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Determining the Mechanical Power of the Air Conditioning Compressor

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Abstract. *Generate mechanical power with low cost and less emissions is great challenge for mechanical engineers overall the world in our contemporary time. Mechanical power is the main reason for excessive fuel consumption and increased CO_2 emissions problems as compensation from the overlay of air conditioning systems. Therefore, this article presents various methods to overcome the problem. Ways to find new different resources for the mechanical energy reduce fuel consumption and reduce CO_2 emissions are achieved through the application of VCC and an absorption system. This study also deals with Alternative control methods for air conditioning systems such as electric compressors and shows power consumption as a function of speed of a conventional compressor and an electric compressor. As a result, it turned out that the electric compressor consumes less power compared to a conventional compressor by up to 18%. This is because there is less load on the car coming from the compressor and energy efficiency is improved. Increasing the internal heat load will increase the fuel supply to both systems.*

Keywords: *mechanical power, undesirable mechanical loads, renewable energy, mechanical compressor, global warming.*

Introduction

The belt driven compressor is a mechanical type compressor, which is the concept of a traditional car air conditioning system. The compressor is connected to the crankshaft of the engine by a belt system. The compressor runs on the power of the engine. Therefore, the engine subjected to work load due to the use of this type of compressor in an A/C system [1-4].

The same authors in their works express the following idea:

This may reduce engine performance. In order to overcome such a problem, replacing the power supply for the AC system with an electrically driven drive will greatly improve the reduction of fuel consumption as well as increase the performance of the engine [1-4].

More recently, scientists at the National Renewable Energy Laboratory (NREL) in the United States were able to figure out that the United States could save over $6 billion a year if all light vehicles in the country reached a modest speed of 0.4 km/L (1-mpg) improved fuel economy [2]. A study done Johnson, V.H. also showed that the US uses 27 billion liters of gasoline for air conditioning annually, equivalent to 6% of domestic oil consumption or 10% of US imported crude oil.

Thus, this article is an overview of an alternative way to reduce fuel consumption in order to operate the air conditioning system and reduce the temperature inside the car when the car is parked in direct sunlight.

The Methods

There are serious effect of A/C system on the ecosystem, because of the amount of fuel burned during the operation, some new way that use high technologies are used to reduce this effect are represented in this research to compare the best way. This article uses general scientific methods such as analysis and synthesis, comparative, descriptive methods.

Influence of the air conditioning system on fuel economy in a car with a gasoline engine.

The air conditioning system is the biggest additional load on a car. This means that the air conditioning system is a key component among all accessories that reduces fuel economy. Therefore, it is important to check the main parameters of the air conditioning system components that affect fuel consumption. The effect of each component of the air conditioning system on the fuel consumption of a vehicle with a conventional gasoline engine running at different engine speeds. The air conditioning mode has been found to increase fuel consumption by up to 90% compared to running without air conditioning at idle. As the vehicle speed increased, the proportion of fuel consumed by the air conditioning compressor increased while the proportion of fuel consumed by the alternator decreased. Other components, such as the supercharger, cooling fan, and clutch, maintained near-constant portions of torque distribution from the alternator regardless of vehicle speed.

The impact of the air conditioning system on fuel consumption has had two main effects.

The first is related to the indirect greenhouse effect due to increased fuel consumption. The second reason has to do with user and market focus on fuel economy as mentioned Benouali, J., et al. (2003) and another research by Vishweshwara, Sudhir Chitrapady, J. Marhoon, and A.L. Dhali. (2013).

Reducing the heat load of a car's interior is essential for improving the fuel efficiency of a car [5].

Between 1995 and 1998, CENERG and ADEME conducted two series of tests to determine excessive fuel consumption due to air conditioning. Gasoline, non-turbocharged diesel engines and turbocharged diesel engines were tested. The tests were carried out at the facilities of the Joint Testing and Assembly Center (UTAC) according to the MVEG cycle for two ambient temperatures: 30°C and 40°C. The results of the study are presented in table 1 found by Benouali, J., et al. (2003).

