

Description

[0001] The present invention relates to a unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle, and, more specifically, to a unit which can adequately estimate a refrigerant suction pressure of a compressor in a refrigeration cycle incorporated into an air conditioning system for vehicles.

[0002] When a refrigerant suction pressure of a compressor in a refrigeration cycle having the compressor, a condenser, a pressure reducing mechanism and an evaporator of refrigerant is determined, in an air conditioning system using a variable displacement compressor an discharge capacity of which is controlled so that an actual refrigerant suction pressure coincides with a set value of refrigerant suction pressure inputted as an external electric signal (a displacement control signal), it is possible to estimate the refrigerant suction pressure from the displacement control signal.

[0003] However, in order to detect a refrigerant suction pressure in an air conditioning system which does not use such a variable displacement compressor controlling the refrigerant suction pressure by an external signal, it is necessary to provide a refrigerant suction pressure sensor, thereby increasing cost.

[0004] Accordingly, it would be desirable to provide a unit for calculating a refrigerant suction pressure of a compressor, which can adequately estimate a pressure of refrigerant sucked into a compressor without providing a a refrigerant suction pressure sensor, even in a case where the above-described variable displacement compressor controlling the refrigerant suction pressure by an external signal is not used.

[0005] A unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to the present invention has a compressor, a condenser, a pressure reducing mechanism and an evaporator of refrigerant, and the unit is characterized in that a pressure of refrigerant sucked into the compressor is estimated based on a detected value of an air temperature at an evaporator exit, which is a temperature of air immediately after passing through the evaporator, or a detected value of a temperature at an evaporator surface, or a detected value of a temperature of refrigerant in the evaporator, and a detected or estimated value of a refrigerant flow rate.

[0006] In the present invention, the estimation of a pressure of refrigerant sucked into the compressor is based on the following technical concept. Namely, because refrigerant at the evaporator is in a two-phase condition of gas and liquid, a refrigerant pressure is determined univocally from a refrigerant temperature in the evaporator. Therefore, it is possible to estimate a refrigerant pressure in the evaporator by detecting a temperature of air after passing through the evaporator or a temperature of an evaporator surface or a refrigerant temperature in the evaporator. Further, in an actual refrigeration cycle, there occurs a pressure reduction of

refrigerant due to a pressure loss in a circuit from the evaporator to a compressor. Since this pressure loss becomes greater as a refrigerant flow rate increases, it is possible to estimate the pressure loss by detecting the refrigerant flow rate. Consequently, the refrigerant suction pressure of the compressor has a close correlation with the refrigerant temperature and the refrigerant flow rate in the evaporator, and by detecting or estimating these two values, it becomes possible to adequately estimate the refrigerant suction pressure.

[0007] In such a unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to the present invention, more concretely, the refrigerant suction pressure is estimated by using the following equation.

$$Ps' = a \cdot Gr + b \cdot Teva + c$$

Where, Ps': an estimated value of refrigerant suction pressure,

Gr : a refrigerant flow rate,

Teva: an air temperature at an evaporator exit, or a temperature at an evaporator surface, or a temperature of refrigerant in the evaporator, and

a, b, c: a constant determined by an examination.

[0008] Further, if the refrigerant suction pressure decreases too much, an amount of sucked refrigerant may decrease too much, a suction amount into the compressor of oil circulated together with refrigerant may decrease too much, and there may be a fear that the compressor is not properly protected by a lack of lubrication. Accordingly, in order to prevent such an excessive reduction of the refrigerant suction pressure, for example, when an estimated value of refrigerant suction pressure is a preset value or less, a drive power of the compressor may be reduced (in particular, in a case of a clutchless variable displacement compressor), or drive of said compressor may be stopped (in particular, in a case of a compressor having a clutch).

[0009] Further, a method can also be employed, wherein, when an estimated value of refrigerant suction pressure is a preset value A or less, a drive power of the compressor is controlled so that the estimated value of refrigerant suction pressure becomes the preset value A, and when the estimated value of refrigerant suction pressure is a preset value B which is smaller than the preset value A, the drive power of the compressor is controlled at a minimum power (in particular, in a case of a clutchless variable displacement compressor), or drive of the compressor is stopped (in particular, in a case of a compressor having a clutch). Namely, two set values A and B are provided, and while frequent on/off operation of the compressor may be avoided, the compressor may be protected properly.

[0010] Such a unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to the present invention is suitable particularly as a

refrigeration cycle incorporated into an air conditioning system for vehicles.

[0011] In the unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to the present invention, it becomes possible to adequately estimate a pressure of refrigerant sucked into a compressor without providing a refrigerant suction pressure sensor, and the cost of the whole of the system may be reduced.

