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DEVELOPMENT OF A VARIABLE CAPACITY ROTARY COMPRESSOR PART II : DESIGN OF RELIABLE CLUTCHING MECHANISM

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ABSTRACT

A novel rotary compressor that controls capacity mechanically without any electronic frequency modulation has been developed. Its major difference from the typical variable capacity compressors that have two cylinders is the variable displacements alternatively operate at each stage according to the external loading condition**.** Due to its structural characteristics having an idle cylinder and controlling the eccentricity by rotation direction of shaft, several problems against the stability of the system may occur. To get rid of such reliability problems, a latching mechanism is developed with the aid of TRIZ, which was developed by Altshuller. In this paper, we will present brief explanations on the new mechanism and test results from a full-scale prototype.

1. INTRODUCTION

In order to reduce the indirect global warming contribution, efforts to improve the efficiency of refrigeration systems are being continued. Recently, a variable capacity compressor has been increasingly used in refrigeration systems, such as air conditioners or refrigerators, to vary cooling capacity as desired, thus accomplishing an optimum cooling operation and saving energy. The capacity modulation is a key technology component in the improvement of efficiency. The variable capacity compressor can provide the solution for the capacity modulation.

Samsung developed a novel rotary compressor, which provides two-step capacity modulation mechanically without using any electronic frequency modulation. It is called "ES compressor" naming after its Energy Saving characteristics.

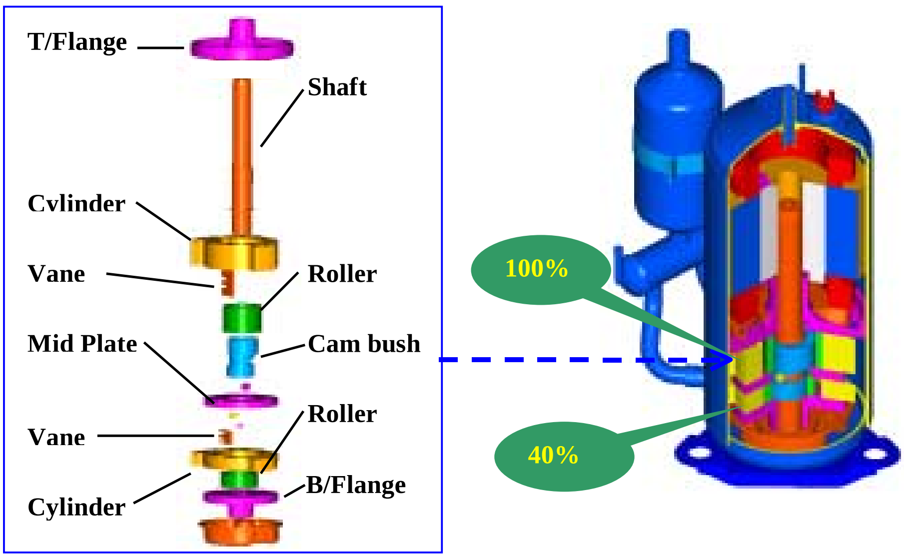


Figure 1. Structure of ES compressor

The major difference of an ES compressor from the typical variable capacity compressors is that ES compressor modulates the capacity in two steps by alternatively operating two cylinders in different compressing volume by a unique latching mechanism of the shaft according to the external load condition.

