JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Building Education & Presentation Examination of E Compressor trendy an Obviously Pronounced Petrol Machine

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Abstract:

Compressors production a vital role in car air conditioning schemes that mostly impact car performance and occupant ease. As motorized skills evolve to meet the stresses of sustainability and efficiency, the integration of excited mechanisms into interior burning engine (ICE) vehicles has develop a focal point of investigation and growth. Conservatively, ICE cars use belt-ambitious compressors, which use train power from the auxiliary belt drive to operate. In this background, our study delves into the integration of an electric compressor (e-compressor) inside the Entry piece vehicle platform, present a comprehensive checkup encompassing an style layout homework, routine investigation, and cost suggestions.

Keywords: E-compressor, Belt-driven compressor, Cooling capacity, Layout study, Coefficient of performance

Introduction

Compressors are combined in an interior burning train vehicle (ICE) for the request of air training schemes that meaningfully influence the car presentation and inhabitant ease. Conservatively, belt-ambitious compressors have been combined with ICE cars to meet the nearside cooling supplies. With the appearance of electronic and cross cars, e-compressors must unlocked new chances for better vehicle presentation [1] and competence [2] by augmented fuel cheap[3], hut cool depressed retro and smaller releases[4]. Gas density (Fig.)[5] theaters a very significant role when it originates to compressors. Vapour density works on the principle of poignant heat from a cold pool to a hot one. This is in contradiction of the additional law of thermo subtleties which makes it needed for some exertion to be completed. The vapor density refrigeration series includes numerous mechanisms viz. the compressor, condenser, heat exchanger, evaporator, and the growth valve/regulate regulator.

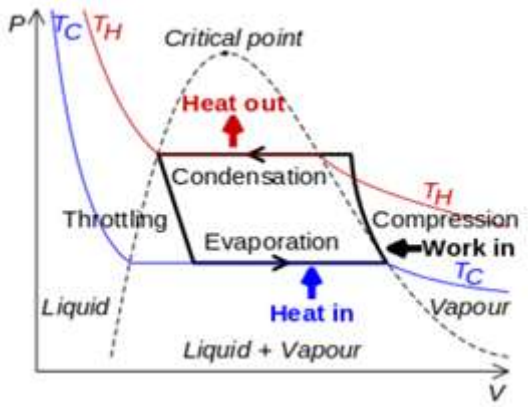

Fig. Vapor compression cycle

As a hydrofluorocarbon (HFC), R134a is recognized for its efficiency in cooling and has become a popular replacement for ozone depleting chlorofluorocarbon (CFC) refrigerants like R12. Known for being ozone-friendly and free from chlorine, R134a contributes to environmental sustainability. The chemical and physical properties of R134a refrigerant is given in Table.

Table. Properties of refrigerant R134a

SNO.	PROPERTIES	VALUE
1	Chemical formula	CH_2FCF_3
2	Molar mass	102.03 kg/kmol
3	Critical pressure	4.06 MPa
4	Maximum pressure	70 MPa
5	Critical point density	511.9 kg/kmol
6	Critical temperature	374 K
7	Boiling point temperature	247.08 K
8	Specific heat @ const.P(S.L @ 25°c)	1.4246
9	Specific heat @ const.P (S.V @ 25°c)	1.0316

The TXV system regulates rate of refrigerant flow into evaporator as governed by evaporator outlet pipe temperatures sensed by the sensing bulb, and the CCOT system controls the evaporator temperature by turning the compressor on and off with a clutch cycling switch. A CCOT automotive A/C system includes a compressor, a condenser, an expansion device, an evaporator and an accumulator.

The system taken into consideration is a TXV A/C system. In a TXV A/C system the expansion valve performs two main functions namely, maintain the pressure differential between low- and high-pressure sides and control the amount of liquid refrigerant entering the evaporator.

