

The Studies of Compressor-reliability for Tropical Region

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Abstract - The environmental issues are challenging and the Chinese goods are increasing here in Thailand. To keep our business stable, we are studying how to improve our compressors.

On the other hand, “refrigerator and air-conditioner” are dependent on the life style of each region. And now, Middle East is enjoying their economic growth. Therefore, it should be necessary for air-conditioner and refrigerator makers to use high quality compressor for them in particular. We also need to study many kinds of the market conditions.

Collaborating with some white goods companies, we studied “actual application specification”. As a result, our customers prefer our reciprocating compressors rather than others. And they prefer our products over other brands for its toughness, even in the tropical region. Here, we define the tropical and we make sure that our lubrication system is better than the others.

Bangkok is an elephant city. Among developing regions of the world, the weather, the power-source, the transportation-systems are worse than those in Bangkok such as Indonesia, Philippines, and Vietnam. We take the advantage of “actual application specification” idea, into the other regions.

Keyword - Compressor-reliability, Tropical Region

I. INTRODUCTION

Basic about compressor and refrigeration-cycle is shown in Fig. 1 and Fig. 2.

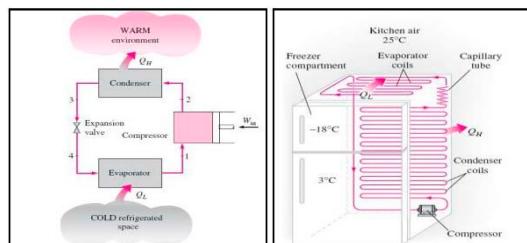


Fig.1 Refrigeration Cycle

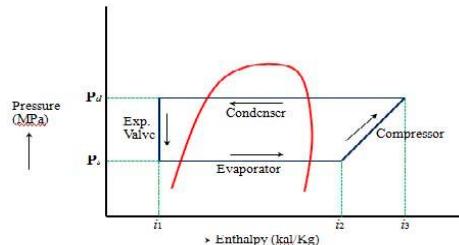


Fig.2 Mollier Chart

Feature of Kulthorn Kirby

KKC is the first compressor manufacturer in Thailand since 1980 and a leading manufacturer in reciprocating compressor for refrigeration and air condition products. KKC has employed vertical integration business model, allowing it to have a more competitive cost and supply chain structure.

Kuthorn (KK) compressors are available from small to large size, ranging from 1/25 HP up to 10 HP with annual capacity of 12 million of which 70% of them exporting with useful experience and certifications. Fig 3 is KK Group affiliated companies.

Company	Established	Products	Annual Capacity
Kulthorn Kirby (KKC)	Mar, 1980	Reciprocate Compressor	5.2 Million
Kulthorn Premier (KPC)	1982(KK acquired in 2004)	Reciprocate Compressor	5.5 Million
Kulthorn Kirby Foundry (KKF)	Nov, 1989	Casting Products	50,000 Ton
Kulthorn Steel (KSC)	June, 2007	Slitting/ Blanking Steel	280,000 Ton
Kulthorn Metal Products (KMP)	Mar, 2005	Forging, Machining	23,000 Ton
Kulthorn Material & Control (KMC)	Aug, 1990	Enamelled Copper Wire	12,000 Ton
Suzhou Kulthorn Magnet wire (SKMC)	2003(KK acquired in 2008)	Enamelled Copper Wire	7,000 Ton
And 2 factories of KULTHORN GROUP			
Thai Compressor Manufacturing (THACOM)	Sept, 1988.	Rotary compressor	1.2 Million
Kulthorn Electric (KU)	Dec, 1987.	Electric motor	1.4 Million

Fig.3 KK Group

II. OBJECTIVES

The aim of this study is to investigate the robustness of reciprocating compressor in other countries including ASEAN and Middle East through 3 case studies. We have listed 3 case studies and 2 boundary conditions.

Based on 3 studies and 2 recent global movements, we found new business opportunities.

III. METHODS

Case Study 1

A. Transportation from Thailand to other countries.

KK supplies its compressor to end-user (consumer) through refrigerator makers. We have distinguished the bad transportation logistics among all of the logistics as shown in Fig. 4.