2. STRUCTURE OF ES COMPRESSOR

2.1 Principle of ES Compressor

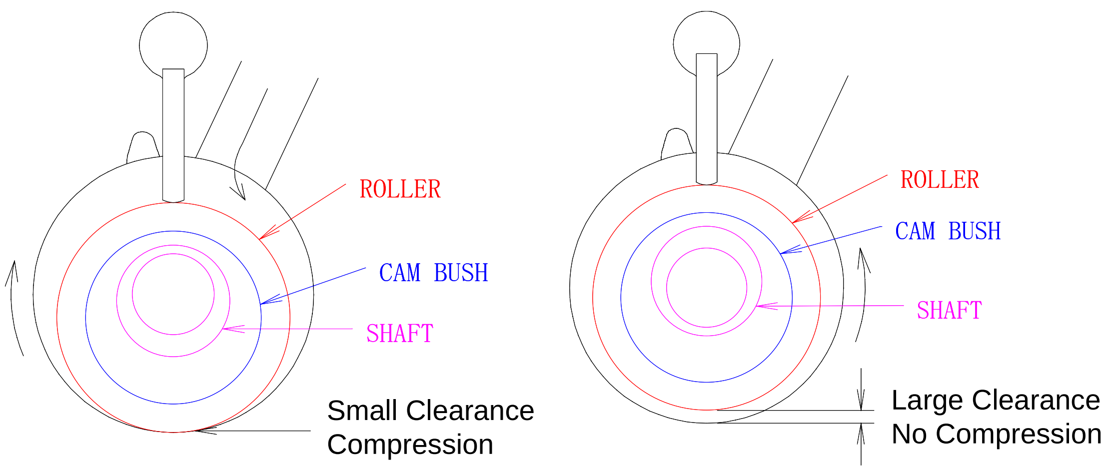
ES compressors are composed of two cylinders like a twin rotary compressor, as illustrated in Figure 1. The variable capacity rotary compressor is operated such that a compression operation is executed in one of the compression chambers having different capacities by the eccentric unit while the idle rotation is executed in a remaining one of the compression chambers, according to a rotation direction of the rotating shaft, thus varying compression capacity of the compressor as desired by simply changing the rotating direction of the shaft. Two cylinders having a different compressing volume are operating alternatively in opposite directions. By changing the rotational direction of a shaft, the eccentricity is controlled and the operating mode of each cylinder is determined. If a shaft rotates clockwise, an upper cylinder compresses the refrigerant while a lower cylinder idles as shown in Figure 2. If a shaft rotates in counterclockwise direction, only the lower cylinder works.

A 3-way valve is used to supply the refrigerent of the low pressure to the working cylinder. The 3-way valve automatically switches the path of the suction gas according to the rotational direction of the shaft as shown in Figure 3. If a shaft rotates in the clockwise direction, the path of suction gas is opened to the upper cylinder. On the other hand, if a shaft rotates counterclockwise, the path of the suction path is switched to the lower cylinder.

2.2 Need for Latching Mechanism

ES compressor modulates the capacity in two steps by alternatively operating two cylinders with different compressing volume according to the external load condition as described previously. The eccentricity of a top and a bottom pump are inverted easily according to a motor rotational direction change.

The shaft assembly of ES compressor is composed of a shaft, a driving pin, and a cam-bush. The shaft and the cam-bush are designed in order that each pump has its own eccentricity. The Figure 2 shows the example that the eccentricity quantity of the shaft is controlled by rotation direction change of the shaft. When the shaft rotates with clockwise direction, the upper eccentric part of the shaft assembly shows the maximum eccentricity, while the lower part has a smallest eccentricity quantity. In consequence, for the upper pump, the compression function is carried out, but the lower pump idles. On the contrary when the shaft rotates with countclockwise direction, the lower pump does a compression work and the upper pump idles.