Meanwhile, the National Renewable Energy Laboratory (NREL) [6] reported that, excessive fuel consumption due to air conditioning systems has reached 35%. Benouali, J., et al. (2003).

Conducted a series of tests to study the fuel consumption of various types of vehicles and weather conditions. Two series of tests, carried out in a climate chamber and on a test bench, showed that, the excess fuel consumption due to the operation of the air conditioner is from 1.0 to 2.45 l / 100 km (21 to 53%) on the European MVEG cycle. That result found depending on study by Alkan, Alpaslan and Murat Hosoz (2010), and Wang M, Zima MJ, Kadle PS (2009).

Researchers have developed various methods to reduce excessive fuel consumption due to air conditioning. One of them made using a variable displacement compressor (VCC) that used Wang M, Zima MJ, Kadle PS. (2009).

Depending on Kaustubh Shete (2015), VCC produces a higher COP (coefficient of performance) than a fixed capacity compressor (FCC) in a high-speed compressor. Although the VCC performance of the low speed compressor is slightly worse than that of the FCC by Alkan, Alpaslan. VCC characteristics related to fuel consumption and CO_2 emissions have studied [7]. For the air-controlled VCC, compressor cycling provides a consistent reheat reduction that

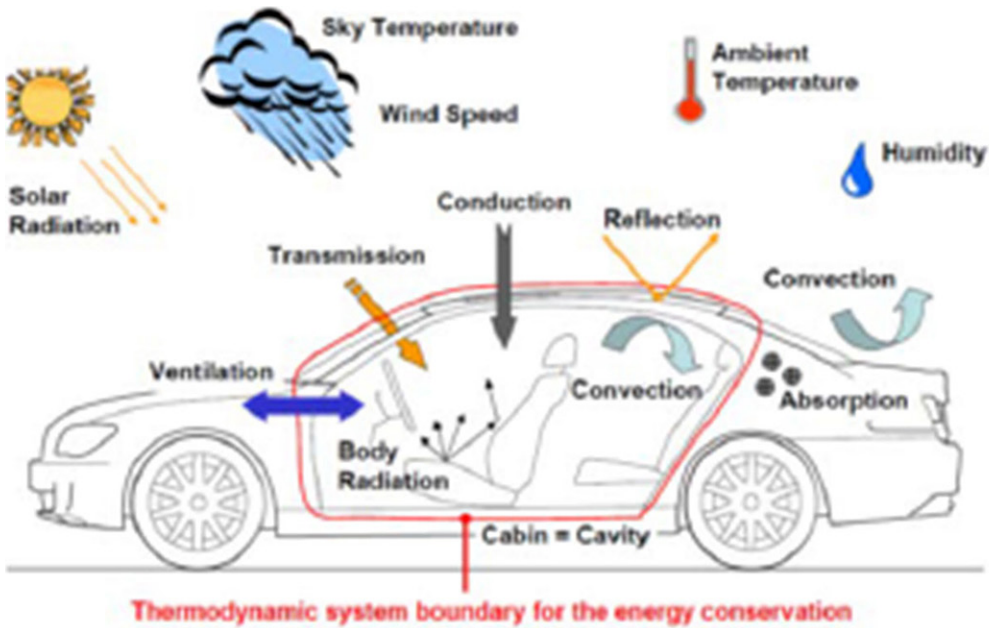

Figure 1 – Car thermal balance [6]

Relative excessive fuel consumption (%) for various vehicles, measured by CENERG and ADEME

Vehicle type	Gasoline engine		Diesel engine		Turbo-diesel engine	
Cycle	30°C	40°C	30°C	40°C	30°C	40°C
Urban	31%	38%	26%	28%	40%	42%
Outside the urban environment	16%	20%	12%	15%	28%	33%

saves 9 liters of gasoline per year and reduces CO_2 emissions by up to 1.0 g/km. For an electronically controlled variable compressor, selective cycling allows the compressor to be switched off for an extended period, resulting in an additional savings of 3.5 liters per year and a reduction in CO_2 emissions of 0.4 g/km. The design of the pneumatic VKK shown in figure (2).

