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A New Design of Variable Displacement Compressor

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Abstract

For car air conditioning, engine power requirements for variable displacement compressor is less than fixed displacement compressor as flow of refrigerant can be varied as per cooling demands. Also, sudden clutching and declutching of fixed displacement type compressor creates problem on smooth running of engine. The invention provides a new design of effective variable displacement mechanism which is suitable to implement in variable displacement compressor for car air conditioning.

1. Introduction

At present, swash plate drive or toggle plate drive[1] variable displacement compressor is mostly used for car air conditioning system. Swash plate drive is comparatively complicated and costly for the provision of slipper joint of piston ends with the rotary swash plate. In toggle plate drive, separate drive plate and toggle plate are required for the necessary drive and there is a sliding friction exists in between the toggle plate and guide ball of the toggle plate actuating angled yoke. From kinematic point of view, the newly designed compressor offers the variable displacement mechanism that can vary compressor displacement effectively. Also, frictional loss is minimized in the driving mechanism of new compressor.

2. Construction

The mechanism is shown in Fig.1. On a circular base platform (1) a number of compressor cylinders (2) are arranged around the centre near the circumference of the platform. Pistons (3) as usual, reciprocate in cylinders for pumping action. A central column (4) stands just at the centre of the base platform. A driving disc (5) mounted at the top end of the column through ball and socket joint (6) at disc centre and the disc can oscillate up and down in every direction throughout 360 degree of horizontal plane about its centre. Piston rods (7) are connected near the outer edge of the driving disc throughout its circumference and these rods are provided with ball and socket joints at both disc and piston ends. The lower end of the vertical driveshaft (8) is forked end and placed just above the centre point of driving disc and shaft pulley (9) is driven by engine crankshaft through belt drive. A driving arm (10) is fixed at its mid position with the fork end of driveshaft by a pin acts as fulcrum pin, so the arm can turn about the fulcrum. Two rolls, one is pressure roll (11) and the other is guide roll (12), are attached with the driving arm and these rolls control the oscillatory motion of driving disc according to the inclination of driving arm. Rotation blocker rod (13) is fixed at the periphery of the driving disc aligned with horizontal axis of the disc and it touches a stopper rod (14) which is attached with compressor casing. The arrangement prevents undesirable rotational movement of driving disc due to the pressure of rotating rolls. A control sleeve (15) enclosed the driveshaft sleeve (16) upside and linked with driving arm through control link (17). The sleeve is further enclosed by eye of stroke control disc (18) as such that the sleeve when rotates, the stroke control disc remains stationary. If stroke control disc is pulled or pushed along the driveshaft axis through servo controlled pistons, the control sleeve also slides up and down along the shaft for upper flange (19) and lower flange (20) of the sleeve and so, through control link the driving arm turns about its fulcrum and amount of inclination of driving disc is determined. To arrange space for driveshaft pulley, servo cylinders (21) are located above the driveshaft pulley and fixed with compressor casing through extended short steel strips (22). Thrust ball bearing (23) is used in between lower flange of the control sleeve and stroke control disc. Sliding contact exists in between upper flange of the control sleeve and stroke control disc so, a stainless steel liner is attached inside of upper flange and bronze liner is provided at upside of stroke control disc to minimize friction. A bronze bush is also fitted inside of stroke control disc bore. The compressor has a casing (24) bolted with base plate. Housing (25) for double row ball bearing of driveshaft is attached with compressor casing. Necessary pipelines are arranged for intake (26) and discharge (27) of the refrigerant from the compressor cylinders.

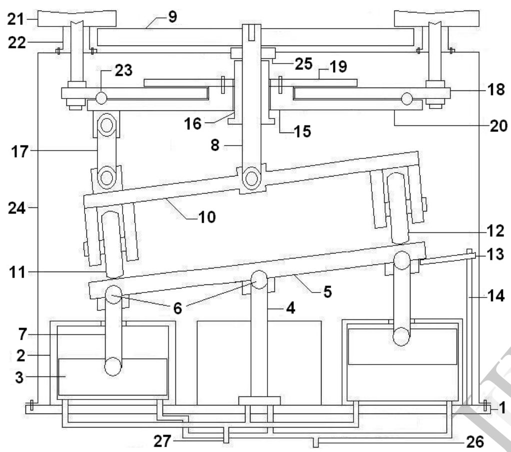

Fig.1. New Variable Displacement Compressor

2.1. Operation

When compressor driveshaft rotates, driving arm also rotates and the rolls continue to roll on the driving disc. When the driving arm is in inclined position then the disc oscillates up and down in all directions of horizontal plane and as a result pistons reciprocate in cylinders. Two rolls are used, as because, pressure roll presses the driving disc and the guide roll opposes the inertia effect thus controls the piston stroke. The rotational blocker and stopper arrangement prevent any undesirable rotational movement of driving disc due to the pressure of rotating rolls. When driving arm rotates with driveshaft, the control sleeve also rotates as it is connected with driving arm through control link. The position of sleeve is controlled by stroke control disc as per requirement. When piston stroke is to be increased, stroke control disc is brought to lower resulting the control link to press the pressure roll end of driving arm more downward, so inclination of driving disc is more and degree of oscillation of disc is also more, hence piston stroke is also increased. When control sleeve is pulled upwards by stroke control disc, the driving arm position changes to discharge refrigerant less as now guide roll presses the driving disc towards horizontal plane and when driving arm is brought to horizontal position there will be no discharge from the compressor.

