Experiment Study of a Water injected Twin Screw Compressor for Mechanical Vapor Compression System (*1138*)

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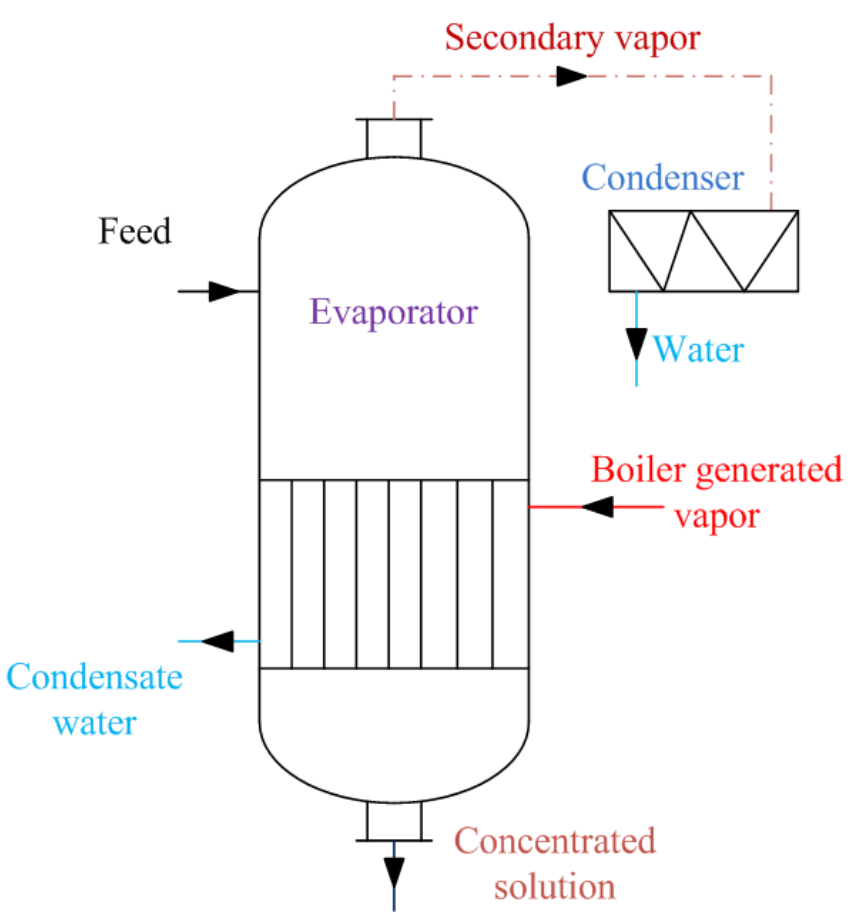
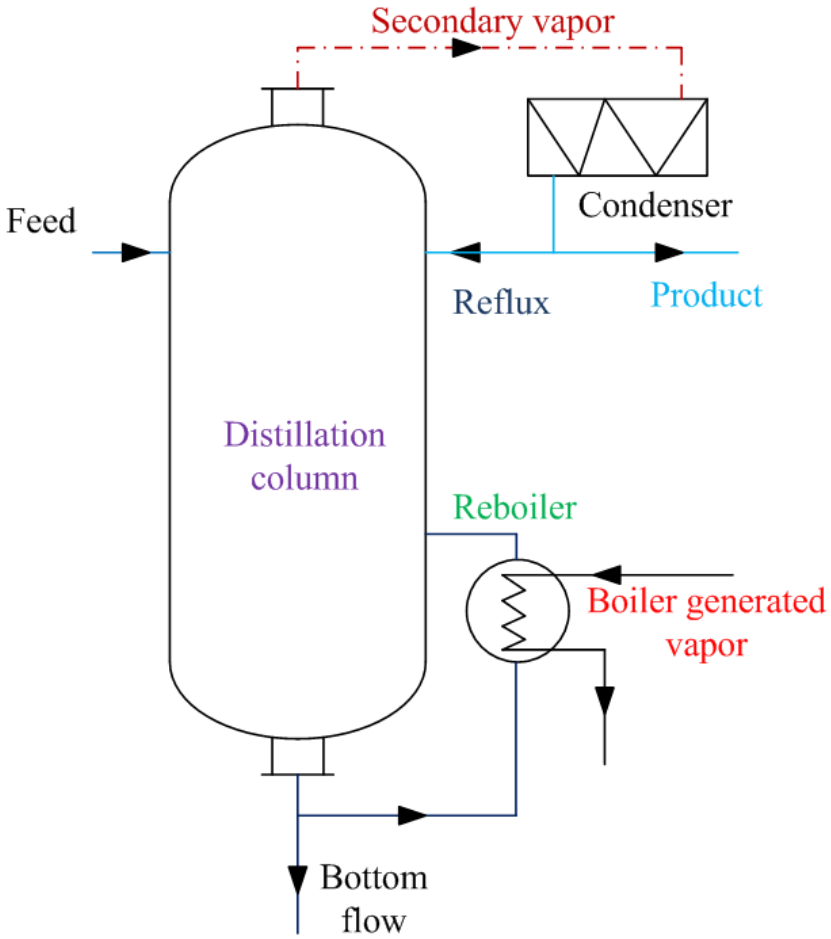
Introduction

