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MULTISTAGE TURBINE IN WHICH THE ROTORS ARE CONNECTED BY MEANS OF DIFFERENTIAL GEAR TRAINS

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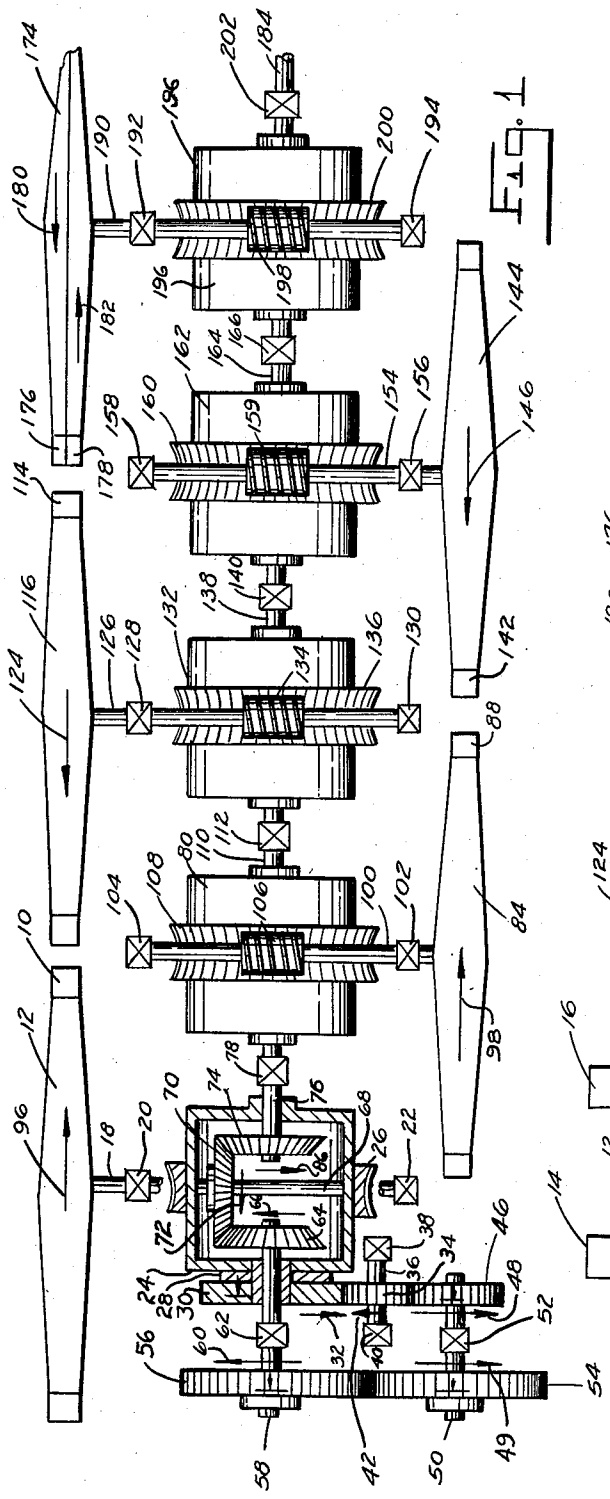


Fig. 1

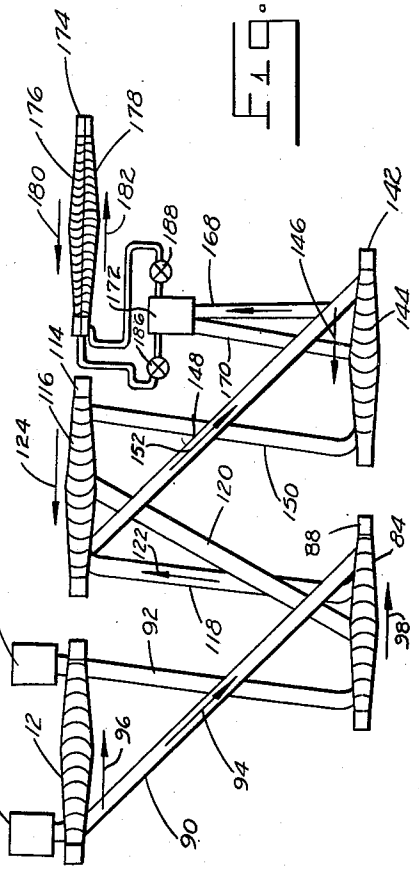


Fig. 2

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MULTISTAGE TURBINE IN WHICH THE ROTORS ARE CONNECTED BY MEANS OF DIFFERENTIAL GEAR TRAINS

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The present invention relates to multi-stage turbines.