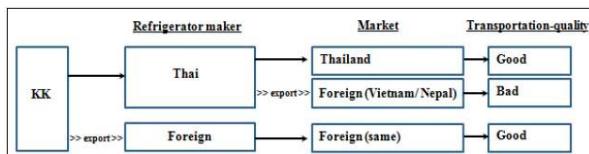


Fig.4 3-typical transportation systems

B. We analyzed the case and got 3 findings.

1. Home Appliance Goods are dependent on the market, which is studied by the maker in its same region. For example Indonesian refrigerator maker knows its market in Indonesia. But Thai refrigerator maker is not familiar with Vietnam market. Generally, every refrigerator maker knows its domestic market. But sometimes, it is not aware of other country's one.

2. In the developing nation, the system of transportation is not good enough, particularly in the countryside. We found "motorcycle-transportation" in Vietnam. We need to distinguish the transportation system in countryside from the big city, such as Bangkok. In addition, the transportation system, including handling is very good in Japan.



Fig.5 Transportation

3. Since KK has improved/solved its transportation toughness, there is no failure during transportation. Recently, KK has started to supply to the Egyptian refrigerator maker, which appreciates this transportation advantage.

Case Study 2

Home Freezer in Indonesia.

Among many kinds of home-freezer in the world, there are some differences. We can show the representative models, here. Fig. 6 is a comparison of home freezer among Indonesia, Japan and EU.

	Indonesia	Japan	EU
Appearance		< -----	
Installation	Restaurant Shop (Indoor/outdoor)	Kitchen Barn	Garage Barn Ware house
Application Concept	Commercial	Home Appliance	Home Appliance
Ambient	Tropical	Ordinary	Ordinary
Cooling Capacity (gas charge)	Larger (Larger)	Ordinary (Ordinary)	Ordinary (Ordinary)
Electric Power Source	Official 220V Actual 82 ~ 268V	102±6V	German 230 ±10V
Compressor starting ability	excessive	Ordinary	Ordinary

Fig.6 Comparison of Home-freezer

Fig. 7 is an example of Indonesian home freezer.



Fig.7 Home Freezer in Indonesia

High pressure and poor electric power source are barriers to start up the compressor. KK has improved the starting ability (model: AZA1370Y) to meet the Indonesian application. Fig. 8 demonstrates the needs of excessive starting ability of KK compressor.

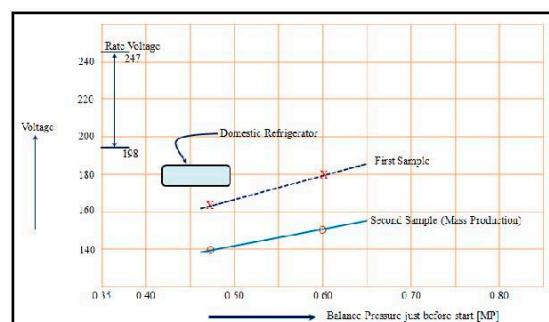


Fig.8 Improvement of Starting Ability

KK has been supplying this model for more than 1 year, without any claim, after the improvement.

Case Study 3

Air-conditioner in Middle East

The Global demand of Air-Conditioner has been growing (Fig 9). Chinese market has been growing very quickly. Middle East market has been also growing. [1]

Region	1995	2000	2005	2010
China	4.4	9.1	19.8	26.7
Japan	8.5	7.8	8.3	7.4
Asia	4.4	4.5	7.6	9.5
Oceania	0.3	0.5	0.8	0.9
Middle East	1.4	1.7	2.9	4.5
Africa	0.4	0.7	1.0	1.7
EU	1.4	2.9	6.2	4.9
N America	9.2	12.3	14.9	11.9
C&S America	1.0	2.1	2.8	4.0

Unit: million

Fig. 9 Trend of Global Market (Less than 3HP)

But from technical viewpoint, there is big difference between these markets. Chinese air-conditioner installs with cheaper Rotary Compressor. But, the Middle East requests the best reliability for Air-conditioners. This is the reason why KK has been supplying its Reciprocating Compressor to the Middle East. There are 3 logistics, from KK to Middle East as shown in Fig. 10.

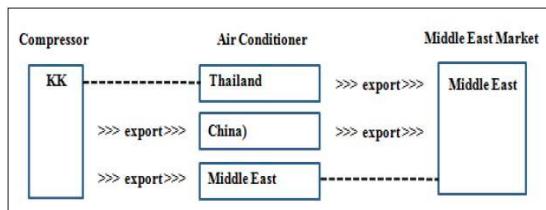


Fig.10 Typical Transportation from KK to Middle East

Among many compressor makers in the world, Middle East markets always trust KK. We are proud of our production. As a result, our compressor has been taking the first place in the air conditioner market in Middle East with approximately 25% market share as shown in Fig. 11.