[0012] Moreover, even in a case where the above-described variable displacement compressor controlling the refrigerant suction pressure by an external signal is not used, namely, regardless of a type of a compressor, the pressure of refrigerant sucked into a compressor can be estimated, and it is possible to utilize the unit as a general calculation unit.

[0013] Furthermore, by estimating the refrigerant suction pressure, an excessive reduction of the refrigerant suction pressure may be prevented, and a lack of lubrication and the like in the compressor may be appropriately prevented.

[0014] Further features and advantages of the present invention will be understood from the following detailed description of the preferred embodiments of the present invention with reference to the accompanying figure, of which:

Fig. 1 is a schematic diagram of an air conditioning system having a unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to an embodiment of the present invention.

[0015] Fig. 1 depicts an air conditioning system for vehicles having a unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to an embodiment of the present invention. A refrigeration cycle 1 has a compressor 2 of refrigerant which is driven by, for example, an engine of a vehicle, and a driving force of an engine is transmitted via an electromagnetic clutch incorporated into the compressor 2. Refrigerant is circulated in the refrigerant circuit of refrigeration cycle 1, a high-temperature and high-pressure refrigerant compressed by compressor 2 is cooled at a condenser 3 by heat exchange with outside air, and condensed and liquefied. The refrigerant in a two-phase condition of gas and liquid is separated into gas phase and liquid phase by a receiver dryer 4, and liquid refrigerant is reduced in pressure at an expansion mechanism 5 (a pressure reducing mechanism). The low-pressure refrigerant reduced in pressure flows into an evaporator 6, and heat exchanged with air sent by a blower 10. Refrigerant evaporated in evaporator 6 is sucked into compressor 2, and compressed again.

[0016] Blower 10 is disposed in an air duct 11 through which air for air conditioning of a vehicle interior passes, and air sucked from an air suction port 12 is sent to evaporator 6 by blower 10. A part of air having passed

through evaporator 6 is a heater unit 9 disposed at a position downstream of evaporator 6. A rate of an amount of air passing through heater unit 9 to an amount of bypassing air is controlled by an air mixing damper 8. In this embodiment, an evaporator exit air temperature sensor 7 is provided to detect a temperature *T_{eva}* of air immediately after passing through evaporator 6, and a signal of the detected temperature is inputted into a control unit for air conditioning 13. In this control unit for air conditioning 13, a unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to the present invention is incorporated. Therefore, this control unit 13 also functions as a unit for calculating a refrigerant suction pressure according to the present invention. Respective air discharge ports 14, 15 and 16 such as a DEF-mode air discharge port, VENT-mode air discharge port, and FOOT-mode air discharge port, and these air discharge ports are controlled to be opened/closed by respective dampers (not shown).

[0017] In such an air conditioning system for vehicles having the above-described refrigeration cycle, a refrigerant suction pressure of compressor 2 is calculated and estimated as follows.

[0018] First, it is necessary to determine the following A and B for estimation of a refrigerant suction pressure.

A: a refrigerant temperature in an evaporator or a physical value having a correlation with the refrigerant temperature in the evaporator
B: a refrigerant flow rate or a physical value having a correlation with the refrigerant flow rate

[0019] In order to detect the above-described A, any of the following (a1) to (c1) is carried out.

(a1) detection by an evaporator exit air temperature sensor
(b1) detection by an evaporator surface temperature sensor
(c1) detection of a refrigerant temperature in an evaporator by a temperature sensor

[0020] In this embodiment, an evaporator exit air temperature *T_{eva}* detected by evaporator exit air temperature sensor 7 is determined as the above-described value A, that is, a refrigerant temperature in an evaporator or a physical value having a correlation with the refrigerant temperature in the evaporator.

[0021] In order to detect the above-described B, any of the following (a2) to (c2) is carried out. Namely, as a value of refrigerant flow rate for estimation of a refrigerant suction pressure, an actual detected value or a estimated value is used.

(a2) detection by a flow rate sensor
(b2) estimation of a flow rate from an opening degree of expansion mechanism 5 (an expansion

valve)

(c2) estimation of a flow rate from a displacement control signal of a variable displacement compressor

[0022] A refrigerant suction pressure P_s is estimated as an estimated value P_s' , for example, by the following equation.

$$P_s' = a \cdot Gr + b \cdot Teva + c$$

Where, P_s' : an estimated value of refrigerant suction pressure,

Gr : a refrigerant flow rate,

$Teva$: an air temperature at an evaporator exit, or a temperature at an evaporator surface, or a temperature of refrigerant in an evaporator, and

a, b, c : a constant determined by an examination.