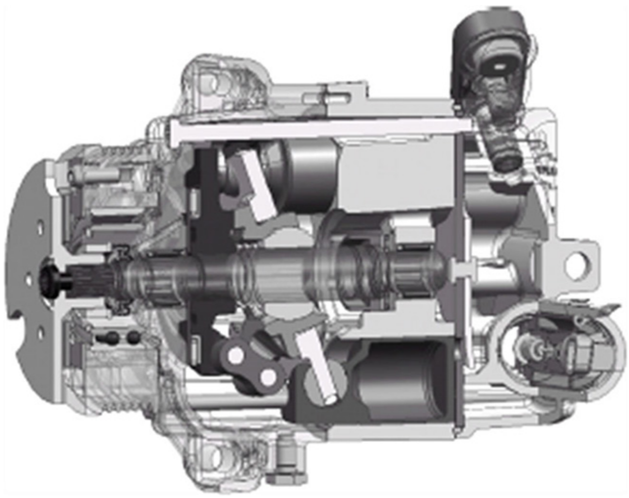

Figure 2 – Pneumatic variable displacement compressor

Discussion

Overall efficiency of the air conditioning system

The overall efficiency of the air conditioning system is affected by:

a. Type of compressor used. The electrically driven compressor used in high-end vehicles is more efficient than its mechanical counterparts.

b. Type of evaporator used – Tube type evaporators have the highest efficiency.

c. Type of condenser used – Evaporative condensers are more efficient than other types of condensers.

d. The type of coolant used – a coolant that has a higher critical temperature, pressure, thermal conductivity and latent heat of vaporization will result in less stress on the engine. Almost all vehicles today use R134a refrigerant.

e. Vehicle speed. The efficiency of air conditioning also decreases significantly with increasing vehicle speed, especially in mechanically driven compressors according to Kaustubh Shete (2015).

Conditions in the cabin

Internal conditions also play an important role in determining the additional load on the vehicle's engine. Example: – A higher peak temperature in the cab will put more stress on the engine.

Interior conditions are also affected by latent heat generation and sensible heat generation from various heat sources both inside and outside the vehicle. The auxiliary load is also affected by the number of passengers in the cabin by increasing the number of passengers in the cabin. In addition, the performance of an HVAC system is affected by many determinants of cab thermal comfort, such as angle of sunlight, glass/glazing properties, ambient heat radiation, and air velocity. Finally, changes in thermal loads on passengers in terms of: thermal sensations, clothing, number of passengers, metabolic rate reduce the reliability of the system. Thus, automotive climate control systems

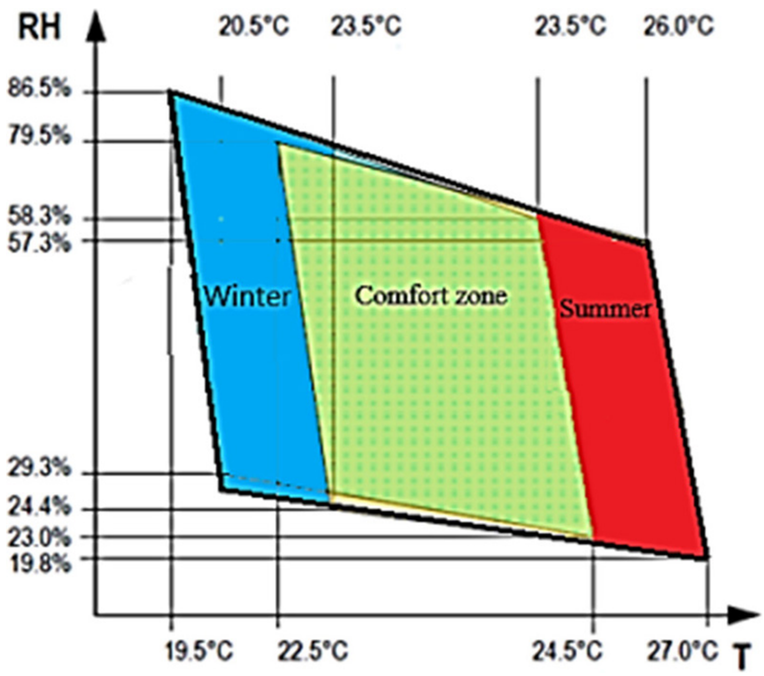

Figure 3 – Diagram of relative humidity (RH) / temperature (T) depending on the comfort zone by Kaustubh Shete (2015)

suffer from previous clear problems as mentioned by Kaustubh Shete (2015).