The compressor's suction helps maintain the low pressure. One major constituent is the air-air-conditioned evaporator which removes the moisture from the hut air and brands it dry. Upon incoming the evaporator, the refrigerant is in a cold, incomplete runny-vapor combination. The evaporator's operating weight and fever, known as suction weight and force infection, individually, influence its presentation. The suction line acts as the channel for conveying refrigerant gas after the evaporator to the compressor. The main purpose of the evaporator is to change the refrigerant from a incomplete liquid-gas state to a fully soaked gas. The employed of an air-air-conditioned evaporator is exposed in Fig.

Throughout this process, heat is transferred to the refrigerant, maintaining a constant temperature as the remaining liquid converts to gas, resulting in a 100% vapor saturation output at the initial constant temperature. Any additional heat introduced to the 100% vapor refrigerant leads to an increase in temperature, which is defined as superheat. [7]

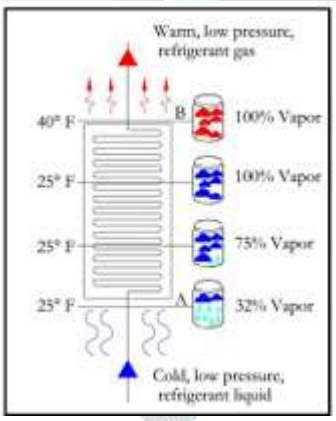

Fig. Working of evaporator

Other major component in the HVAC loop is the air-cooled condenser unit which is a heat exchanger that removes heat from refrigerant vapor. The refrigerant, having transitioned from the compressor, now exists as a hot, high-pressure gas upon entering the condenser. Heat dissipation occurs as the hot refrigerant gas releases heat to the condenser's cooling medium. Finally, the 100% saturated liquid undergoes sub-cooling. In an ideal condenser, sub-cooling does not occur, and once the refrigerant achieves a fully saturated liquid state, any additional heat loss results in a reduction in temperature.

Selection of Components

From Fig. the schematic layout of adapting an e-compressor in an ICE vehicle can be seen.

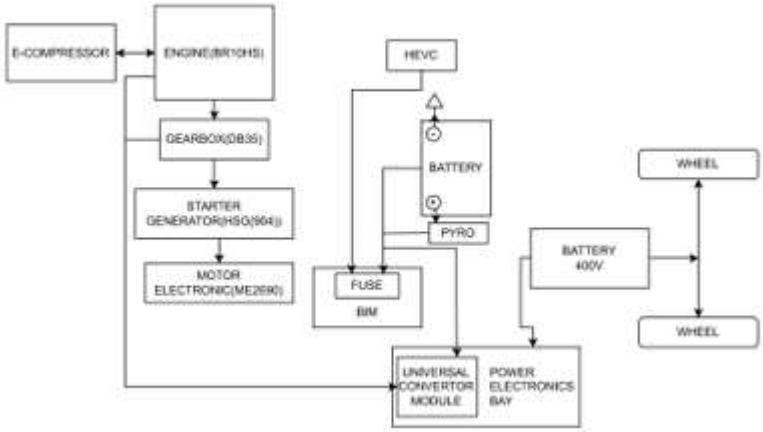

Fig. Schematic layout of e-compressor integration in an ICE vehicle

Despite the drawbacks in cabin temperature distribution and cooling effect observed in the DC compressor for automobile AC systems, its overall performance surpasses that of conventional compressors.

Selection of Compressors

Also, belt-driven compressor can provide better cooling performance at high engine speeds making them effective to use in hot weather or demanding driving conditions.

The displacement capacity spans from 7.5 cm^3 to 125.11 cm^3 per revolution, indicating versatility in handling different refrigeration requirements. The compressor's pliability is obvious in its burst pressure stipulations, with the high-weight side accomplished of enduring up to 12.4 MPa and the low-heaviness side up to 4.81 MPa. General, these compressor attitudes out for its adaptability, efficiency, and healthy design, making it suitable for various air conditionings or cooling needs.

