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ABSTRACT

The offset angle of the upper and lower part of the crankshaft will affect the resistance of discharge of low pressure stage cylinder and suction of high pressure stage cylinder in the rotary two-stage inverter compressor with vapor injection, and then affect the performance of compressor. This paper presents the performance of the rotary two-stage inverter compressor in different bias angle of the crankshaft, which calculated by CFD soft and compared with the experimental results. Under the operation of close vapor injection and open vapor injection, the performance of compressor can be improved by optimize the bias angle of crankshaft。

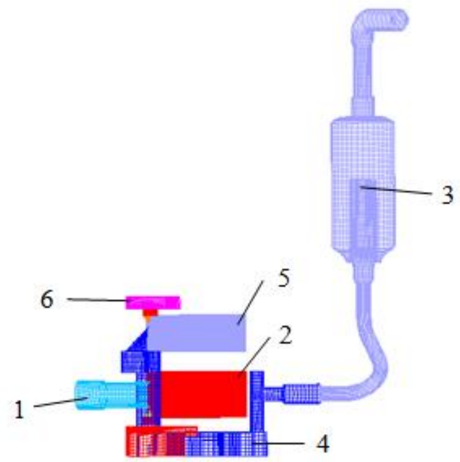
1. INTRODUCTION

Under the extremely atrocious weather conditions for a traditional rolling piston rotary compressor in home air-conditioner, the efficiency of refrigeration or thermal energy usually become worsen due to lack of motivation. The rotary two-stage inverter compressor can solve this problem by open vapor injection.
Huifang Luo et al.(2014) studied the optimal displacement ratio of rotary two-stage inverter compressor with vapor injection based on theory of thermodynamics and experiments. Sicao Zhang et al.(2014) discussed the effect of intermediate pressure gas compensating parameters on the thermal performance of the system. The intermediate pressure gas compensating parameters are changed primarily for exhaust of low pressure stage cylinder and suction of high pressure stage cylinder.
This paper study the influence of offset angle of the upper and lower part of the crankshaft on performance of rotary two-stage inverter compressor by CFD and experimental analysis.

2. CFD Model of Rotary Two-Stage Inverter Compressor

The discharge gas of low pressure stage cylinder mixed with intermediate pressure vapor which injected from flash tank passes through interior channels arrive the gas suction of the high pressure stage cylinder, which form two stage compression. The vapor from flash tank can improve the efficiency of the compressor by cooling the discharge gas which from the low pressure stage cylinder and increasing the suction gas volume of high pressure stage cylinder. On the other hand it causes more exhaust resistance loss by increasing the discharge pressure of low pressure stage cylinder.