[0023] Thus, based on an evaporator exit air temperature $Teva$ as a physical value having a correlation with a refrigerant temperature in an evaporator, a refrigerant pressure in the evaporator is estimated, and a factor with respect to a refrigerant flow rate is considered as a physical value having a correlation with a pressure loss from the evaporator to a compressor, further, an amendment item (c) is added, and a refrigerant suction pressure of the compressor is estimated.

[0024] This refrigerant suction pressure is estimated by calculation without providing a refrigerant suction pressure sensor, and because such a refrigerant suction pressure sensor becomes unnecessary, it is possible to reduce a cost of the whole of the system. Moreover, even in a case where a compressor other than a variable displacement compressor controlling a refrigerant suction pressure is used, namely, regardless of a type of a used compressor, it is possible to estimate a refrigerant suction pressure. Furthermore, by adequately estimating a refrigerant suction pressure, an excessive reduction of the refrigerant suction pressure can be prevented, and a trouble of a compressor due to an excessive reduction can also be prevented.

[0025] For example, if a refrigerant suction pressure decreases too much, an amount of sucked refrigerant decreases too much, an amount of oil sucked into a compressor together with refrigerant decreases too much, a lack of lubrication may occur and the compressor may not be protected properly. In the present invention, however, in order to prevent such an excessive reduction of a refrigerant suction pressure, the following control is carried out in accordance with the above-described estimated value of refrigerant suction pressure. Namely, when the estimated value of refrigerant suction pressure becomes a preset value (for example, 0.15 MPaG) or less, the following control is carried out.

[0026] In a case of a compressor having a clutch, drive of a compressor is stopped by interrupting the clutch. Alternatively, in a case of a variable displacement

compressor without a clutch, an excessive reduction of refrigerant suction pressure is prevented by reducing a discharge capacity. Further, in a case of an electric motor driven clutchless compressor, an excessive reduction of refrigerant suction pressure is prevented by reducing a rotational speed of the motor.

[0027] Further, the above-described inconvenience may be adequately prevented by using the following two set values. Namely, a set value A (a limit value of refrigerant suction pressure which does not have a fear of a lack of lubrication of a compressor due to a lack of returning oil) and a set value B (a value of refrigerant suction pressure which has a fear of a lack of lubrication of a compressor due to a lack of returning oil if less than this set value) are provided, and they are set to be $A > B$.

[0028] When an estimated value of refrigerant suction pressure is A or less, a compressor is controlled so that the refrigerant suction pressure becomes A (a clutch signal or a displacement control signal or a motor rotational speed signal is controlled). When the estimated value of refrigerant suction pressure is B or less, a drive power of a compressor is controlled zero (clutch off or displacement zero (or a minimum displacement) or motor rotational speed zero).

[0029] Thus, by providing set values A and B, for example, when a refrigerant suction pressure becomes the set value B or less, a drive power for a compressor may be immediately controlled to be zero in order to prevent a damage to the compressor. Further, when a refrigerant suction pressure becomes the set value A or less, by controlling the refrigerant suction pressure at the set value A, it is possible to avoid a condition where the refrigerant suction pressure frequently becomes the set value B or less and the compressor frequently operates on/off.

Claims

1. A unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle having refrigerant compressor, condenser, pressure reducing mechanism and evaporator, **characterized in that** a pressure of refrigerant sucked into said compressor is estimated based on a detected value of an air temperature at an evaporator exit, which is a temperature of air immediately after passing through said evaporator, or a detected value of a temperature at an evaporator surface, or a detected value of a temperature of refrigerant in said evaporator, and a detected or estimated value of a refrigerant flow rate.
2. The unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to claim 1, wherein said refrigerant suction pressure is estimated by the following equation:

$$Ps' = a \cdot Gr + b \cdot Teva + c$$

where, Ps': an estimated value of refrigerant suction pressure,

Gr : a refrigerant flow rate,

Teva: an air temperature at an evaporator exit, or a temperature at an evaporator surface, or a temperature of refrigerant in said evaporator, and

a, b, c: a constant determined by an examination.