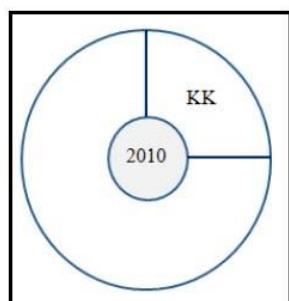


Fig.11 Compressor-share among the Middle East Air-Conditioners



Fig. 12 Air Conditioners in Middle East

From viewpoint of protective design at the severe condition, varnished lamination and IOL (Inner Overload Relay), and IPRV (Inner Pressure Release Valve) are very effective to prevent from the critical condition. But basic design is more important. Here are the structures of each compressor. From lubrication viewpoint, the biggest difference is the pressure in the case and its oil-pump.

In case of reciprocating compressor, suction gas (low pressure) is filled at the running. The oil pump is equipped in the crank-shaft. And it pumps up the lubricant oil, which lubricates the bearing parts and compression parts, simply.

On the other hand, in case of rotary compressor, discharge gas (high pressure) is filled at the running. The oil pumps, also equipped in the crank-shaft, pump up the lubricant oil, which lubricates only bearing parts. Therefore, the pressure difference between discharge gas (high pressure) and suction gas (low pressure), push the lubricant oil in the bottom and guides into the compression area and lubricates the surrounding parts. Each structure and oil flow is shown in Fig. 13 and Fig. 14.

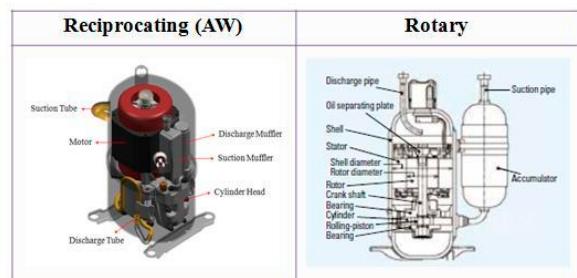


Fig.13 Structure of Reciprocating compressor and Rotary compressor

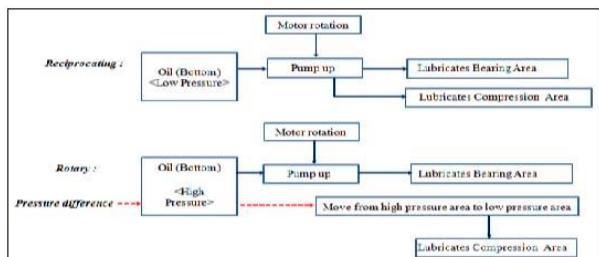


Fig.14 Lubrication design

Besides the structure difference, there are big differences between each compressor.

Here are 3 conditions, i.e. (1) Starting, (2) Running and (3) Tropical-- condition. We have confirmed the difference at each condition.

(1) Starting condition

Fig 15 shows the changing of pressure cycles (Discharge, Suction) during 1 cycle, from SW-On to SW-Off.

The lubrication of reciprocating compressor is always stable. But the lubrication of the compression area of rotary compressor is not good because of insufficient pressure difference at the starting period.

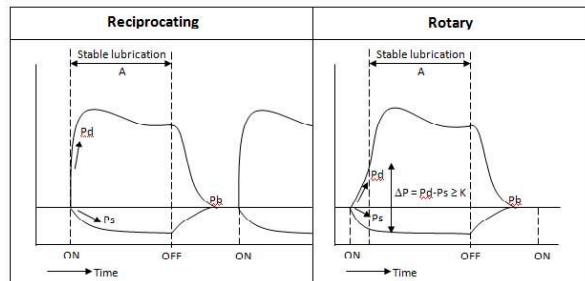


Fig. 15 Pressure changing during 1 cycle

Pd = Discharge Pressure

Ps = Suction Pressure

(2) Running condition

The viscosity of the lubricant oil is dependent on both conditions, temperature and refrigerant gas solubility. The gas solubility is dependent on the temperature and ambient pressure. Therefore, lubricant oil in the rotary compressor changes from very high to very low.

Due to high temperature and high discharge pressure, viscosity of the lubricant oil is low. Due to low temperature and low discharge pressure, viscosity of the lubricant oil is low.

Here are the oil solubility chart and viscosity chart in Fig 16. One of the example, the solubility of this oil (22cSt/40c, 0%), is 35% at 80c and 2.0MP (point A) and 10% at 80c and 0.5MP (point B).