(a) Working upper cylinder (b) Idling lower cylinder

Figure 2. Control of the eccentricity

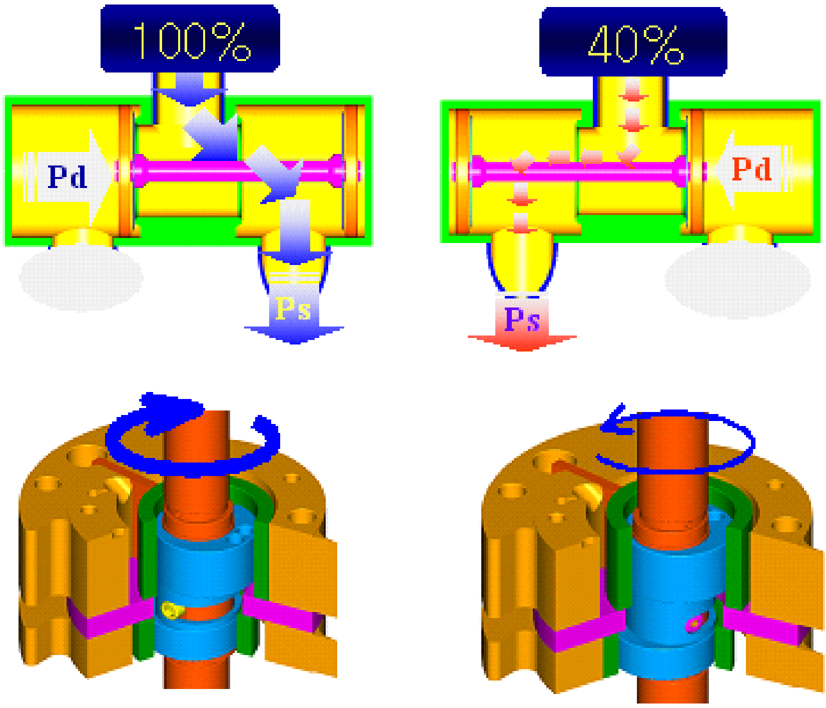


Figure 3. Latching mechanism and three way suction valve

The rotational motion of a shaft is transmitted to a cam-bush by a driving pin. In order to ES compressor working properly, the shaft and the cam-bush must adhere tightly each other while the motor rotates. If the cam bush has a relative speed with the shaft, the bumping noise is generated by the impact and the reliability can get worse. The relative rotational speed between the shaft and the cam-bush is influenced by the roller that is one of components to compose the compressing chamber in a rotary compressor. From the previous researches(K Imaichi, et al 1982, M Franco, 1986). on the dynamics of a roller, it is well known that the rotational speed of a roller changes periodically according to the frictional forces generated by the vane and the shaft. The Figure 5 shows the function block diagram of ES compressor. As shown from the figure, a speed change of the roller induces a bumping phenomenon. As a result, the driving pin bumps periodically with the cam-bush during the operation.

Due to its structural characteristics having an idle cylinder and controlling the eccentricity by the rotational direction of the shaft, several challenges to secure the stability of the system arose. However, these challenges were addressed by the development of a unique reliable latching mechanism.

2.3 Development of Latching Mechanism Using TRIZ

This paper presents the development of the latching mechanism, which is preventing the bumping phenomena between the driving pin and the cam-bush. The TRIZ technique is adopted to develop the latching mechanism. Figure 4 shows the TRIZ procedure briefly. The main goal of the first part of TRIZ is the transition from an indefinite inventive situation to the clearly created and extremely simple model of the problem. TRIZ helps to resolve conflicts between parameters of a product routinely guiding to a complete set of breakthrough solutions. A Technical contradiction is a situation in problem solving where improving something in the system causes the deterioration of something else. The technical contradictions for latching mechanism are defined as follows;

The technical contradiction 1 is:

"If the latching pin is not connected with the cam-bush solidly, then the cam-bush is switched easily but cam-bush is bumped with driving pin."

The technical contradiction 2 is:

"If the pin is connected with cam-bush solidly, then driving pin does not destroy the cam-bush but it cannot switch."

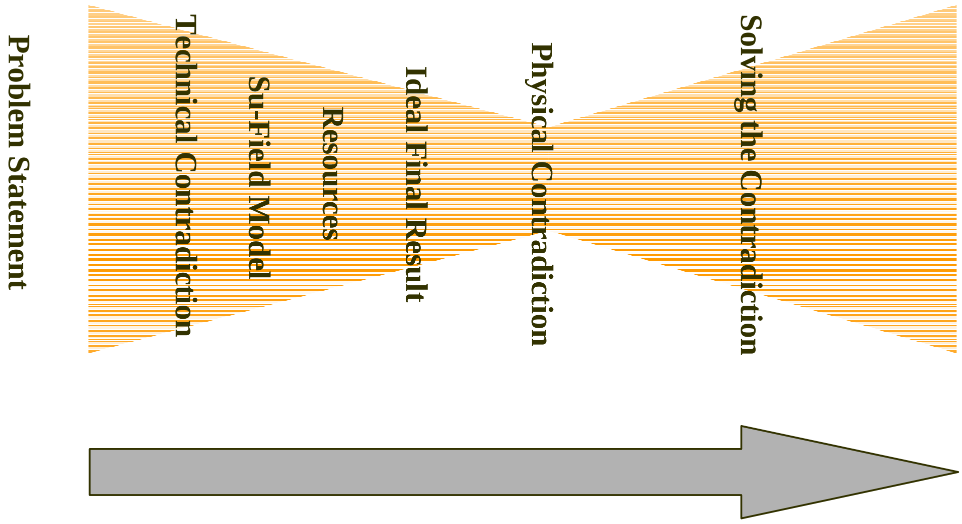


Figure 4. Algorithm for inventive problem solving

The Ideal final result for the latching mechanism can be expressed as follows:

"Latching mechanism itself provides the fixed connection between latching pin and cam bush without bumps during the shaft rotates without any complication." Secondly, a physical contradiction is defined, which is the two mutual exclusive requirements to the same parameter of a component of the system. The Physical contradiction of a latching mechanism of ES compressor is defined as follows.

"The connection between a latching pin and a cam-bush should be fixed for elimination of shocks between them and the connection should not be fixed for switching rotational direction."

The goal of second part of TRIZ is inventory of available resources, which may be used to solve problems. To solve the contradiction, TRIZ recommends using the resource of the system and solving the problem. In this project the centrifugal force of the shaft is used to solve the problem.