3. The unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to claim 1 or 2, wherein, when an estimated value of refrigerant suction pressure is a preset value or less, a drive power of said compressor is reduced or drive of said compressor is stopped. 15
4. The unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to claim 1 or 2, wherein, when an estimated value of refrigerant suction pressure is a preset value A or less, a drive power of said compressor is controlled so that said estimated value of refrigerant suction pressure becomes said preset value A, and when said estimated value of refrigerant suction pressure is a preset value B which is smaller than said preset value A, said drive power of said compressor is controlled at a minimum power or drive of said compressor is stopped. 20 25 30
5. The unit for calculating a refrigerant suction pressure of a compressor in a refrigeration cycle according to any preceding claim, wherein said refrigeration cycle is a refrigeration cycle incorporated into an air conditioning system for vehicles. 35

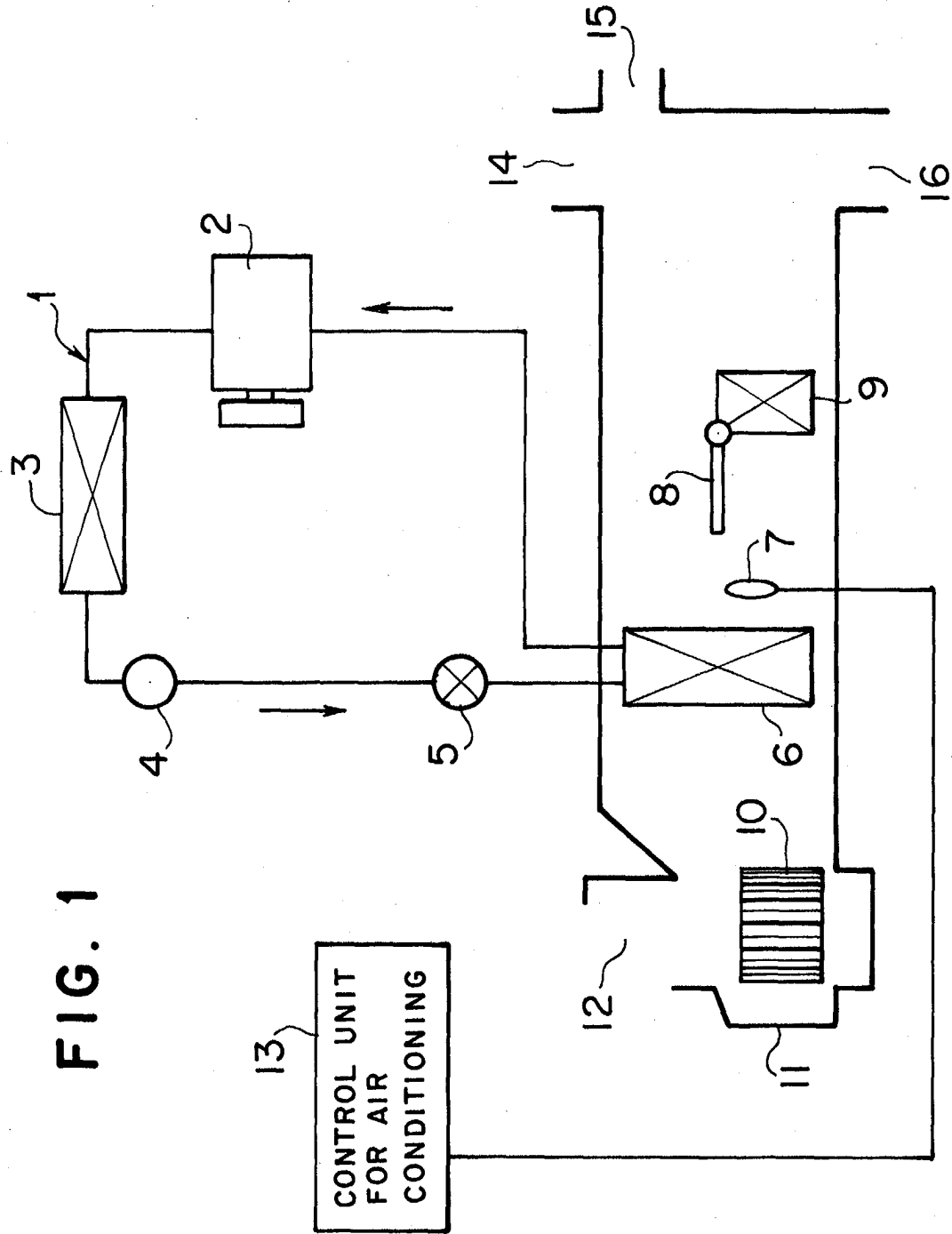
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FIG. 1





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 04 25 3375

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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A	EP 1 158 166 A (DAIKIN IND LTD) 28 November 2001 (2001-11-28) * paragraph [0069]; figure 3 *	1-5	
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The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.Cl.7) F25B B60H
Place of search Munich		Date of completion of the search 22 September 2004	Examiner Ritter, C
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 04 25 3375

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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