Alternative Control Methods for Air Conditioning Systems

Based on the study done by Guyonvarch, Gwénaël, et al. (2001). Most automotive air conditioning systems operate on a vapor compression cycle. However, the requirements for engine efficiency have developed in the absorption system [8].

Use of thermal energy of exhaust gases to power absorption air conditioning systems in passenger cars. This work was used, although it produced only a small efficiency, 0.8 to 0.9. The A/C absorption system has also studied [9, 11]. The system is capable of producing a cooling effect from 1 to 1.2 kW with a COP value of 0.4 to 0.45. Another study of the absorption system is also underway rely on Shrotri, A. (2015).

The basic diagram of an A/C absorption system shown in figure 4. Recently, an absorption system has also developed on a ternary liquid [10, 12].

Vasta, Salvatore, et al. (2012), with a water-cooled system that uses a cooling liquid circuit as a power source (Figure 5), presented another absorption air-conditioning system. Testing is carried out by installing an adsorption chiller on the cab of a truck to confirm the performance of the prototype. This system is capable of producing 9°C air that passes through the evaporator, with an expected cooling effect of up to 2kW.

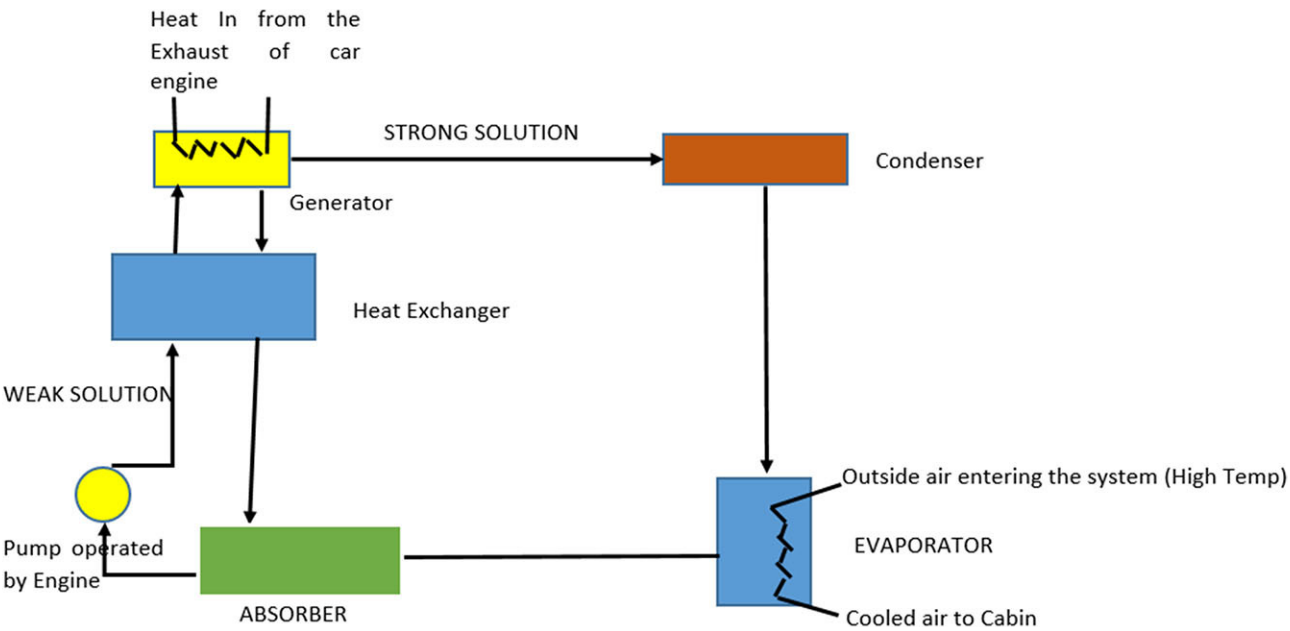

Figure 4 – Basic layout of the absorption air conditioning system build on Shrotri, A. (2015) research