Fig. Conventional belt-driven compressor

The e-compressor in consideration as exposed in fig. has a volume of 27cc, scroll type functioning within a multipurpose speed range of 1000 to 3200 rpm. With a salaried infection range with a leg on each side of from -10°C to 85°C, this e-compressor is planned to role proficiently transversely a band of conservational environments.

Notably, it maintains a suction pressure of 0.3MPa and a discharge pressure of 1.5MPa, indicative of its capability to handle varying pressures in different operational scenarios. The degree of superheating and supercooling is specified at 10K and 5K, respectively, highlighting the precision and control embedded in this e compressor's design.

S.NO	CONTENTS	PARAMETERES
1	Bore	29.3mm
2	Stroke(min-max)	1.9-30.9mm
3	Type	Piston type – Variable displacement
3	Displacement (min-max)	7.5-125.11 cm^3//rev
4	Refrigerant	R-134a
5	Burst pressure	HP side: 12.4 MPa LP side: 4..81 MPa

The Table. At 1000 rpm, the e-compressor demonstrates a cooling capacity of 0.84 kW with a power consumption of 0.47 kW, resulting in a Coefficient of Performance (COP) of 1.78. As the rotational speed increases to 2000 rpm, the cooling capacity nearly doubles to 1.70 kW, accompanied by a power input of 0.77 kW, yielding a higher COP of 2.23.

Continuing the trend, at 3000 rpm, the e-compressor achieves a cooling capacity of 2.63 kW with a power consumption of 1.16 kW, maintaining a relatively efficient COP of 2.26.

These results explains the e-compressor's ability to deliver higher cooling outputs as the rotational speed increases, showcasing its adaptability and efficiency in meeting varying cooling demands.

Speed / rpm	Cooling capacity / kW	Power/ kW	COP
1000	0.84	0.47	1.78
2000	1.70	0.77	2.23
3000	2.63	1.16	2.26

Table. Cooling capacity of e-compressor.

Fig. shows the structural comparison between the conventional belt driven compressor and e-compressor taken into consideration.

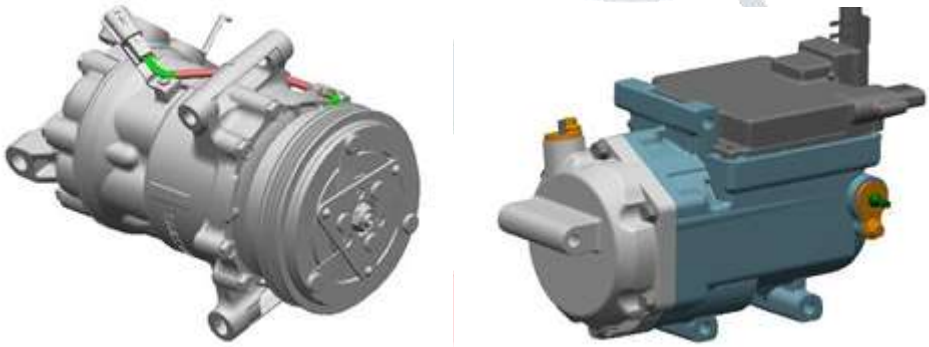

Fig. Depicts the structural comparison between belt-driven compressor and e-compressor.

Architecture Integration study

Architecture Layout Study:

The integration of electrified components is pivotal in optimizing vehicle architecture. In our analysis, the packaging of both conventional and scroll-type e-compressors within the Entry Segment Platform is meticulously examined. By comparing these configurations, we aim to uncover insights into spatial requirements, potential design challenges, and the overall impact on the vehicle's layout. Special attention is given to the distinctive characteristics of e-compressors, exploring how their compact design and smooth operation influence the integration process.

In the examination of the architectural layout within the Entry Segment Platform vehicle platform, our study encompassed both belt-driven and electric compressors, revealing a strategic placement of both components within the front zone of the engine bay area. From the Fig. we can see that the belt-driven compressor is mounted behind the cooling module of the vehicle. The assessment involves examining potential water splash exposure from the wheel well to the engine bay area, ensuring that the compressor remains protected from such elements. Additionally, careful consideration is given to the positioning and layout of cooling hoses connected to the compressor, a crucial aspect of the packaging process.