➢ Background

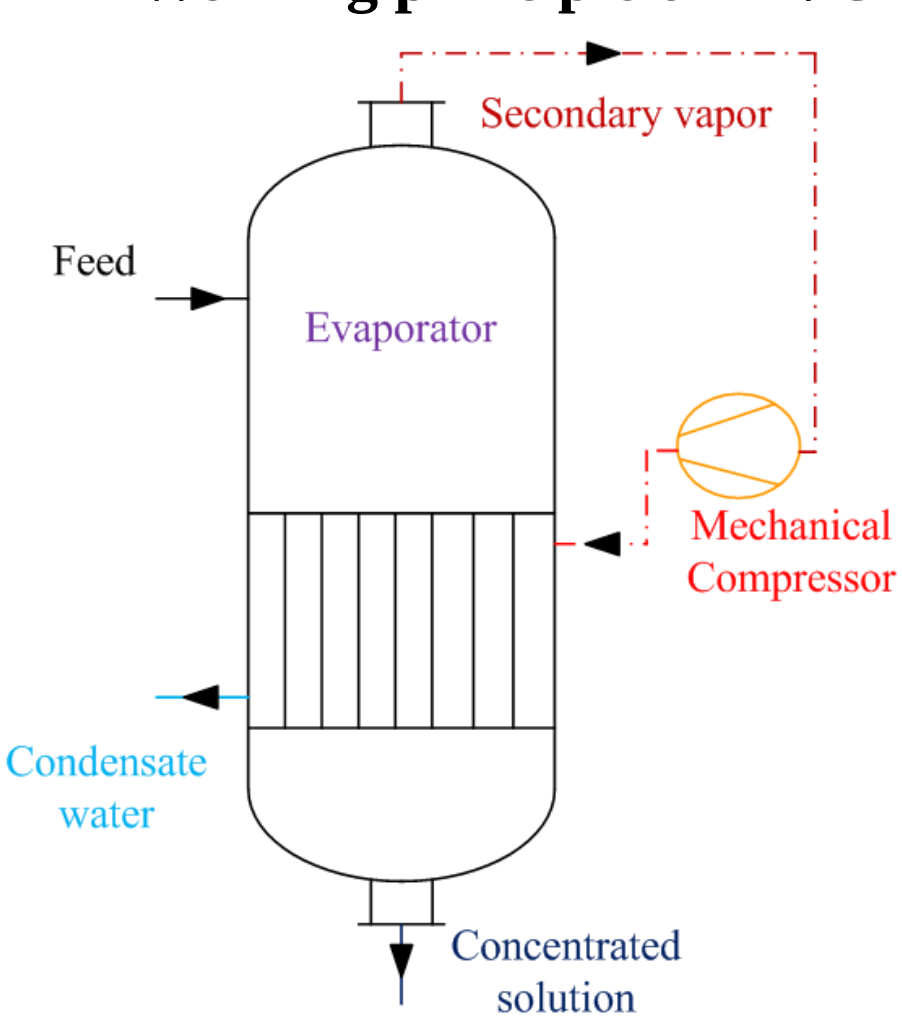
1. Crisis of renewable energy sources and sharp increase of fuel prices
2. Energy recycling of vapor in industries of distillation and concentration