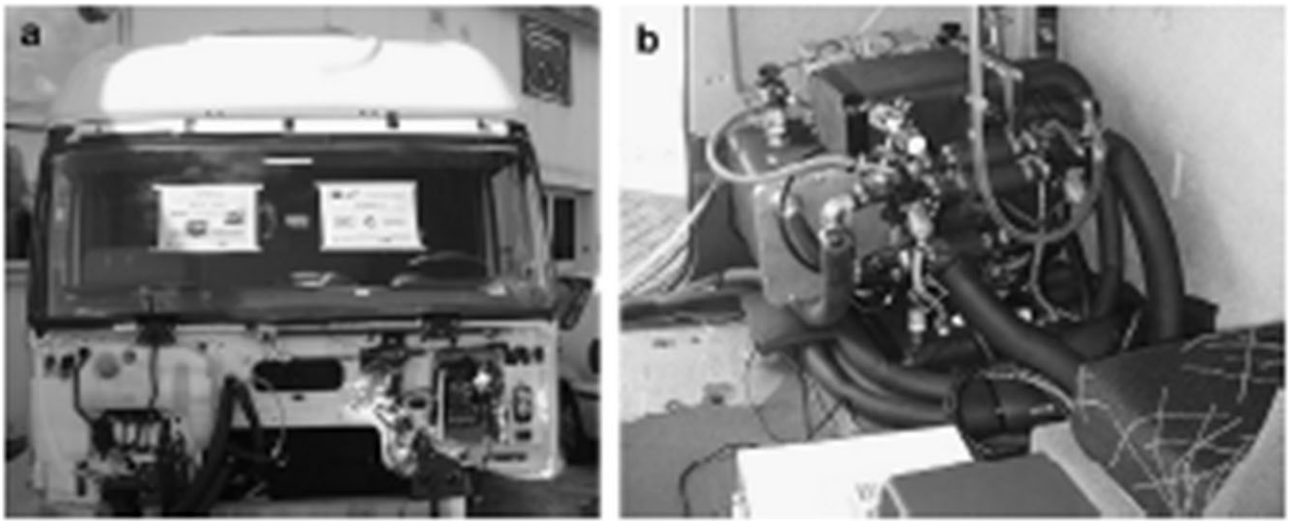

Figure 5 – a, b. Adsorption air conditioning system mounted on the cab of an IVECO Stralis truck by Vasta, Salvatore, et al. (2015)

A new method of controlling the A/C compressor to reduce the load on the engine has implemented using turbocharging (Figure 6). According to Kumar, S., et al. (2014) the kinetic energy and pressure of the exhaust gases are used to rotate the blades of the turboprop and then to rotate the air conditioning compressor using a magnetic transmission. The main advantage of this method is that it can be easily applied to low power motors and provide high power. This method allows better use of exhaust gases and lower fuel consumption.

Recently mentioned by Setiyo, Muji, and et al. (2016), that the potential cooling effect of LPG-fuelled vehicles to cool the vehicle interior has studied. Numerical simulations have been performed to calculate the potential heat absorption of an LPG evaporator. The cooling effect potential that can be obtained from a 2000 cc engine. See, rated at over 1 kW at 3000 rpm. However, the results of this simulation have not been carried out along with experimental studies to determine the actual cooling capacity that can be collected.

Conventional compressor and electric compressor

Figures 7 (a) and (b) show the fuel consumption versus vehicle speed of a conventional compressor and an electric compressor. An electric compressor consumes up to 18% less fuel compared to a conventional compressor. This is due to the fact that there is less load on the car coming from the compressor and energy efficiency is improved. Increasing the internal heat load will increase the fuel supply to both systems.