In prior art turbines, the rotor of each stage is mounted on a common shaft so that the speed of rotation of the turbine is dependent upon the rotation that can be developed by the last stage. Thus, the number of stages is limited by the design conditions of the last stage, the speed of which is controlled by the energy imparted by the fluid, such as steam, water or gas, to the last or low pressure stage.

My invention on the other hand contemplates the provision of a multi-stage turbine in which the rotor of each stage is mounted on a shaft which is separate from and independent of any other stage but in which each rotor is operatively interconnected so that the energy developed by each stage is added to the energy developed by the succeeding stage. Thus, each rotor, since it is independent of any other rotor, may be operated at its most efficient speed and under the optimum conditions.

I contemplate the provision of a multi-stage turbine in which the rotor or turbine wheel is connected through a differential gear train to the next rotor or turbine wheel. There is thereby provided an arrangement in which the speed of rotation of the preceding stage is added to the speed of rotation of the succeeding stage, thereby increasing the speed of the output shaft, which heretofore was limited to the speed of the last or low pressure stage.

In prior art multi-stage turbines, there is provided between each stage a stationary set of buckets which serve to reverse the direction of flow of the fluid exhausted from the preceding stage before it is directed to impinge on the moving buckets of the succeeding stage since, by reason of the fact that each stage is mounted on a common shaft, the buckets of each stage must move in the same direction. Such change in direction absorbs energy from the fluid which therefore does not perform any useful work.

My invention on the other hand provides a construction whereby the exhaust from one stage is directed in a substantially straight path of movement to impinge tangentially on the rotor of the next stage so that no power is use'essly absorbed by changing the direction of flow of the fluid exhausted from any stage. Thus, the absorption power of each independently operated rotor is differentially added to the succeeding rotor.

My invention contemplates a multi-stage turbine in which there is provided a plurality of independently operating turbine wheels in the

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first of which energy from a source of power is received tangentially and converted into rotary motion with the exhaust therefrom passing directly to the succeeding turbine wheel to impinge tangentially thereon without change of direction.

The present invention still further contemplates the provision of a multi-stage turbine in which the turbine wheel or impeller of the last stage is provided with duplicate sets of blades or buckets set in opposite directions and having a suitable accumulator leading into two separately operated control valves to permit selected clockwise or counter-clockwise rotation of the last stage impeller or turbine wheel shaft. Thus, by reason of the differential power transmission, the rotation of the last stage may be added or subtracted from the rotation of the turbine output shaft to thereby provide a ready means for controlling the speed of the multi-stage turbine output shaft between maximum and minimum limits.

The present invention may be applied to impulse or reaction turbines, having any number of stages, and driven by any source of power such as steam, gas, water or the like.

Objects and advantages of the present invention will be clear from the description which follows and from the drawing appended thereto, which is schematic, and in which drawing

Fig. 1 is a schematic plan view, partially in section of a multi-stage turbine according to my invention;

Fig. 2 is a schematic plan view of the piping diagram therefor.

In the drawing I have illustrated a five-stage turbine, though it will be understood that any lesser or greater number of stages may be utilized.

The driving fluid, whether steam, water or gas, is directed onto the buckets 10 of the first stage rotor 12 from an inlet chest or chests indicated by the reference characters 14 and 16. The rotor 12 of the first stage is mounted on the shaft 18 which may be journaled, as in the bearings 20 and 22.