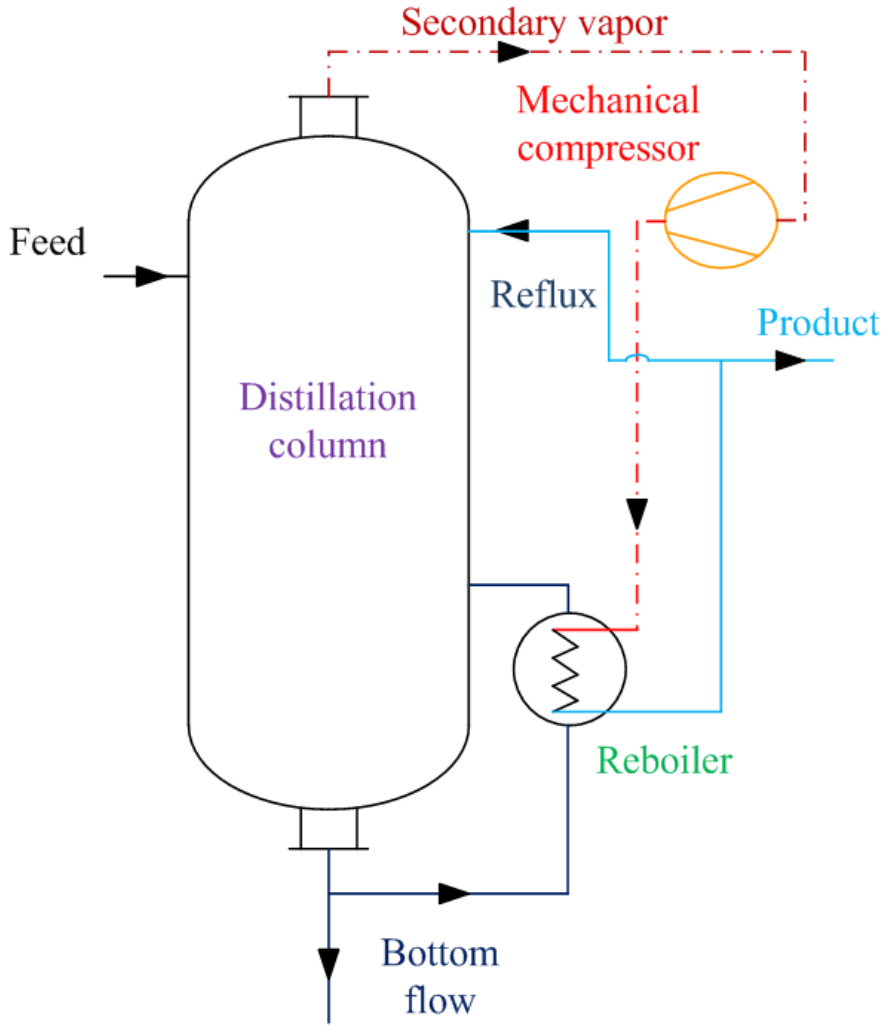




Introduction

➢ Working principle of MVC





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Introduction

- **Technical demands of compressors for MVC application**

1. High volumetric flow capacity with an acceptable compressor dimension
2. High compression ratio (saturate temperature difference as high as 40 K)
3. High efficiency and stability

- **Major types of compressor for water vapor compression**

1. Blowers of multi-stage (temperature difference no higher than 12K)
2. Lobe compressors (poor efficiency and low volume flow rate)
3. Centrifugal compressors (quite expensive with poor reliability)