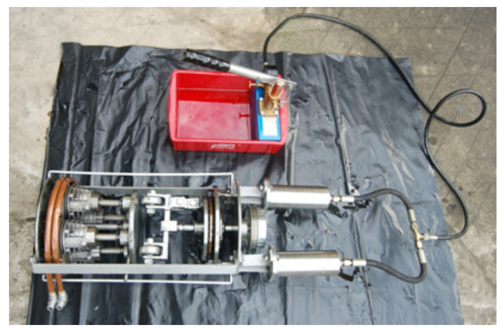

Fig.2. Driving arm horizontal, no piston movement for driving arm rotation

Fig.3. Pistons reciprocate for the rotation of inclined driving arm

3. Unique features of the new design

a. In the new design, simply rolls are used for controlling driving disc inclination.

b. Stroke length is accurately controlled for the implementation of guide roll.

c. Another benefit of newly designed compressor is that, absence of any significant friction in the driving mechanism for the use of pressure and guide rolls and for the provision of rolling balls in between lower flange of the control sleeve and stroke control disc.

d. In this new compressor, piston rods, pressure roll, control link joints, ball recess in between lower flange of the control sleeve and stroke control disc are all kept aligned so that, undesirable bending stress on the components cannot be developed. In the design, servo pistons provided in two sides of stroke control disc impart uniformly distributed pressure to the lower flange of the control sleeve through uniformly spaced rolling balls.

4. Engineering design

For prototype formation, few specifications of present day typical one cylinder A.C. compressor of Maruti Alto car are followed. Compressor power is considered as 4 BHP and maximum compressor rpm is taken as 3000. 4 number cylinders are used in present prototype and total swept volume of cylinders is 133cc. R-134a is selected as the refrigerant for this compressor. Delivery pressure of refrigerant is taken as 16kg/sq.cm absolute. Suction pressure is considered as 3kg/sq.cm absolute at a temperature of minus 15 degree Celsius. Ratio of isobaric specific heat (CP) and isochoric specific heat (CV) is taken as 1.16 [2].

4.1. Component of materials and analytically derived specifications

Piston

Material- Carbon steel, chrome finished surface and without piston ring.
Piston rod ball ends are case hardened and surface finished. Threaded lock ring is provided to secure the ball on its seat.

Piston diameter- 2.8cm
Length of the piston- 3.7cm
Piston stroke length- 3.1cm
Clearance length- 0.3cm.
Diameter of piston rod- 1cm
Diameter of ball end- 2cm
Length of the piston rod- 10cm

Cylinder

Material – Carbon steel, Die Cast.

Seamless steel pipes of internal diameter 0.6cm are fitted with inlet and discharge ports of the cylinder head.

Length of cylinder with head- 10.8cm
Cylinder wall thickness- 1cm
3cm thick cast cylinder head with valve assembly is bolted with cylinder flange.
Diameter of the flange- 8.6cm.
Thickness of the flange- 1cm.

Valve design

Valve material- Alloy steel
Diameter of valve disc- 1cm
Lift of valve- 0.3cm.

Pressure roll and guide roll with pins

Material- Carbon steel, case hardened

Diameter of pressure roll and guide roll- 6cm
Thickness of the rolls- 1.7cm
0.3cm thick bronze bush is inserted inside of bore of the rolls
Diameter of roll pin- 1.4cm
Length of the pin in between forks- 1.9cm
Outer diameter of eye of fork joint located at the bottom of driving arm near the ends- 2.8cm
Thickness of eye- 0.7cm
Total length of the pin- 3.3cm excluding pin head at one end and threaded opposite end. Castle nut with split pin is provided to lock the pins of rolls.