As will be described in greater detail, the rotor of each stage is connected to the rotor of the succeeding stage by means of a differential interconnecting mechanism such as the mitre gear differential or planetary gear differential illustrated in my co-pending application Ser. No. 628,903 filed by me November 15, 1945, now abandoned, for power transmission, although in the present application I have illustrated my invention with a mitre gear differential transmission.

The rotor 12 is connected to the differential

housing 24 by means of a suitable reduction gearing, which, for purposes of illustration may be of a forty to one ratio, and which drives the worm gear 26 mounted on the periphery of the housing.

Secured to one face of the housing on the collar 28, I provide the gear 30. Thus, the gear 30 is rotated in the same direction as is the housing 24 that is in the direction of the arrow 32.

It will of course be recognized that the direction of rotation of the housing of any differential is determined by the direction of thread of the driven external housing worm gear and that of the intermeshing driving worm gear of the reduction gearing.

Meshing with the gear 30, I provide the gear 34 which is mounted on the shaft 36 journaled in the bearings 38 and 40. Thus, the gear 34 is driven in the direction of the arrow 42 to drive the gear 46, which meshes with it, in the direction of the arrow 48.

The gear 46 is mounted on the shaft 50 which is journaled in the bearing 52. The shaft 50 has mounted on it the gear 54 which rotates in the direction of the arrow 49 and meshes with the gear 56 mounted on the shaft 58 and which is thus rotated in the direction of the arrow 60.

For purposes of illustration, the gears 30, 34, 46, 54 and 56, comprising a train of gears through which the differential housing 24 is operatively connected to the power transmission input shaft 58, are of a one to one ratio, so that the shaft 58 is rotated at the same speed as is the housing 24.

The shaft 58 is journaled in the bearing 62 and at its inner end, which is positioned inside of the housing 24, has mounted thereon the bevel or mitre gear 64. This bevel or mitre gear 64 rotates in the direction of the arrow 66.

Secured to the housing 24 by means of the shaft 68, on which it rotates, I provide the bevel or mitre gear 70, which is rotated in the direction of the arrow 72.

Meshing with the gear 70, I provide a third mitre or bevel gear 74, which is mounted on the shaft 76 journaled in the bearing 78 between the housing 24 and the housing 80 which is driven by the second stage rotor 84, as I shall describe.

The gear 74 is thus driven in the direction of the arrow 86 and the housing 24 is carried for free rotation on the input shaft and the output shaft 58 and 76.

By this differential power transmission arrangement, it will be recognized that the rotation of the input shaft 58 is added to the rotation of the housing 24, developed by the first stage rotor 12; that is the speed of rotation of the output shaft 76 is the sum of the speed of rotation of the housing 24 and the shaft 58.

The power transmission illustrated in the present application is the same as that illustrated in my said co-pending application Ser. No. 628,903, now abandoned, though it will be understood that any other type of gear train or differential transmission may be used.

The mitre gears of the first stage differential power transmission, gears 64, 70 and 74, (and as I shall describe the gears of each succeeding differential power transmission) are preferably of a one to one relation.

In the illustration given, assume that the first stage rotor 12 operates at 12,000 R. P. M., then because of the forty to one reduction gearing, the housing 24 and so the shaft 58 will operate at 300 R. P. M. Therefore, by reason of the differential power transmission, the output shaft 76 is operated at 600 R. P. M. because it is positively connected through gearing to the shaft 58 to which the rotation of the differential housing 24 is added.

The exhaust steam or gas from the first stage rotor 12 is directed against the buckets 88 of the second stage rotor 84 through the pipes 90 and 92 and flows in the direction of the arrow 94. It should be noted that the first stage rotor 12 is rotated in the direction of the arrow 96 and the second stage rotor 84 in the same direction as illustrated by the arrow 98.

The direction of rotation of each rotor will be dependent upon the position on its circumference, that is the quadrant at which the driving fluid is introduced. I desire to have the steam travel from one rotor stage to the next rotor stage in as nearly a straight line as is possible so that there will not be any change of direction with resulting useless absorption of power. I further desire that the shortest fluid pipe or conduit from one stage to the next stage be utilized.