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Introduction

- **Additional technical difficulties of water vapor compressors**

1. Lower the discharge temperature of the compressor under a high compression ratio

2. Overcome the erosion of compressor

3. Solve the sealing problem

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Introduction

➢ **Twin screw compressor (tolerate wet compression)**

1. High compression ratio (high temperature difference) with saturate discharge vapor temperature by water injection.

2. High durability and reliability

3. Stability of performance for a wide operation range

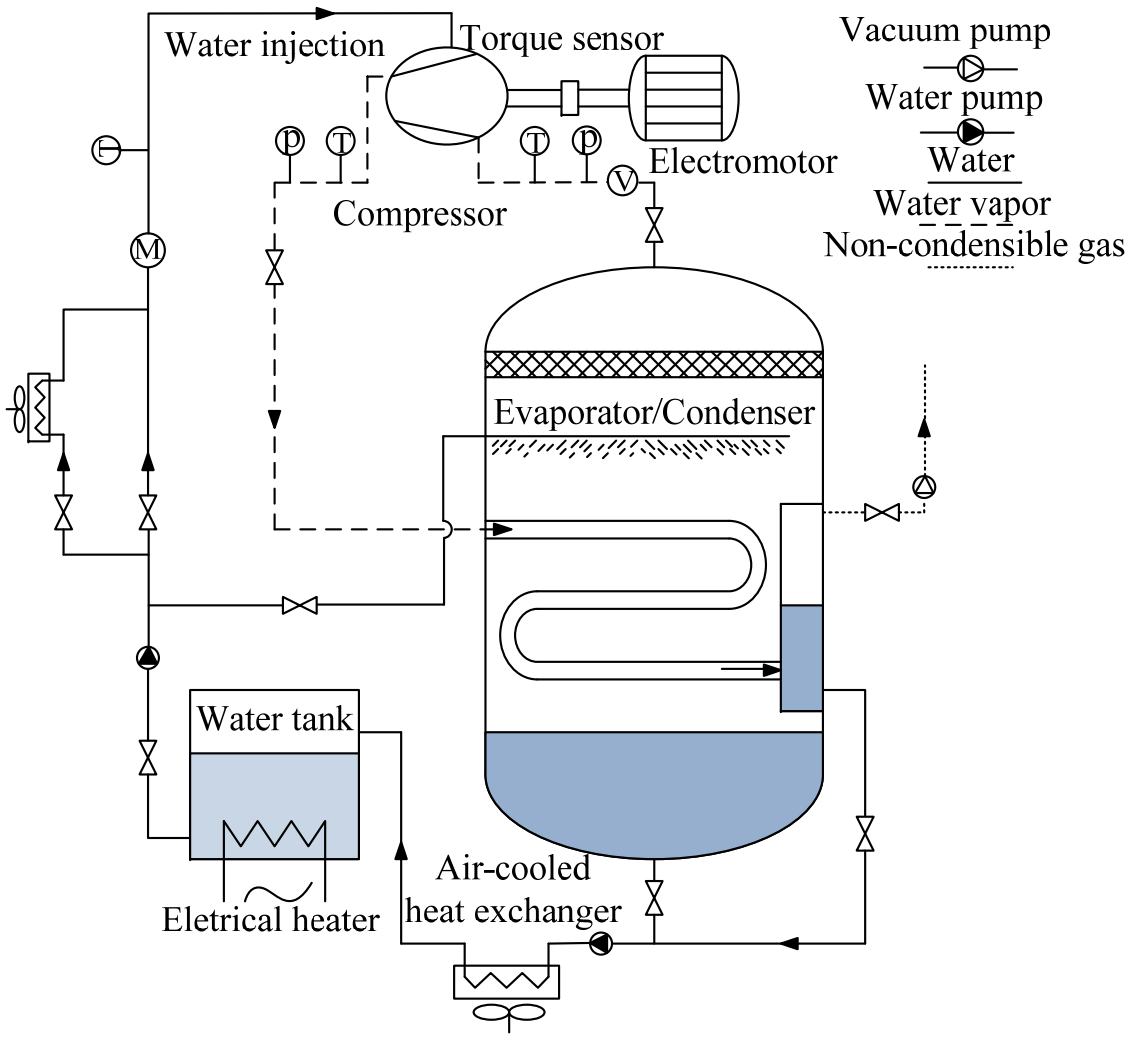
4. Less expensive

To study the performance variation of water injected twin screw compressor, a test rig on the base of MVC was built.

Especially the p-t diagram of the working process was measured.

Experimental setup and procedure

➢ Schematic diagram of the test rig



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Experimental setup and procedure

- **Photograph of the test rig**

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Experimental setup and procedure

➢ Experimental procedure

The working performance of water injected twin screw water vapor compressor which is decided by:

1. temperature or pressure of the suction water vapor
2. rotate speed
3. mass of the injected water
4. Temperature of injected water

Keep three of them constant and change the rest one to record the parameters including shaft power, discharge temperature and pressure.

The p-t diagrams of the operation process with and without water injection can be measured and compared.