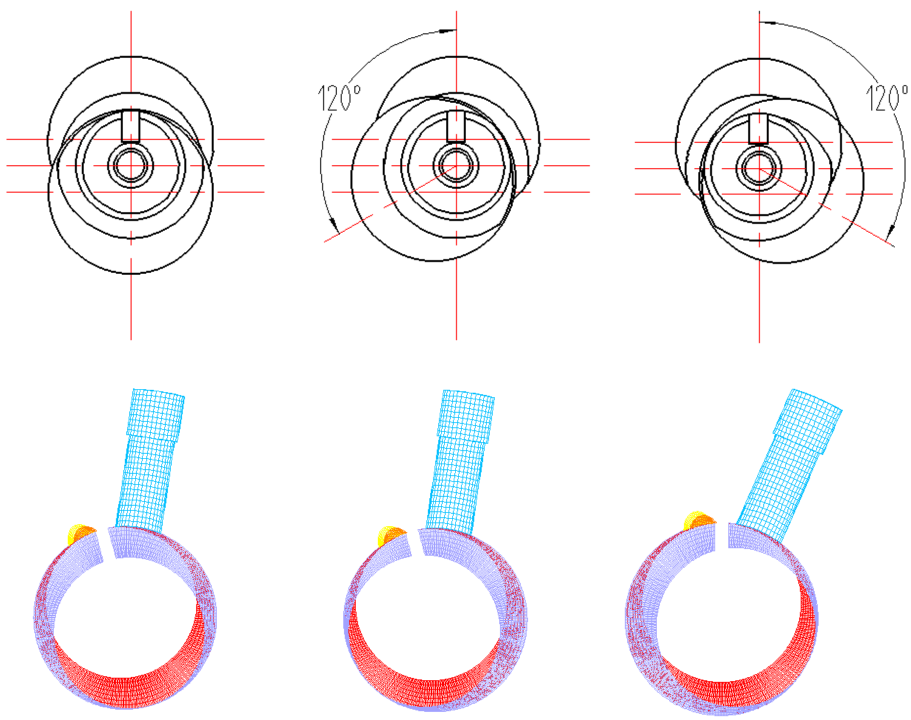
Figure 1 shows the mesh model of rotary two-stage inverter compressor which contains suction pipe, low pressure stage cylinder, intermediate pressure chamber, flash tank, high pressure stage cylinder and exhaust chamber. The calculation model use hexahedral grids and total number of mesh is 511,119. Sliding mesh model is adopted, in which the cylinder parts are moving grids, and the rest parts are stationary. Event file is used to connect the adjacent attach boundary and invoke .cgrd file controls the moving mesh.
The turbulent model use K-Epsilon/RNG model, standard wall function is adopted in the near wall treatment. The physical properties of R410A are used as ideal gas. Operation frequency of the rotary two-stage inverter compressor is 60HZ. The inlet of suction pipe, flash tank and the outlet of exhaust chamber all use pressure boundary.



1. Suction pipe 2. Low pressure stage cylinder 3. Flash tank 4.Intermediate pressure chamber 5. High pressure stage cylinder 6. Exhaust chamber

Figure 1: Mesh model of rotary two-stage inverter compressor

This paper has three calculation schemes; crankshaft and main mesh part of each scheme are showed in figure 2:
Scheme 1: Use the crankshaft of traditional rotary double cylinder compressor, the offset angle of upper and lower part of the crankshaft is 180 degrees. (Fig 2(a))
Scheme 2: On the basis of Scheme1, the offset angle of upper and lower part of the crankshaft is counter-clockwise 120 degrees. (Fig 2(b))
Scheme 3: On the basis of Scheme1, the offset angle of upper and lower part of the crankshaft is clockwise 120 degrees. (Fig 2(c))