Therefore, a rotor may operate in different directions of rotation, which, since the rotors are independent from each other and the direction of rotation of any housing may be selected by the proper choice of the driven external housing worm gear and the intermeshing driving worm gear, will be of no consequence.

In order to obtain such a straight line flow, it is only necessary to provide a pipe construction which preferably assumes the outline of a helical screw thread. This provides an unimpeded, smooth unchanging in direction and uniform travel of the exhaust from the rotor of one stage to the rotor of the next stage.

Thus, a multi-stage turbine is provided which does not change the direction of flow of the driving fluid from one stage to the next stage and in which the output shaft of each stage will be rotated in the same direction although some of the rotors themselves may be rotated in opposite directions and independently of each other.

The rotor 84 for the second stage is mounted on the shaft 100 journaled in the bearings 102 and 104. The differential housing 80 of the second stage is connected to the rotor 84 by means of a reduction gearing, which in the illustration has a forty to one ratio, the last worm gear 106 of which drives the worm gear 108, secured around the outside of the housing 80.

There are provided a series of gears joining the shaft 76 to the shaft 110 which is journaled in the bearing 112. These gears are the same as those illustrated in the interior of the first stage housing 24 and therefore need not be illustrated further.

It will be seen that the shaft 76 constitutes the output shaft of the first stage and the input shaft of the second stage and the shaft 110 constitutes the output shaft of the second stage and the input shaft of the third stage.

The second stage rotor 84, since it is operated by the exhaust from the first stage, will operate at a speed less than the speed of the first stage rotor 12, say 9,000 R. P. M. Thus the speed of rotation of the second stage differential housing 80 will be 225 R. P. M. By reason of the differential power transmission, this speed of rotation will be added to the speed of rotation of the input shaft 76, which as pointed out operates at 600 R. P. M., so that the speed of rotation of the second stage output shaft 110 (which constitutes the input shaft for the third stage) will operate at 825 R. P. M.

The steam, water or gas exhausted from the

second stage rotor is directed to the buckets 114 of the third stage rotor 116, through the pipes 118 and 120 in the direction of the arrow 122. This rotates the third stage rotor 116 in the direction of the arrow 124, which by reason of the piping arrangement is opposite to the direction of rotation of the second stage rotor 84.

The third stage rotor 116 is mounted on the shaft 126, which is journaled in the bearings 128 and 130 and drives the differential housing 132 through a speed reduction gearing (of an assumed forty to one ratio), the worm gear 134 of which meshes with the gear 136 on the housing 132. The shaft 138 journaled in the bearing 140 is driven by a similar set of gears as described for the first stage and thus becomes the output for the third stage and the input for the next or fourth stage.

Thus, in the illustration, the third stage output shaft 138 (which also constitutes the input shaft of the fourth stage), assuming the third stage rotor 116 operating at 6,000 R. P. M., will rotate at a speed of 975 R. P. M., the sum of the rotative speed of shaft 110 (825 R. P. M.) and the rotative speed of the third stage housing 132 (150 R. P. M.).

Steam, water or gas from the third stage rotor 116 is directed to the buckets 142 of the fourth stage rotor 144, which is driven at say a speed of 3,000 R. P. M. in the direction of the arrow 146, through the pipes 148 and 150 in the direction of the arrow 152. The fourth stage rotor is mounted on the shaft 154 journaled in the bearings 156 and 158 and through the worm gears (and a forty to one reduction gearing) 159 and 160 drives the differential housing 162 which in turn by the construction heretofore described drives the shaft 164 journaled in the bearing 166.

Thus, in the illustration, the fourth stage output shaft 164 (which also constitutes the input shaft of the fifth stage, here the last stage), will rotate at a speed of 1050 R. P. M., the sum of the rotative speed of shaft 138 (975 R. P. M.) and the rotative speed of the fourth stage housing 162 (75 R. P. M.).

Exhaust from the fourth stage rotor 144 is directed through the pipes 168 and 170 into the accumulator chest 172, from which accumulator chest it is directed to the last stage rotor 174. The rotor 174 is provided with two sets of buckets or blades 176 and 178, which buckets or blades are set in opposite directions.