Components and instrumentation system

➢ Components of the test rig

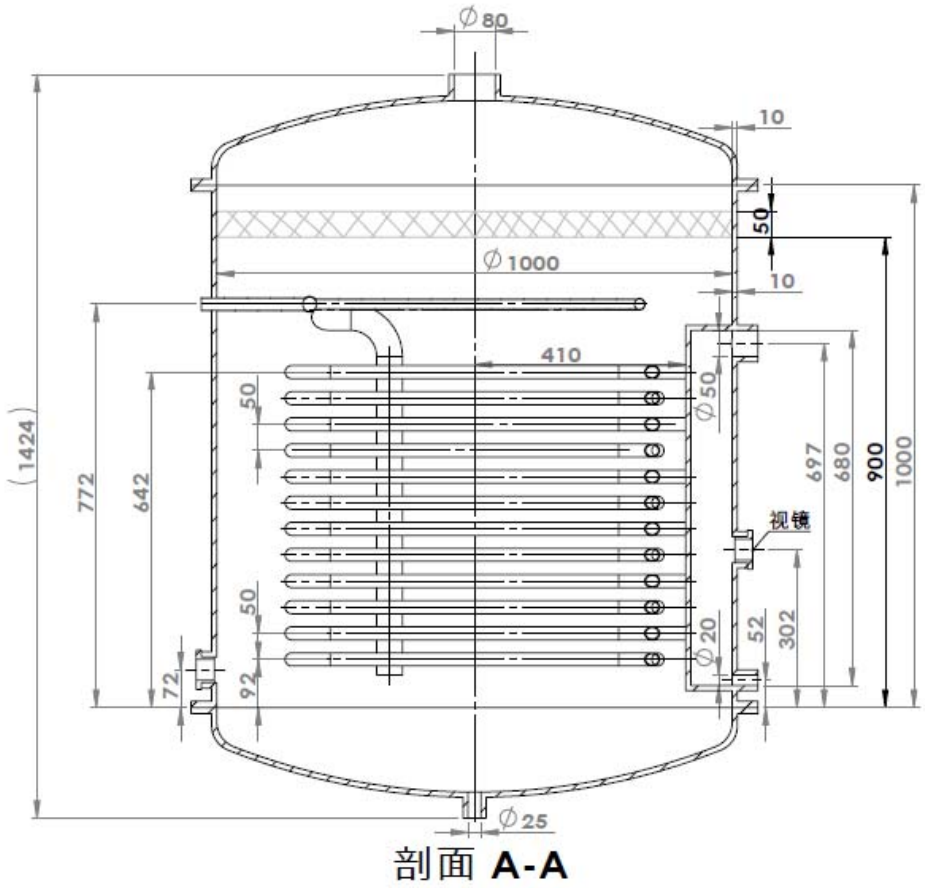
Components	Specifications
Twin-screw compressor	Discharge pressure is 0.25MPa for air compression at a rated speed of 1800 rpm with a speed increasing ratio of 3.72. The theoretical volume flow rate is 0.00236 m^3 per revolution.
Converter	wp-VFA 030-3
Electromotor	Three-phase asynchronous motor, YJTG225S-4/37Kw/380V/5-100HZ
Evaporator/condenser	Carbon steel shell with a inner diameter of 1m and a height 0f 1.4m, 12 stainless steel tubes inside with a total heat transfer area of 4.5 m^2
Water tank	Made by carbon steel with a size of 0.5m×0.5m-0.6m
Air-cooled heat exchanger	20kW plate-fin heat exchanger

Components and instrumentation system

➢Components-compressor

Components and instrumentation system

➢Components-evaporator/condenser



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Components and instrumentation system

- **Components-converter and electromotor**

Components and instrumentation system

➢Instrumentation system

Pressure meter in the suction line	-0.1~0MPa,±0.4%
Pressure meter in the discharge line	-0.1~0.3MPa, ±5%
Thermometers	0~200℃, ±1℃
XFV vortex-shedding flow meter	5.5t/h， ±0.5%
DK800-6 glass rotameter	0~60L/h, ±3%
JN338-200A torque sensor	0~200Nm, 0~5000r/min,±0.5%
XTL-190M Pressure sensors of Kulite	0~0.35MPa with respective sensitivity for each sensor

Besides a DEWE-1201-All-In-One standard instrument was used to collect the data of pressure sensors. The other experimental data were recorded manually

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Results and discussion

➢Overview of the experimental process

1. Vacuumizing of the system cannot be realized

2. Low speed start, vented the gas and sprayed heated water into the evaporator

3. the compressed vapor cannot be condensed during the operation

4. Part of the uncondensed vapor was kept venting

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Results and discussion

➢Overview of the experimental process

5. Discharge pressure was a bit higher than the local atmosphere pressure

6. Suction pressure was a bit higher than the saturated pressure corresponding to the suction vapor temperature

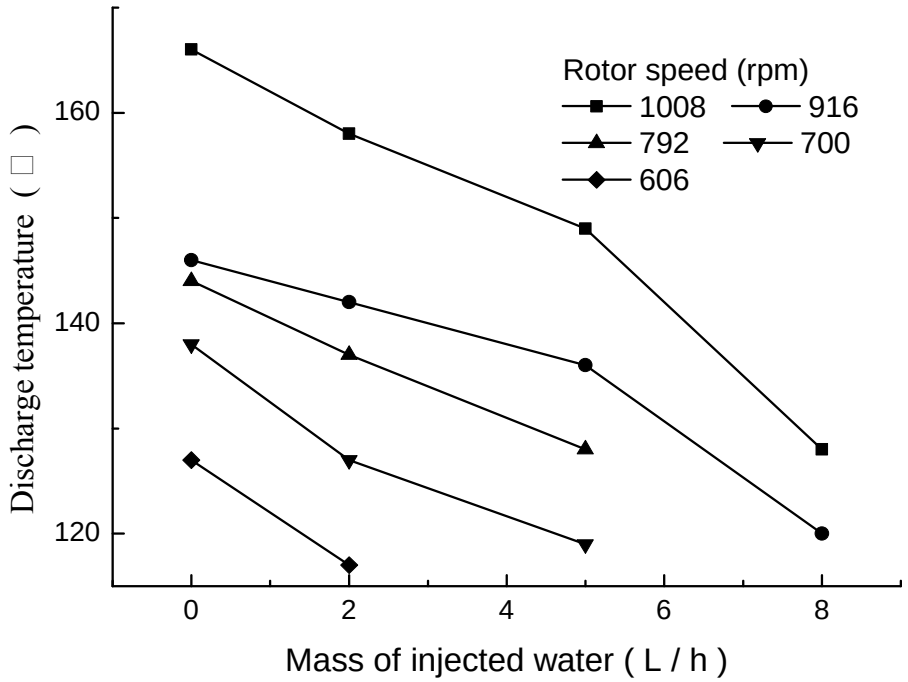
7. Discharge temperature can be lower than the saturated temperature corresponding to the discharge pressure