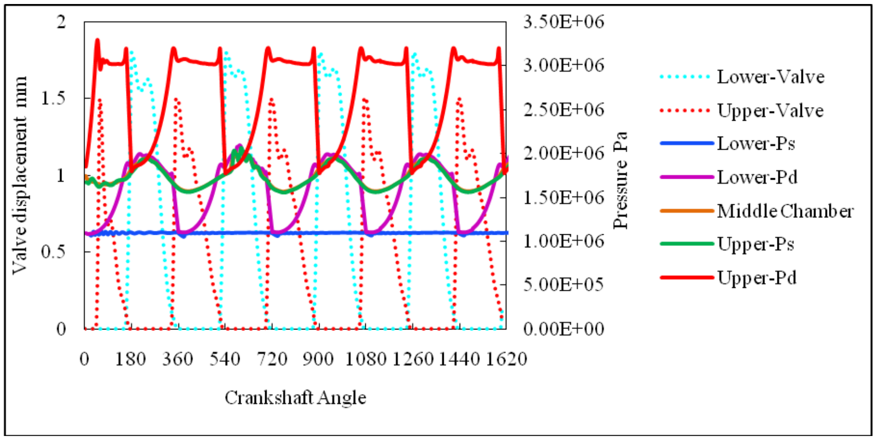


(a) Scheme 1 (b) Scheme 2 (c) Scheme 3

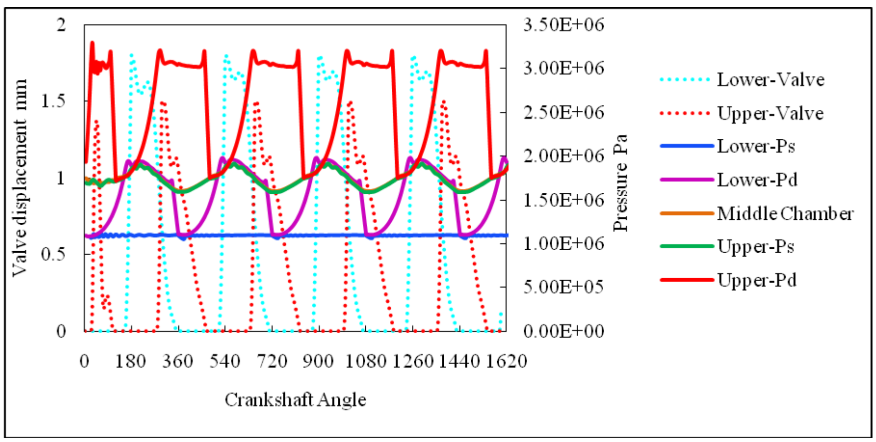
Figure 2: Crankshaft and main mesh part of each scheme

3. Results of CFD Analysis

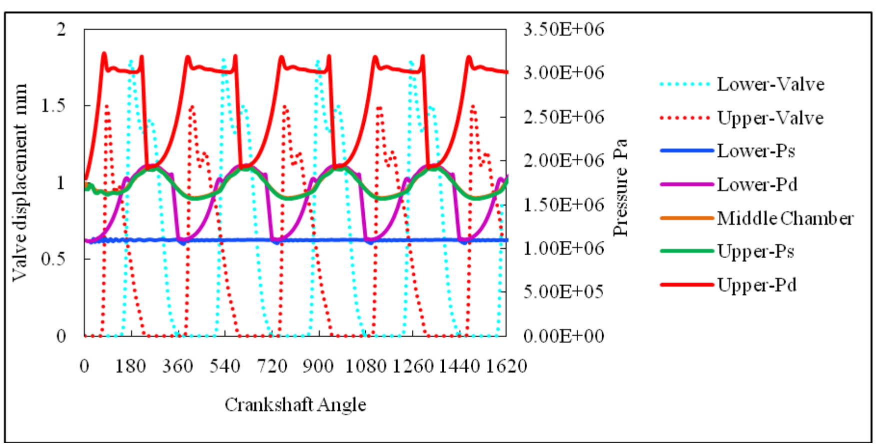
The first three period results of calculation are listed in figures as calculation become stability from the third period. The low pressure stage cylinder is tagged as lower and the high pressure stage cylinder is tagged as upper in result figures.