Thus, if steam, water or gas is directed onto the buckets 176, the rotor 174 is operated in the direction of the arrow 180 but if it is directed onto the buckets 178, the rotor 174 will be operated in the opposite direction illustrated by the arrow 182.

In order to direct the driving fluid onto the desired buckets or blades to control the speed of the multi-stage turbine output shaft 184, as will be described, I arrange between the rotor 174 and the accumulator chest 172, the valves 186 and 188, which permit the driving fluid to be directed onto the selected one of the sets of buckets or blades and shut off from the other set of buckets or blades.

The rotor 174, which is assumed to operate at 1500 R. P. M. is mounted on the shaft 190 journaled in the bearings 192 and 194. The rotor 174 is connected to the last stage differential housing 196 by means of a reduction gearing (forty to one) and the intermeshing gears 198 and 200. The shaft 184, which is journaled in the bearing 202 is connected to the shaft 164 by means of the mitre gears illustrated for the first stage.

Rotation of the rotor 174 in one direction will add its rotative speed to the speed of the input shaft 164 and rotation of the rotor in the opposite direction will subtract its speed from the shaft 164 by reason of the differential power transmission. Thus where there is an addition of the speed, the output shaft 184 will rotate at a maximum of 1085 R. P. M., the sum of the speed of rotation of the shaft 164 (1050 R. P. M.) and the speed of rotation of the housing 196 (35 R. P. M.) and where there is a subtraction of the speed, the output shaft 184 will rotate at a minimum of 1015 R. P. M., the difference between the speed of rotation of the input shaft 164 (1050 R. P. M.) and the speed of rotation of the housing 196, in the opposite direction, (35 R. P. M.).

Therefore, by means of the accumulator chest, valves and oppositely set buckets, the speed of the output shaft of my multi-stage turbine may be selectively varied through maximum and minimum limits.

It will thus be recognized that each rotor is functionally independent of any other rotor and each will be driven at the speeds determined by the energy of the fluid which impinges on it, which impingement is a tangential one.

Each rotor therefore independently adds its absorbed revolutions (and horsepower) differentially to the multi-stage turbine output shaft. Thus, if there is developed 100 H. P. in the first stage, 75 H. P. in the second stage, 50 H. P. in the third stage and 25 H. P. in the fourth stage, my multi-stage turbine will develop 250 H. P. minus mechanical losses and gas velocity losses.

By the invention here described, the efficiency of each stage is added to that of the first stage to thereby produce a maximum overall efficiency, since each rotor is totally independent and will not absorb any load from any other rotor. Thus a true evaluation of the power value of exhaust driving fluid can be accurately determined since in the construction described, the exhaust at each stage can be controlled by venting.

I claim:

1. In a multi-stage turbine, a plurality of rotors, each rotor connected to a differential power transmission comprising an input shaft and an output shaft, a differential housing mounted for free rotation on the said shafts and means carried by the housing for connecting the input shaft to the output shaft, the output shaft of the preceding stage power transmission constituting the input shaft of the succeeding stage power transmission, the housing of the first stage power transmission driving the input shaft of the first stage power transmission, the output shaft of the last stage power transmission constituting the output shaft of the multi-stage turbine, the rotor of the last stage having a double row of blades set in opposite directions and means for selectively directing the turbine driving fluid onto one of said rows of blades.

2. In a multi-stage turbine, a plurality of rotors mounted independently of each other in the turbine, a differential power transmission connecting the rotor of a preceding turbine stage to the rotor of a succeeding turbine stage and means for connecting the exhaust from the rotor of one stage to the inlet for the rotor of the succeeding stage to direct the exhaust from one stage to the succeeding stage substantially in a straight path of movement and to impinge said exhaust tan-

gentially on the rotor of the succeeding stage without change of direction upon leaving the rotor of the preceding stage.