Building a diagram that includes the chain of the useful functions and the chain of the harmful functions helps to understand the actual performance of the system, its basic function, and the conflict that is worth solving. The Figure 6 shows the function block diagram of the ES compressor with new latching mechanism.

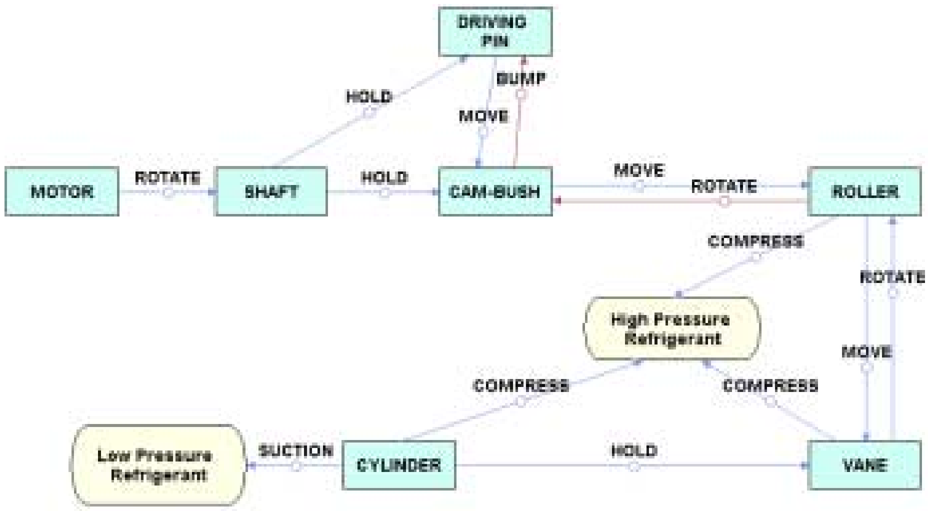


Figure 5. Function block diagram of ES compressor (old type)

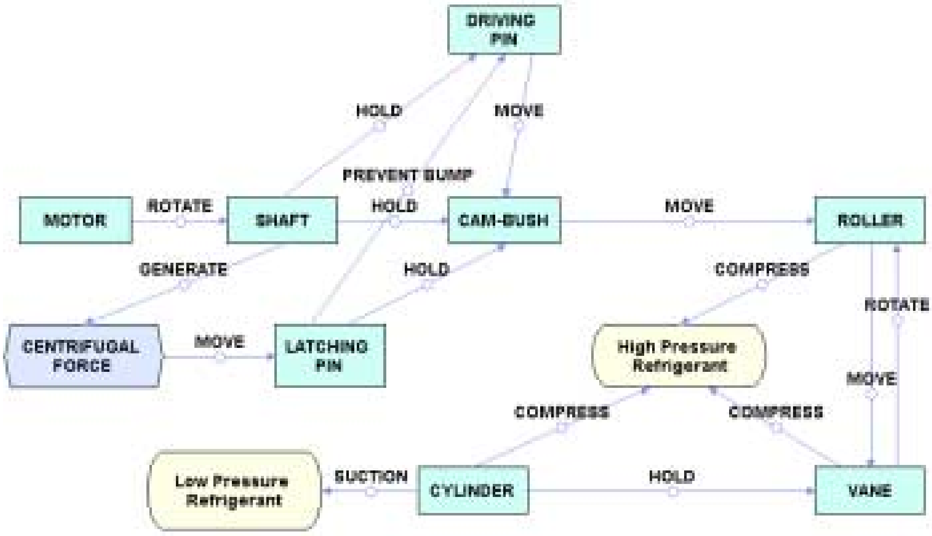
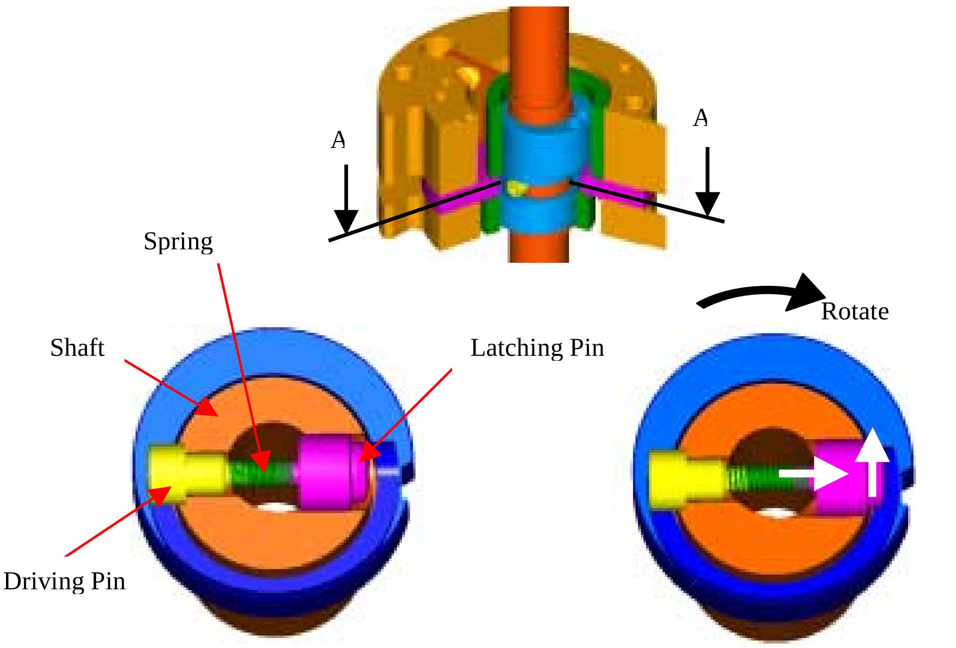