(a) Scheme 1



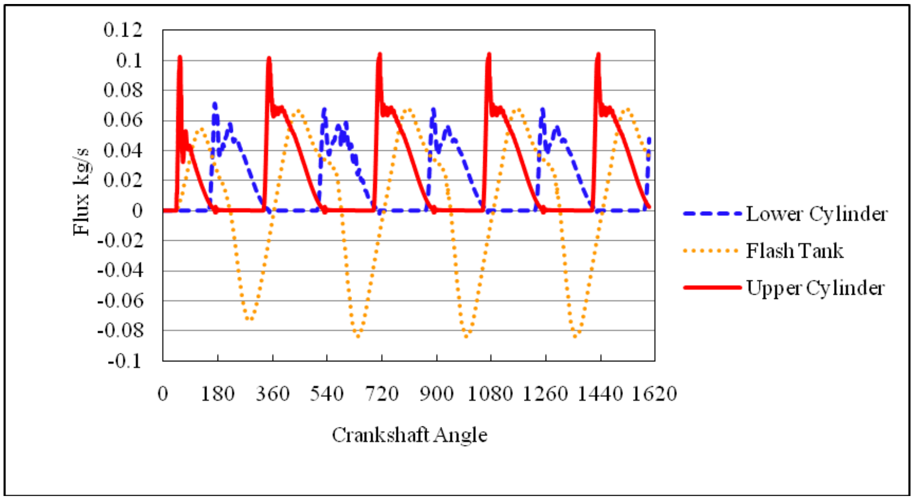
(b) Scheme 2



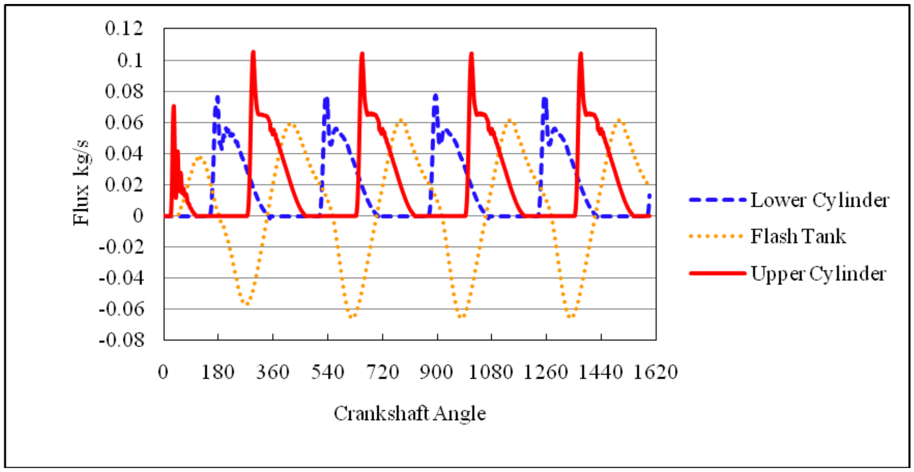
(c) Scheme 3

Figure 3: Valve displacement and pressure translation curves of each scheme

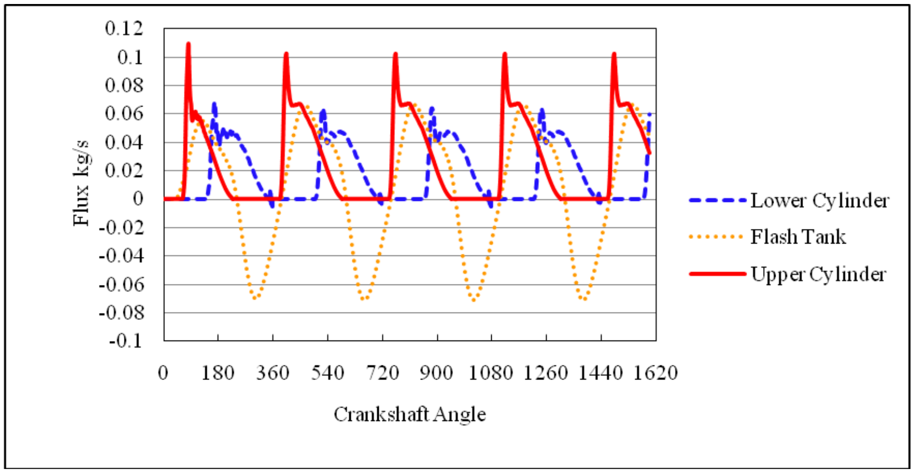
Figure 3 shows the displacement curves of valves and pressure translation curves of each chamber. Horizontal axis is Crankshaft angle, Vertical axis on the left is valve displacement and on the right is pressure.
As figure 3(a) shows, the crankshaft angle of upper valve open is near to the close angle of lower valve. The upper cylinder starts a new round compression and suction after the valve of lower cylinder has opened about 30 degrees. In figure 3(b), the crankshaft angle of upper valve open is before the close angle of lower valve. And a new round compression of the upper cylinder is before the gas discharge of lower cylinder. The interval angle is about 30 degrees.
In figure 3(c), the starting point of a new round compression of upper cylinder is at the middle point of discharge gas line of the lower cylinder.
Figure 4 shows the flux curves of the lower cylinder, the flash tank and the upper cylinder of each scheme, the peak exhaust gas flow rate of lower cylinder is according decreasing order of scheme 2, scheme 1and scheme 3; The inflow rate peak of flash tank is almost equivalent for scheme 1 and scheme 3 which both greater than scheme 2; But the reflux of scheme 1 and scheme 3 also greater than scheme 2 significantly, and the greatest reflux is scheme 1.



