through the pipes 26' under emergency conditions.

Under normal conditions the actuator 22' moves the control scoop tube 17 to the required positions. The arm 27', abutment 30 and spring 32 ensure that the scoop tube moves with the scoop tube 17. Under emergency conditions the quick-emptying scoop tube 23 is forced by the actuator 25' against the resistance of the spring 32 into its fully operating position in which it rapidly empties the working circuit W and scoop chamber 9 of the coupling.

When the invention is applied to scoop-trimmed couplings having twin working circuits, that is having two impeller elements connected together and two runner elements connected back to back and two scoop chambers, a quick-emptying scoop will be provided for each scoop chamber.

By way of example, two applications of the couplings described above will now be described in more detail.

The first of these applications relates to synchronous electric motor drives.

It has recently been ascertained that within the approximate power range of 2,500 to 10,000 H.P. it may be preferable to employ a synchronous electric motor with a liquid filled coupling. The advantage of using such a motor is that more efficient and having better start-up characteristics of the usual synchronous motor.

The exact boundaries of this favourable horse-power zone depend to a certain extent on the actual application and the particular motor speed. Furthermore, it may be possible to obtain power factor correction if desired with the synchronous motor may confer substantial improvement in the operation of the complete plant.

However, synchronous motors are unfortunately very sensitive to supply voltage fluctuations or temporary supply interruptions. Thus, if the supply voltage falls to zero within a quarter-of-a-cycle and thereafter three seconds are required to restore full line voltage, then the motor would drop out of synchronism and unless the load can be removed it would not re-synchronize. Obviously, a variable filling fluid coupling is very suited to relieving the motor load during such voltage loss conditions.

A further typical requirement is that within 15 seconds of the initial supply disturbance the motor must be back on line, the fluid coupling full and normal drive restored.

This requirement would arise for example with a half-duty standby and start-up boiler feed pump required for a turbo-alternator boiler unit of, say, 500 M.W. capacity.

Normally the fluid coupling is controlled by a servo motor receiving its signals from the automatic boiler control system in the case of a boiler feed pump.
Therefore, the scoop tube would normally be moved at a rate determined by this servo gear and to match the overall dynamics of the plant it may take anything from 10 to 20 seconds for the scoop tube to be moved through its full travel from circuit full to circuit empty.

Therefore, if the normal scoops were to be used also to empty the fluid coupling very rapidly on loss of the synchronous motor supply voltage, then not only must the normal control gear be over-ridden, but furthermore the scoops must be moved at a much faster rate. This would lead to complications with the control gear.

This difficulty is overcome by the completely separate quick-emptying scoop which is under the control of electrical equipment intended specifically to detect loss of motor supply voltage. A typical detector would be a power factor type pull-out relay of already well-known design, see for example “Out-of-Step Protection for Synchronous Motors” by L. C. Trickey A.M.I.E.E. in “AEI Engineering” February 1961 (Associated Electrical Industries Limited, Manchester, England), and could be fitted with automatic re-synchronising features.

The quick-emptying scoop is held normally at the circuit full position until signalled to move, whereafter it would empty the fluid coupling to a sufficient degree within, say four seconds, that is to say the auxiliary scoop tube would go through about 90% of the full travel in four seconds, whereafter the fluid coupling could not transmit more than, say, one-quarter full load torque. As soon as the main voltage is restored, a suitable detector would again actuate the scoop to move very quickly to the circuit full position and the fluid coupling working circuit would be refilled by the oil pump to the level called for by the control scoop tube very quickly. Therefore, throughout the cycle the control scoop tube connected to the usual automatic control equipment need not move, and on resumption of normal operation would continue to regulate the fluid coupling in the usual way.

The second application of the invention to be described in more detail relates to the direct driving of main boiler feed pumps by turbo-alternator sets. In a typical example, a 275 mw. turbo-alternator running at 3,000 r.p.m. drives an 8,000 H.P. boiler feed pump through a scoop trimming coupling having a double working circuit, that is having two impellers, two runners and two scoop chambers with a trimming scoop in each chamber, the two runners being connected together back-to-back.

The fluid coupling is particularly chosen to have a low minimum slip so that the torque transmitted by the working circuit when the output is stalled is many times the nominal full load torque value.

In a normal motor-driven application, if the boiler feed pump should seize with the fluid coupling circuits full, then the motor would be electrically “pulled out” and the set would come to rest. In the case of the turbine-driven fluid coupling, however, the horsepower rating of the feed pump is very small compared with that of the turbine. Thus if the feed pump were to seize, the full stalled torque capacity of the fluid coupling would be generated in heat leading, of course, to an extremely rapid rise in temperature of the oil acting as working liquid.

Here again, for reasons connected with the rest of the plant, the trimming scoops are usually arranged to move at a rate not faster than full travel in, say, 10 to 20 seconds. Therefore, if a quick-emptying scoop were provided for each circuit, they could have their servo actuating means responsive to the output of a temperature sensor such as a thermocouple in the oil leaving the working circuit. In the event of the fluid coupling stalling and a dangerous rise in temperature ensuing, the quick-emptying scoops would be moved very rapidly and thus empty the fluid coupling circuits and keep them empty.

1. A scoop-trimmed hydraulic turobocoupling comprising vaned impeller and runner elements which together define a toroidal working circuit for the working fluid, a casing which rotates with the impeller and extends around the runner to form a scoop chamber into which extends a moveable trimming scoop, the scoop chamber being in communication with the working circuit, and wherein the coupling includes a second moveable scoop constructed as a quick-emptying scoop and actuating means for moving the quick-emptying scoop to empty the scoop chamber and thereby the working circuit in response to a signal from a detector for detecting an abnormal operating condition necessitating abnormally rapid reduction in the torque transmitted by the coupling.

2. A coupling according to claim 1, wherein the quick-emptying scoop is arranged to remain stationary during normal operation of the coupling and of the trimming scoop with its scooping orifice just clear of the circuit full position.

3. A coupling according to claim 1, wherein the quick-emptying scoop and its actuating means may move with the trimming scoop during normal operation, with the scooping orifice of the quick-emptying scoop retracted relative to the trimming scoop so as to lie a short distance outside the radial level of liquid determined by the scooping orifice of the trimming scoop.

4. A coupling according to claim 1, wherein liquid is delivered to the working circuit by a pump and the coupling includes a diverter valve for diverting the said liquid from entering the working circuit on actuation of the quick-emptying scoop.

5. A coupling according to claim 1, wherein the quick-emptying scoop has thicker walls and a larger scooping orifice than the main trimming scoop.

6. A coupling according to claim 1, wherein the said detector is a power factor pull-out relay associated with a synchronous electric motor connected to drive the coupling.

7. A coupling according to claim 1, wherein the said detector is a thermally sensitive device responsive to temperature increases in the liquid leaving the working circuit.

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