8. Water was injected automatically due to the pressure difference and regulated by the glass rotameter

Results and discussion

➢Influence of rotor speed and mass of injected water

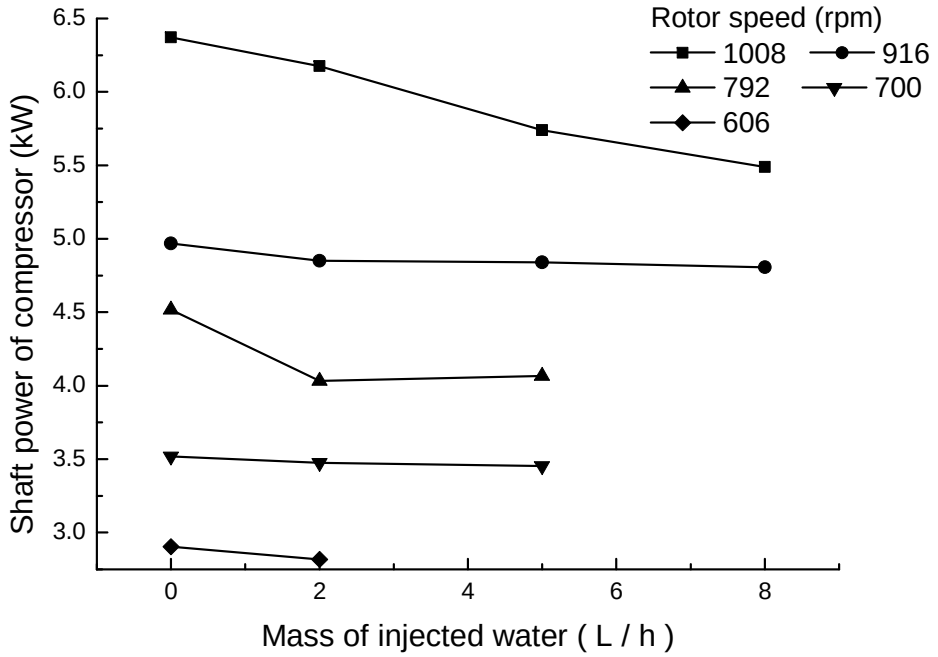
The suction vapor temperature 60 ℃ , injected water temperature 55 ℃



1. Water injection has obvious cooling effect
2. Discharge temperature increased with the speed and reduced with the mass of injected water
3. At different speed, the discharge temperature trend to lower to the saturated temperature

Results and discussion

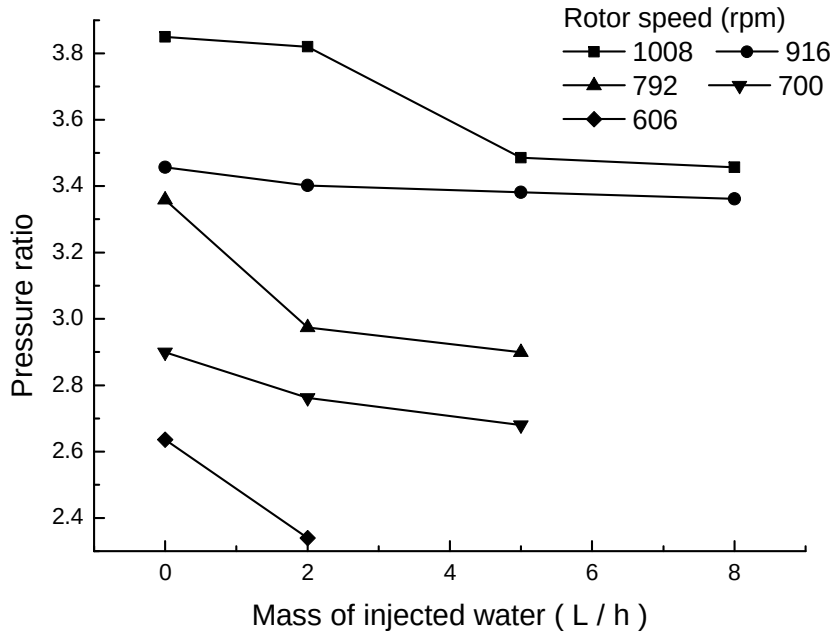
➢Influence of rotor speed and mass of injected water