(a) Scheme 1



(b) Scheme 2



(c) Scheme 3

Figure 4: Flux curves of each scheme

Figure 5 shows the PV curves comparison of each scheme. The lower cylinder's PV curves almost overlap during the compression process. Significant difference between the lower cylinder's PV curves of each scheme appeared in the stage of gas exhaust. The exhaust pressure of scheme 2 is the maximal at the beginning of discharge, when compression volume change smaller than 4000mm^3, the exhaust pressure of scheme 1 become bigger than scheme 2 gradually. After compression volume is smaller than 2300mm^3, the discharges pressure of scheme 2 becoming the smallest while the scheme 3 becoming the biggest. The upper cylinder's PV curves both have obviously difference during either the suction process or the compressing process. The area which contains discharge loss of lower cylinder and suction loss of upper cylinder enclosed by pressure curves of each scheme are listed on the right of figure 5 and the area of scheme 2 is the smallest among these schemes.

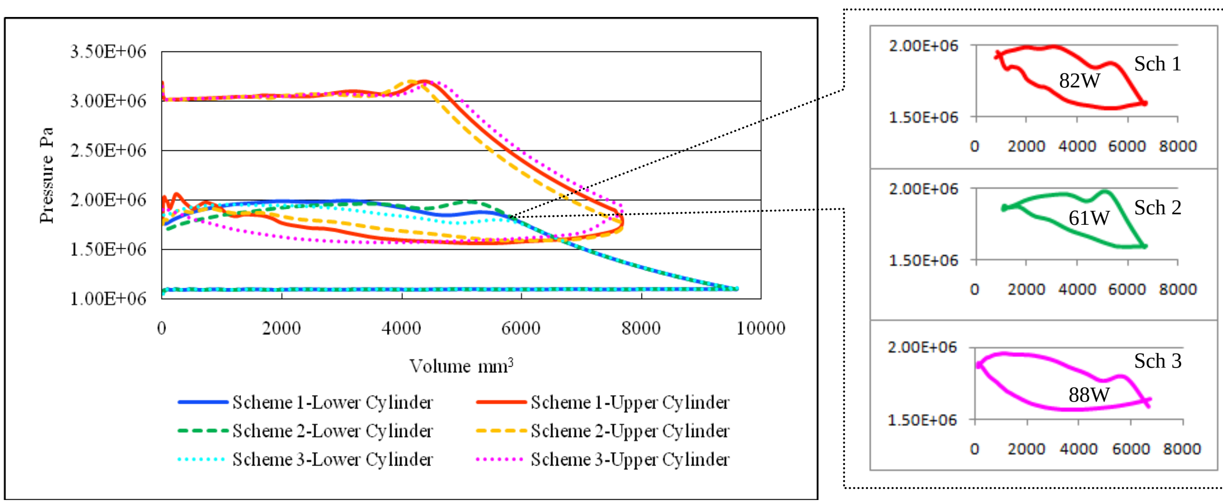


Figure 5: PV curves comparison of each scheme

Table 1: Exhaust flux and indicated power of each scheme

	Flux(Kg/h)				PV(W)			
	Lower Cylinder	**Flash Tank**	**Upper Cylinder**	**Difference**	**Lower Cylinder**	**Upper Cylinder**	**Total**	**Difference**
Scheme1	65.39	16.31	81.70	/	355.99	508.93	864.92	/
Scheme2	65.29	15.68	80.97	-0.90%	349.15	472.60	821.75	-4.99%
Scheme3	65.09	17.21	82.29	0.72%	341.15	544.76	885.92	2.43%

According to figure 4 and figure 5 statistical exhaust flux and indicated power of each scheme are shown in table 1 which use scheme 1 as the original contrast data. Discharge flux from upper cylinder of scheme 2 has decreased 0.9% due to the flux of lower cylinder and flash tank both have decreased slightly, while in scheme 3 the flux of the upper cylinder has increased 1.78% . The total indicated power of scheme 2 has decreased 4.99% while in scheme 3 have increased 2.43%.