Driving disc

Material- Carbon steel, case hardened

Maximum disc inclination- 15 degree
Driving disc radius- 9cm
Thickness of disc- 1.3cm
0.3cm deep grooves are cut in driving disc to insert all ball joint seats.
Horizontal axis of all the balls of piston rod and central column are kept in same plane.
Distance of piston rod ball joint from driving disc centre- 6cm
Distance of pressure and guide roll from driving disc centre- 6cm

Driveshaft

Material- Carbon steel
Diameter of shaft- 1.2cm
Length of the driveshaft- 18cm

Keyway and thread is cut at the end of shaft to provide drive pulley
Width of the keyway- 0.5cm
Depth of keyway in shaft- 0.3cm
Outer diameter of shaft sleeve- 2.4cm
Length of the shaft sleeve- 6.5cm
Thickness of the control sleeve- 3.8cm.
Collar is provided at the lower end of shaft sleeve to prevent excess downward movement of the control sleeve in case of failure of servo piston stroke control mechanism.
Diameter of fork end pin- 1.2cm.
Length of the pin in between forks- 1.5cm.
Outer diameter of the fork- 2.4cm.
Thickness of eye- 0.6cm.
Total length of the pin- 2.7cm excluding groove to fit retainer rings at both end
Diameter of driveshaft pulley- 12.5cm

Driving arm

Material- Carbon steel, rectangular in shape

Length and width of the arm at mid position where the arm is connected with drive shaft fork end- 2.4cm
Width of the arm except mid position- 1.2cm
Thickness of the arm- 1.4cm
Thickness of arm at the location of control link fork joint and at both ends- 4.2cm.
Length of arm at both thick ends where fork joint eyes of pressure roll and guide roll to fit- 4.3cm
0.3cm thick bronze bush is fitted inside the hole at arm centre where driving arm fork end is attached through pin.
Length of the driving arm- 16cm

Central column

Material- Carbon steel, round in shape.

Diameter of column- 1cm
Diameter d of ball end- 2cm.

Length of column- 18cm including height of the inbuilt flanged base
Diameter of the flanged base- 5cm to fix up the flange bolts with base plate
Thickness of the flange- 1cm.

Control link

Material- Carbon steel, rectangular in shape

Width of the link- 1.4cm
Thickness of the link- 1.7cm
Outer diameter of eye portion of the control link- 2.8cm
Outer diameter of the fork ends provided in driving arm and bottom of the lower flange- 2.8cm
Thickness of eye portion of control link- 2cm
Thickness of eye of the fork in driving arm and in lower flange of the control sleeve- 0.7cm
0.3cm thick bronze bush is fitted inside of control link eyes
Diameter of link pin- 1.4cm
Length of pins in between fork ends- 1.75cm
Total length of the pin- 3.15cm excluding pin head at one end and groove to fit retainer ring at opposite end.
Distance of control link fork joint from driveshaft- 6cm

Control sleeve and stroke control disc

Material- Carbon steel

Outer diameter of control sleeve- 4.8cm.
Outer diameter of the upper flange- 9.6cm
Outer diameter of lower flange- 16cm.
Diameter of ball recess- 12cm
Thickness of the upper flange- 0.5cm
0.3cm stainless steel liner is attached inside of upper control flanges
0.5cm thick bronze liner is attached at upside of stroke control disc.
0.3cm bronze bush is also fitted inside of the bore of stroke control disc.
Thickness of lower flange- 1cm
Thickness of ball recess- 0.6cm
Diameter of eye of stroke control disc including 0.3cm thick bronze bush- 4.85cm
Outside diameter of stroke control disc- 21cm
Thickness of the stroke control disc with ball recess- 1cm
0.5cm thick bronze liner is provided at upside of stroke control disc
Diameter of liner- 9.6cm

Base plate

Material- Aluminium alloy, die-cast.

Diameter of the base plate- 25cm
Thickness of the plate- 1cm

Compressor casing

Material- 0.6cm thick die-cast aluminium alloy.
Casing is fitted with pump base plate by casing flange bolts. Bearing is enclosed the driveshaft at

the location of casing wall. Servo cylinders are fixed with the casing by short steel strips.

Servo cylinder, pistons and compression spring

Material of both cylinder and piston- Stainless steel
Compression spring material- Manganese steel

Servo cylinders are located above the driveshaft pulley and fixed with compressor casing through extended short steel strips.
Maximum oil pressure required to actuate the servo piston- 7.3kg per sq.cm.

Bore of the servo cylinder- 5.5cm
Cylinder wall thickness- 0.5cm
Cylinder length- 15.4cm including 1.5cm thick threaded end cover at piston rod end and 1cm end cover at opposite end
Diameter of the piston- 5.4cm
Length of the piston- 5.4cm
Diameter of the piston rod- 1cm
Length of the rod - 20cm

Mean diameter of spring- 4.8cm
Spring wire- SWG- 5
Number of active turns- 4.85
Solid length of the spring- 2.6cm
Free length of the spring- 6.5cm

5. Conclusion

The new compressor design provides kinematic linkage benefits. Moreover, frictional loss is also minimized in the driving mechanism of new compressor design. However before final implementation, detailed testing of .presently available prototype is required at first. Depending upon test results of initial prototype, a refined prototype is to be built and further tests to be carried out after fitment of the compressor in an actual car air conditioning system.

6. Reference

[1] Jacques Gordon, Technical Editor, Cooling System, Variable Displacement A/C Compressor, Motor Age April 2005.

[2] Reference literature of Industrial Refrigeration Consortium, University of Wisconsin, USA.