The experiment showed that the percentage of fuel consumption reduction of an electrically driven compressor in relation to a belt driven compressor is from 5 to 14% [12, 13].

Conclusion

Several automotive air conditioning technologies have developed to reduce fuel consumption and CO_2 emissions.

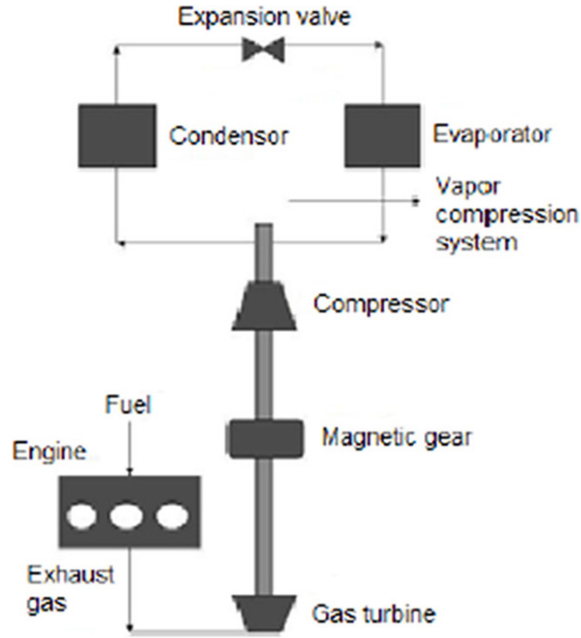

Figure 6 – Turbo A/C concept eliminating the use of belts and pulleys according to Kumar, S., et al. (2014)

The use of a variable displacement compressor shown has positive effects. An interesting idea is to use the kinetic energy of the exhaust gases to drive a compressor on a turbo air conditioning system. Other technologies are an alternative system to replace the existing vapor compression system. One of which is absorption air conditioning systems that use the thermal energy of exhaust gases, despite the low efficiency. Meanwhile, extreme interior temperatures when the car is parked in direct sunlight have become a serious problem. The use of portable automotive cooling systems and fans can increase comfort and reduce the risk of damage to vehicle interior components. In conclusion, a lower start temperature will shorten

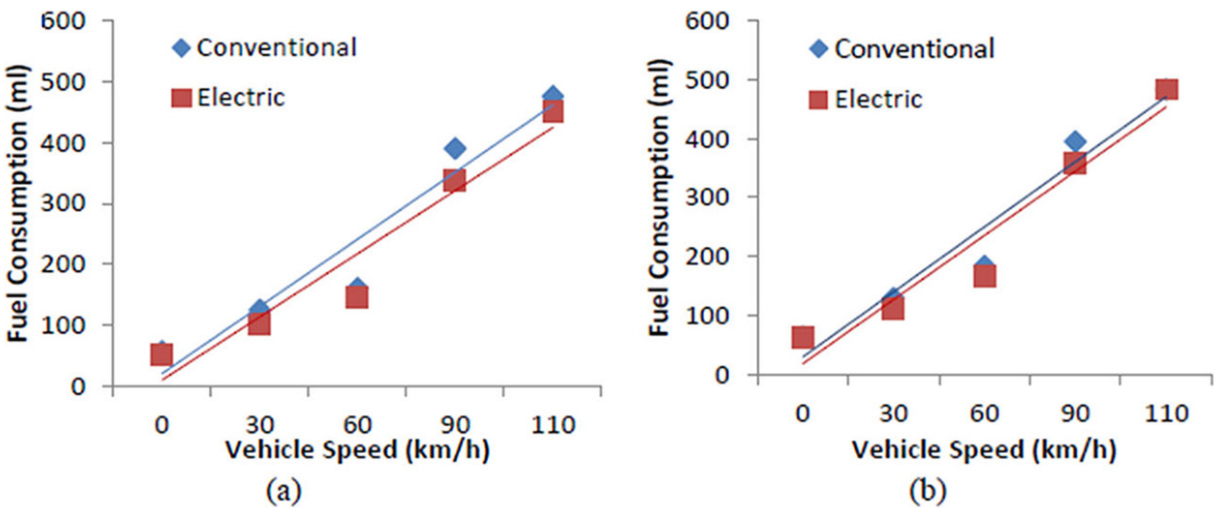

Figure 7 – Fuel consumption depending on vehicle speed; (a) 100 W internal heat load and (b) 400 W internal heat load

the stretch time, so comfort temperature is reached quickly.