The integration of these components is particularly significant as it occurs before the docking of the powertrain unit. In the case of the belt-driven compressor, special attention is directed toward the oil drain area to enhance overall packaging efficiency. These factors collectively contribute to the architectural packaging of the belt-driven compressor, ensuring its resilience and optimal functionality in the intended operational environment.

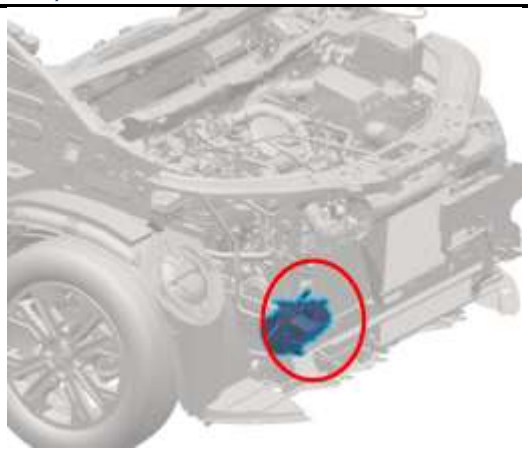

Fig. Isometric view of belt-driven compressor in entry segment vehicle platform

Fig. represents the mounting of e-compressor in the entry segment platform vehicle . A key aspect of the layout optimization involved considerations for tool accessibility during the assembly process. This e-compressor is mounted on the body with the help of stiffened rubber mounting to eliminate the NVH caused by the compressor in load conditions. Also, the e-compressor is packaged in a way that the HV harness from the DC-DC invertor is connected to the compressor.

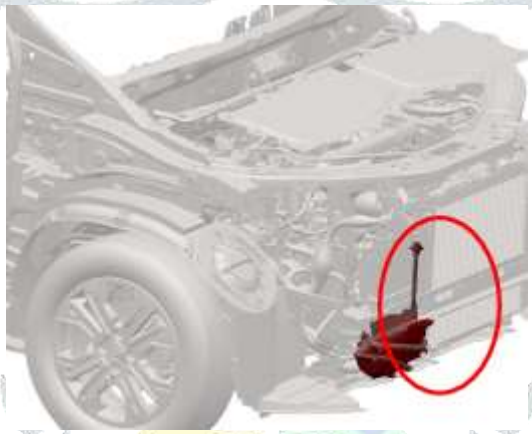

Fig. Isometric view of e-compressor in Entry segment vehicle platform

By placing the compressors in relation to the powertrain unit and incorporating a tailored assembly approach, the architectural layout enhances both the manufacturing efficiency and the operational performance of the integrated compressor systems.

Packaging Impacts:

Packaging study was carried out with replacement of belt driven compressor with e-compressor in Entry Segment Vehicle platform, which shows the impact of integrating an e-compressor with ICE powertrain. The integration of an e-compressor into an internal combustion engine (ICE) vehicle primarily influences body interfaces, hose routing, and harness routing. The adaptation process involves ensuring integration of the electrical components with the vehicle structure and optimal routing of hoses and harnesses. These considerations highlight the key impact areas associated with the adaptation of an e-compressor, emphasizing the importance of planning for implementation within the ICE vehicle architecture. Other Impacts on Packaging Includes , the need to improve the NVH, Cooling Pipes & Interface Brackets Contribute to the Packaging Environment.

Modifications required:

When integrating an e-compressor in entry-segment ICE vehicle there need to be addition of several electronic components to the vehicle.

DC-DC Invertor:

Electric compressors typically require a specific voltage level to operate optimally. In an electric vehicle, the main power source is the high-voltage battery, which may operate at a voltage level different from what the e compressor needs. The DC-DC inverter as shown in Fig. facilitates the conversion of the high-voltage DC power from the EV's battery to the voltage level required by the e-compressor, ensuring compatibility and efficient operation. By addition of DC-DC invertor the harness routing of the electrical components are also modified accordingly.