3. In a turbine, a rotor, a differential power transmission including an input and an output shaft, a housing mounted for free rotation on the shafts and means mounted in the housing for connecting the shafts, means connecting the rotor to the housing and means connecting the housing to the input shaft.

4. In a turbine, a rotor, an input shaft, an output shaft, a differential housing mounted for free rotation on the shafts, a train of gears connecting the input shaft to the output shaft and carried by the differential housing, gear means connecting the rotor to the housing and second gear means connecting the housing and the input shaft.

5. In a multi-stage turbine, a plurality of rotors, each rotor connected to a differential power transmission comprising an input shaft, an output shaft, a housing mounted for free rotation on the said shafts and gear means carried by the housing for connecting the input shaft to the output shaft, the output shaft of a preceding stage power transmission constituting the input shaft of the succeeding stage power transmission, gear means operatively connecting the housing of the first stage power transmission to the input shaft thereof.

6. In a multi-stage turbine, a plurality of rotors mounted independently of each other, a differential power transmission means connected to the output of each rotor, each differential power transmission means being operatively connected to the input of the succeeding power transmission means and means for connecting the exhaust of a preceding stage to the inlet of a succeeding stage to direct the exhaust from one stage to the succeeding stage substantially in a straight path of movement and to impinge said exhaust tangentially on the rotor of the succeeding stage without change of direction upon leaving the rotor of the preceding stage.

7. In a multi-stage turbine, a plurality of rotors mounted independently of each other, a differential power transmission means connected to each rotor, each transmission means being operatively connecting to the succeeding power transmission means for connecting the exhaust of a preceding stage to the inlet succeeding stage, said exhaust and inlet connecting means directing the flow of the exhaust from one stage to the next stage in the path of the helical screw thread.

8. In a turbine having a plurality of stages, the rotor of each stage mounted independently of the rotors of the other stages, a differential power transmission for each stage, the output shaft of a power transmission of a preceding stage constituting the input shaft of the power transmission of the succeeding stage.

9. In a turbine having a plurality of stages, the rotor of each stage mounted independently of the rotors of the other stages, a differential power transmission for each stage, the output shaft of a power transmission of one stage constituting the input shaft of the power transmission of the succeeding stage, and the rotor of the last stage having a double row of blades with a row of said blades being set in the opposite direction of the other row of said blades.

10. In a turbine, a rotor, a differential power transmission connected to the rotor and comprising an input shaft, an output shaft, a train of gears connecting the input shaft to the output shaft and a housing mounted for free rotation on the said shafts and carrying the said train of gears and gear means connecting the housing to the input shaft for driving the input shaft.

11. In a multi-stage turbine, each stage comprising a rotor, a differential housing connected to and driven by the rotor, an input shaft, an output shaft and a train of gears connecting the shafts and carried in the housing, the output shaft of a preceding stage being common with the input shaft of the succeeding stage and the differential housing of each stage mounted on the input and output shafts of said stage.

12. The multi-stage turbine of claim 11, the differential housing of the first stage driving the input shaft of said stage.

13. The multi-stage turbine of claim 11, the exhaust of a preceding stage being connected to the exhaust of a succeeding stage.

14. The multi-stage turbine of claim 11, the rotor of the last stage having a double row of blades, each row set in a direction opposite to the other row and valve means for selectively directing the exhaust from the preceding stage to one of the said rows of blades.

15. In a multistage turbine, a stage comprising a rotor, a differential housing connected to and driven by the rotor, an input shaft, an output shaft and a train of gears carried in the housing and connecting the shafts, the differential housing mounted for free rotation on the shafts.

16. In a multi-stage turbine, a pluraltiy of stages, the rotor of each stage being mounted for rotation independently of any other stage, a differential power mechanism operated by the rotor of each stage, the output of each differential power transmission being connected to the input of the differential power transmission of a succeeding stage, the output of the differential power transmission of the last stage constituting the output of the turbine.

17. The multi-stage turbine of claim 16, means connecting the exhaust of a preceding stage to the inlet of a succeeding stage and directing the flow of the exhaust substantially in a path unchanging in direction.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,398,124	Cake	Nov. 22, 1921