1. Shaft power decreased once water was injected
2. The shaft power would increase if the mass of injected water increased
3. Shaft power increased with the rotor speed

Results and discussion

➢Influence of rotor speed and mass of injected water



1. The pressure ratio increased with the rotor speed as the discharge pressure increased
2. The pressure ratio decreased with the mass of injected water

Results and discussion

➢Influence of suction vapor and injected water temperatures

The rotor speed 701 rpm with 4 L/h water injection; electric heater inside the water tank kept working

Suction temperature （℃）	**Temperature of injected water**（℃）	**Discharge temperature**（℃）	**Shaft power**（**kW**）	**Pressure ratio**
49	40	75	3.4559	2.730
51	44	87	3.3259	2.594
52	47	101	3.5263	2.425
53	48	100	3.5515	2.438
54	50	89	3.5482	2.438

1. Discharge temperature firstly increased with the suction temperature and then reduced

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Results and discussion

➢Influence of temperatures of suction vapor and injected water

2. The variation of other data was small. It can be concluded that: temperature of injected water temperature has small influence to the performance of compressor as the cooling effect is mostly a result of its latent heat

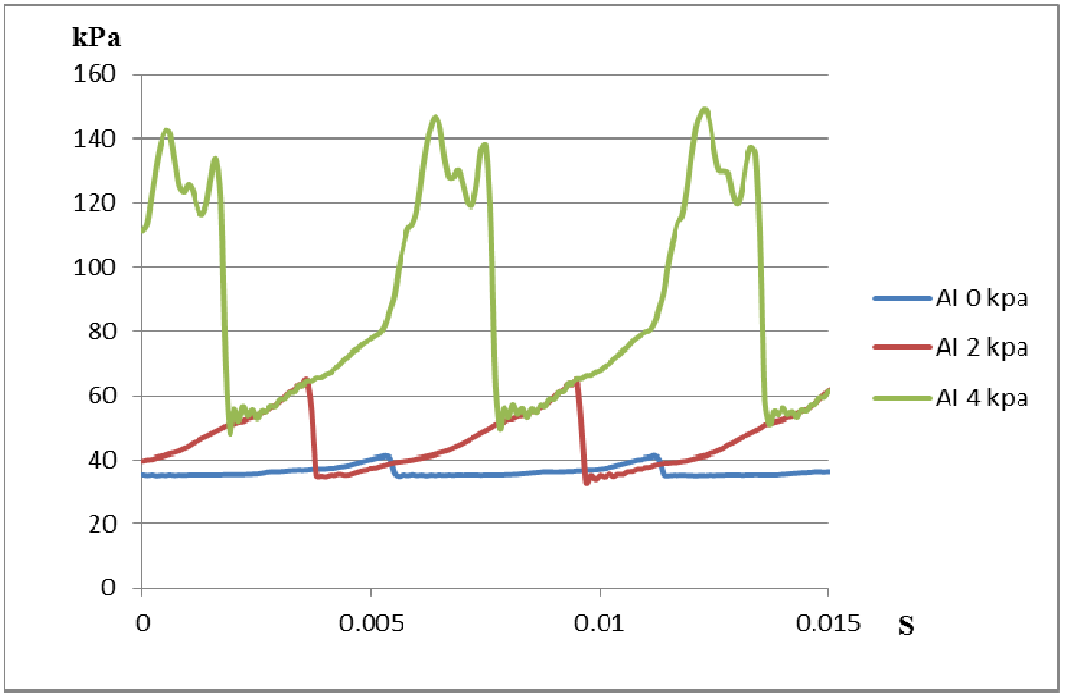
3. It is suggested that the injected water temperature should be the same as or a bit higher than the suction temperature as the evaporation temperature is decided by the pressure of working chamber

4. Discharge port of water injected twin screw water vapor compressor should be set downward to reduce the leakage of water into the suction chamber