Figure 6. Function block diagram of ES compressor (new type)

The Figure 7 shows the construction of a newly developed latching mechanism. We arranged a latching pin, which is connected to the spring in the opposite direction of a driving pin. The stiffness coefficient of the spring is selected with considering the centrifugal force of latching pin at the operating speed. As shown from Figure 7 (a), if the rotation of the shaft stops, the latching pin enters inside of the shaft by the tension of the spring. As a result the latching pin does not hinder a rotational direction switch. On the other hand, if the shaft begins to rotate, the centrifugal force is bigger than the tension of the spring. As shown in Figure 7 (b) when the shaft rotates, the latching pin projects to the outside of the shaft. The cam-bush is bounded with driving pin and the latching pin and revolves with adhering to the shaft, therefore bumping noise does not happen between a cam-bush and activated shaft.



(a) When the Shaft Stops (b) When the Shaft Rotates

Figure 7. Construction of latching mechanism (Section A-A)

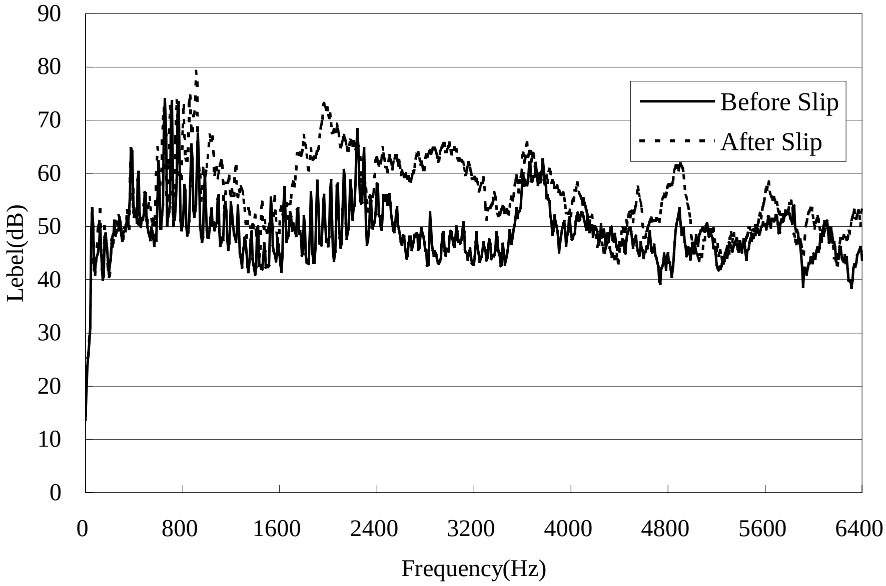


Figure 8. Comparison noise level- old type vs. new type

The Figure 8 compares the noise spectrum of ES compressor with and without adopting the latching mechanism. The dashed line represents the noise spectrum of ES compressor without latching mechanism, and there are some peaks for bumping noise are observed. And the solid line represents newly developed ES compressor. As shown from the Figure, the bumping noise is not generated.

3. CONCLUSIONS

In this paper we introduce the ES compressor that controls capacity mechanically by change the rotational direction. The unique latching mechanism has been developed with the aid of TRIZ. The capacity modulation is successfully accomplished by the unique latching mechanism of the shaft assembly. The algorithm of TRIZ for developing the latching mechanism is briefly introduced. From the test results of ES compressor with the new latching mechanism, it is shown that the abnormal bumping phenomenon induced by the collision between the cam bush and the driving pin has been successfully eliminated.

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