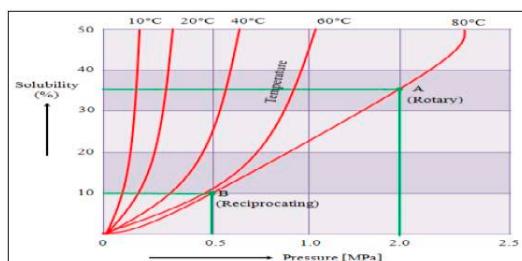


Fig.16 Oil Solubility Chart

One of the examples, this oil (22cSt/40c, 0%), will change 0.5cSt/80c, 35% (point C) in rotary, or will change 4.0cSt/80c, 10% (point D) in reciprocating.

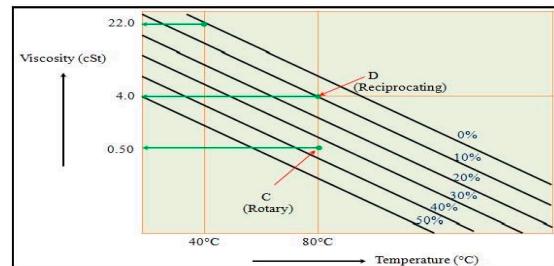


Fig.17 Oil viscosity chart

As a result, to keep the performance and clearance control, reliability, material selection, and surface treatment are very important issue for the rotary compressor as shown in Fig. 18.

	Reciprocating Compressor	Rotary Compressor
Ambient	Low Pressure (Suction Gas)	High Pressure (Discharge Gas)
Viscosity	Drops slightly	Drops too much
Lubrication Pattern	Fluid ↓ Mixed	Fluid ↓ Boundary ↓ Metal contact
Remarks		1. Precision machining 2. Smaller clearance 3. Surface treatment

Fig.18 Lubricant Comparison at the Usual Running.

(3) Tropical condition

In the tropical region, such as Middle East, due to high ambient temperature, discharge pressure raises too high. This is the simplest reason why rotary compressor cannot be accepted. Here are one of the examples about the difference between ordinary region and tropical region. According to the application specification issued by the rotary compressor makers, maximum discharge pressure is around 3.0MP or less. On the other hand, one of ours is more than 5.0MP as shown in Fig. 19.

Condition	Ambient temp.	Condensing temp.	Vapor pressure (HFC407C)
Standard	32°C	55°C	2.2MP
Tropical	50°C	70°C	3.4MP

Fig.19 The difference between Ordinary and Tropical Condition (Example)

Additionally, rotary compressor is not suitable for refrigerator. Here is an "Envelope", as an example. It is very easy to show the wide application of ours in Fig. 20.

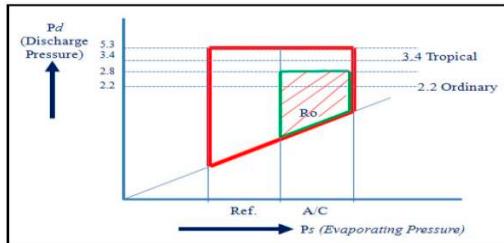


Fig.20 Envelope, showing the difference at LBP (Low Black Pressure), Tropical conditions

Findings

1. We found many kinds of refrigerator-transportation system in countryside. And we improved the transportation toughness to prevent from the failure even if at terrible conditions.
2. We found actual usage of home freezer with our compressor. We confirmed and achieved tough starting ability under the bad condition (poor electric supply and tropical ambient).
3. We find out stable lubrication in the reciprocating compressor compared with rotary compressor.

Other Business conditions

1. Environment issue

COP 21(the 21st-Conference of the Parties) was held in Paris last December 2015. Nearly 200 countries took part in the negotiations. Finally, all of the countries and regions reached to the agreement, which calls about Green House Gas Emissions. Global Temperatures review the progress every 5 years and financial idea. We will pay our effort to these expectations.

Among our field, the GWP (Global Warming Potential) is the biggest issue. We are now studying the refrigerant gas how to reduce the CO2 emission, safety and economically.

Final solution of Refrigerant gas for Refrigerator is HC600a. It has been approved in Japan, EU and China. High flammability (A3) is the critical issue.