By comprehensive comparison, in the case of little change in the amount of cooling, the scheme 2 can be used as optimal plan due to the power consumption has significantly reduced.

4. Results of Experimental Research

Experiments were made to compare the performance of each scheme under the conditions of close vapor injection and open vapor injection which results have been shown in figure 6.The operating frequency is 60HZ and 90HZ. Horizontal axis is operating frequency and name of each scheme, vertical axis on the left is energy and power while on the right is COP. The differences of energy and power between three schemes are not very distinct. But the COP of the scheme 2 is the best both under the operating condition of close vapor injection and open vapor injection.

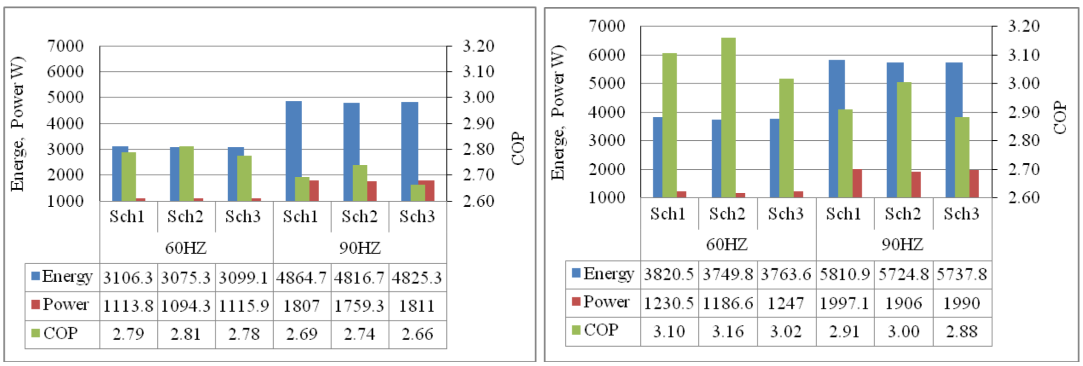


Figure 6: Performance compared with scheme 1

Table 2 list the percent of performance difference compared with scheme 1. The energy both have decreased for scheme 2 and scheme 3 whenever vapor inject is close or open under operating frequency of 60HZ and 90HZ. The power consumption have decreased obviously for scheme 2 while increased slightly for scheme 3 except under open vapor inject operating condition at 90HZ.

Over all, the scheme 2 is the best in performance due to the reduction of power consumption. Scheme 3 has no obvious advantages in both the energy and the power consumption. The calculated results are in agreement with the experimental results in prediction the optimal scheme.

Table 2: Percent of performance difference compared with scheme 1

Scheme	vapor inject	Frequency	Energy	Power	COP
Sch2	Close	60 HZ	-1.00%	-1.75%	0.77%
		90 HZ	-0.99%	-2.64%	1.70%
	Open	60 HZ	-1.85%	-3.57%	1.78%
		90 HZ	-1.48%	-4.56%	3.23%
Sch3	Close	60 HZ	-0.23%	0.19%	-0.42%
		90 HZ	-0.81%	0.22%	-1.03%
	Open	60 HZ	-1.49%	1.34%	-2.79%
		90 HZ	-1.26%	-0.36%	-0.91%

5. CONCLUSIONS

The CFD model of the optimal offset angle between upper part and lower part of the crankshaft of rotary two-stage inverter compressor with vapor injection has been developed and verified with the experimental data in this paper. From above analysis and comparison, Change offset angle between upper part and lower part of the crankshaft have slightly influence on energy of rotary two-stage inverter compressor, but the optimal offset angle between upper part and lower part of the crankshaft can improve the performance by decrease power consumption of rotary two-stage inverter compressor obviously especially with vapor injection.

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