Studies also show that the performance of an electrically driven compressor is about 15% to 54% higher than that of a belt driven compressor. The experiment showed that the percentage of reduction in fuel consumption of an electrically driven compressor in relation to a compressor with a belt drive is from 5 to 14%.

As a result, the use of a DC compressor has a high probability of reducing the load on the engine system and will lead to a higher coefficient of performance and lower fuel consumption. This can help in fuel economy of the car.

These methods contribute to the reduction of emissions and fuel consumption, however, only in small quantities. Thus, reducing the load of car air conditioning on the engine is clearly the need of the hour, making tomorrow's cars more fuel efficient while maintaining passenger comfort.

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Кондиционер компрессорының механикалық қуатын анықтау

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Аңдатпа. *Төмен құнмен және аз шығарындылармен механикалық қуатты өндіру біздің қазіргі уақытта бүкіл әлемдегі инженер-механиктерге үлкен міндет болып табылады. Механикалық қуат отынның шамадан тыс тұтынылуының және ауаны кондиционерлеу жүйелерінің қабаттасуынан болатын өтемақы ретінде* CO_2 *шығарындыларының жоғарылауының негізгі себебі болып табылады. Сондықтан, бұл мақалада мәселені шешудің әртүрлі әдістері ұсынылған. Механикалық энергияның жаңа әртүрлі ресурстарын табу жолдары отын шығынын азайтады және* CO_2 *шығарындыларын азайтады, VCC және сіңіру жүйесін қолдану арқылы қол жеткізіледі. Бұл зерттеу сонымен қатар электр компрессорлары сияқты ауаны баптау жүйелерін басқару-*

дың балама әдістерін қарастырады және кәдімгі компрессор мен электр компрессорының жылдамдығының функциясы ретінде қуат тұтынуды көрсетеді. Нәтижесінде электр компрессоры кәдімгі компрессормен салыстырғанда 18%-ға дейін аз қуат тұтынатыны белгілі болды. Себебі компрессордан келетін көлікке жүктеме аз болады және энергия тиімділігі артады. Ішкі жылу жүктемесін арттыру екі жүйеге де отын беруді арттырады.

Кілт сөздер: *механикалық қуат, қалаусыз механикалық жүктемелер, жаңартылатын энергия, механикалық компрессор, ғаламдық жылуы.*

Определение механической мощности компрессора кондиционера

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Аннотация. *Генерация механической энергии с низкими затратами и меньшими выбросами является серьезной задачей для инженеров-механиков во всем мире в наше современное время. Механическая мощность является основной причиной чрезмерного расхода топлива и проблем с повышенным выбросом* CO_2 *в качестве компенсации от наложения систем кондиционирования воздуха. В статье представлены различные способы преодоления проблемы. Пути поиска новых ресурсов для механической энергии, снижения расхода топлива и сокращения выбросов* CO_2 *достигаются за счет применения VCC и абсорбционной системы. Также рассматриваются альтернативные методы управления системами кондиционирования воздуха, такими как электрические компрессоры, и показано потребление энергии в зависимости от скорости обычного компрессора и электрического компрессора. В результате оказалось, что электрический компрессор потребляет меньше энергии по сравнению с обычным компрессором до 18%. Это связано с меньшей нагрузкой на автомобиль от компрессора и повышением энергоэффективности. Увеличение внутренней тепловой нагрузки увеличит подачу топлива в обе системы.*

Ключевые слова: *механическая мощность, нежелательные механические нагрузки, возобновляемая энергия, механический компрессор, глобальное потепление.*

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