Results and discussion

➢Results of p-t diagram

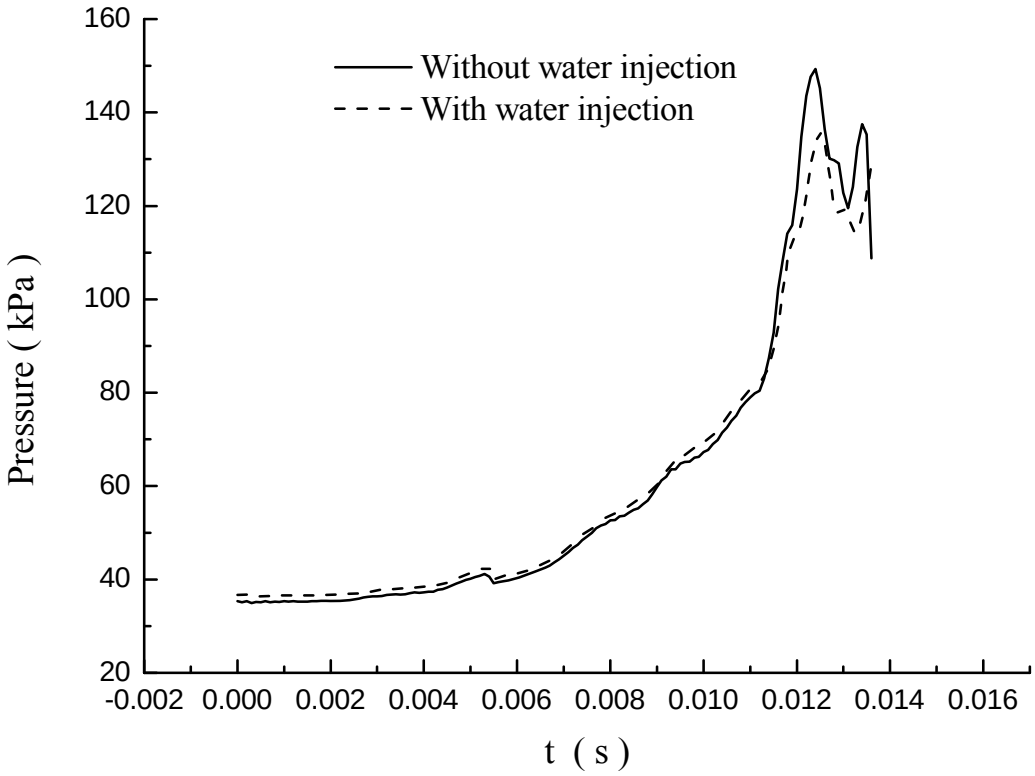
Three XTL-190M pressure sensors of Kulite were installed in the case of compressor.



Results and discussion

➢Results of p-t diagram

Without and with 2 L/h water injection at 916 rpm with a suction temperature 60 ℃, injected water temperature of 55℃ in the same diagram

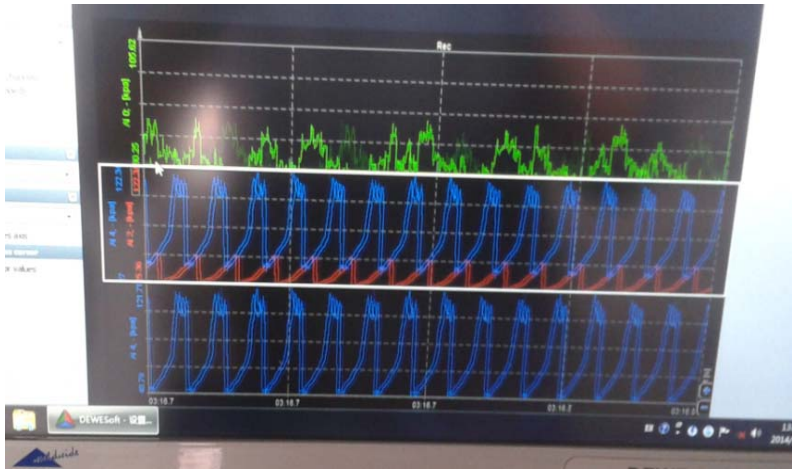


1. The suction pressure with water injection was higher due to the water evaporation
2. The discharge pressure with water injection was smaller
3. Over compressing can be found in both diagrams

Results and discussion

➢Results of p-t diagram

The suction chamber pressure measuring sensor failed to work once too much water was injected :



The pressure sensor cannot be used for conductive medium. Injected water leaked into the suction chamber, flowed with the suction vapor and entered into the hole for pressure sensor installer

Conclusions

➢Conclusions

1. Water injection has obvious effect for the discharge temperature reduction
2. The injected water may leak into the suction chamber where it evaporates to increase the suction pressure and also may reduce the suction volume flow
3. Water injection can reduce the power consumption
4. Too much water injection may deteriorate the performance
5. Temperature of injected water has small influence to the performance

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Thank you !!