Refrigerator	CFC12 (Faded out)	HFC134a	HC600a
ODP	1.00	0	0
GWP	8100	1430	20
Flammability	A1	A1	A3

Fig. 21 Property of Refrigerant for Refrigerator

For air-conditioner, the final refrigerant gas is still under discussion. [2]

Air-C	HCFC 22*	HFC 407C	HFC 410A	HFC 32	HFC 1234yf **	HC 290	CO2 ***
ODP	0.05	0	0	0	0	0	0
GWP****	1810	1800	2100	675	44	20	1
Flammability	A1	A1	A1	A2L	A1	A3	A1

Fig. 22 Property of Refrigerant for Air-conditioner

HC290, HFC32 and HFC1234yf** are nominated as promising candidates. HCFC22* will fade out soon. HFC1234yf** does not perform well in energy saving. CO2*** has high pressure, currently used for limited application (e.g. water-boiler). GWP**** is “F-gas Regulation” in EU which may regulate GWP less than 50. Many chemical brands in the world are studying new candidates. Honeywell one of the chemical companies is proposing R-444B, R447A and R-450A as such.

2. Threats

In China, the production of Home appliance goods has been increasing in the past 10 or 20 years. Fig. 23 shows annual production of compressor for refrigerator from 2003-2014. The world demand in 2014 was about 165 million units. Namely, Chinese production is larger than this demand [3].

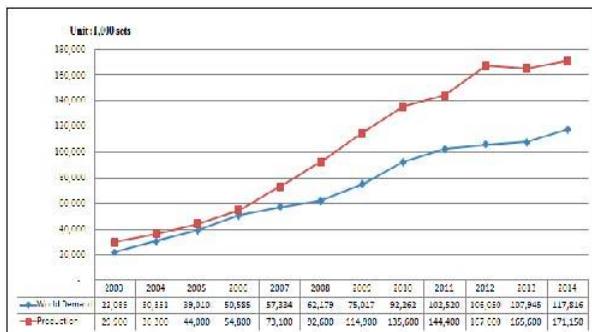


Fig.23 Production Trend of compressor in China

According to the newspaper, Chinese economy is going down, recently. Especially, there were some real estate issues, stock market issue, which damaged its economy growth. Therefore, Chinese makers have already steered towards exporting from domestic demand. Now, we can see many kinds of Chinese goods here, in Thailand as shown in Fig. 24



Fig.24 Chinese Home Appliance Goods displayed in Bangkok

IV. NEXT OPPORTUNITY

Compressor is dependent on its application. And now, we are responsible to keep nature and we need to protect from foreigner's threats. Fig. 25 is a set-theoretical model.

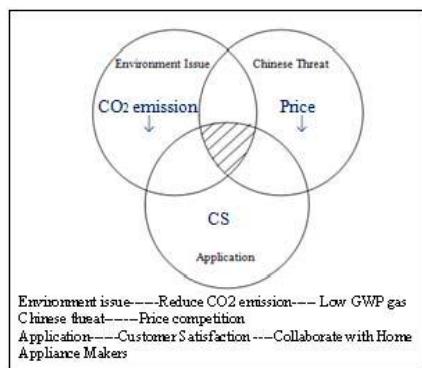


Fig. 25 Set-theoretical model.

How to expand our business

Chinese brands are making much effort to improve their reliability and performance to continue their business or create new business. Based on this idea, KK need to reconfirm the difference against the Rotary compressors.

And KK need to improve its features to keep the top share status in Middle East. And KK will make sales promotions into other tropical regions or heavy duty market. And KK will develop robust compressors. Our next opportunities are outlined in Fig. 26.

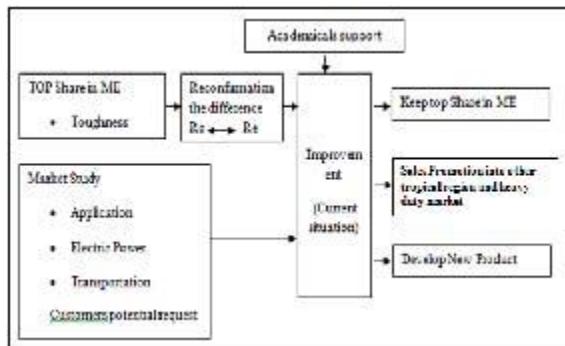


Fig. 26 Seeking for the next opportunity

Here are our basic ideas towards the future.

ASEAN market is a promising market with 600 million in population. As ASEAN Economic Community (AEC) has started last year, tighter market integration will bring more opportunities. In addition, other tropical regions, such as India and Africa, are also interested to be explored.

Moreover, shift toward heavy duty products is our next direction, from home use to commercial/industrial usage. Furthermore, shift of high pressure gas from HFC410A, HFC32 to CO2 is our new direction as well.

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