Fig. DC-DC Invertor

Body Interfaces:

For mouting the compressor on BIW specifically stiffened rubber mounts are employed for better NVH(Noise, Vibration & Harshness) characteristics of both the compressor and the body parts. These adjustments are crucial for ensuring seamless integration and optimal performance of the e compressor within the overall vehicle architecture.

BSG:

As shown in Fig. the belt-driven starter generator in automobiles plays a dual role: initiating engine startup by turning the crankshaft during ignition and, once the engine is operational, serving as a generator This is facilitated by a robust belt connecting the starter generator to the engine's crankshaft, ensuring the efficient transfer of mechanical energy. Regarding its integration with a DC-DC inverter, the starter generator generates AC power, which is subsequently converted to DC to supply electrical power to various car components. An additional noteworthy feature is its potential contribution to energy efficiency through regenerative braking, where the system captures and converts braking energy into electrical energy, further enhancing the overall efficiency of the vehicle.

Performance Analysis of belt-driven compressor:

In test condition 1 as shown in Table the Pd/Ps ratio(Pressure Ratio) is taken as 1.5/0.3. From the table. it is evident that, as the rotational speed (Nc) of the compressor increases from 2000 RPM to 6000 RPM, the power consumption also rises from 1.77KW to 5.59KW(Fig.). This suggests that higher rotational speeds demand more electrical power for the compressor operation.

Table . Performance test results of test condition 1 with Pd/Ps = 1.5/0.3

Condition	Pd/Ps (Mpa)	Nc(RPM)	Cooling Capacity Q (KW)	Power L (kW)	COP	Discharge T(°c)
S/H 10K S/C 5K	1.5/0.3	2000	2.7	1.77	1.525	<120
		4000	4.49	3.17	1.416	<120
		6000	7.9	5.59	1.307	<120

As the compressor speed rises from 2000 to 6000 RPM, there is a consistent trend of higher cooling capacity(Fig), indicating an enhanced ability to remove heat from the system. However, this comes at the expense of increased power consumption(Fig), as reflected in the escalating values for power consumption at higher speeds. Despite the higher power consumption, the system's efficiency, measured by the coefficient of performance (COP), experiences a slight decline with increasing compressor.

This suggests a trade-off between achieving greater cooling capacity and maintaining optimal energy efficiency. Also the discharge temperature is effectively controlled and remains below 120°C across all tested conditions, emphasizing the system's ability to operate safely within specified temperature limits. This inference underscores the importance of carefully balancing compressor speed to meet performance requirements while considering the associated energy consumption and system efficiency trade-offs.

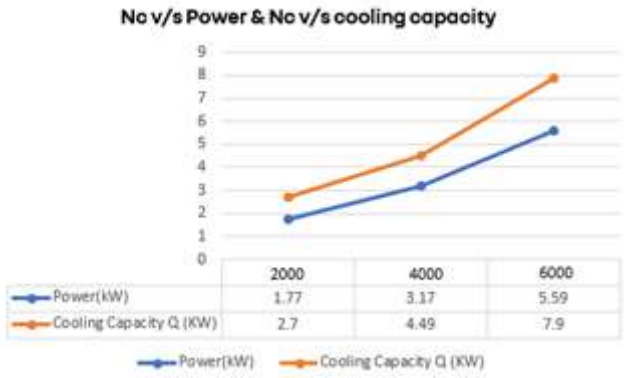

Fig. Nc v/s Power(kW) & Nc v/s Cooling capacity

Performance Analysis of e-compressor:

As shown in Table the rotational speed (Nc) of the compressor increases from 2000 RPM to 6000 RPM, the power consumption also rises from 0.67KW to 2.01KW(Fig.). This suggests that higher rotational speeds demand more electrical power for the compressor operation.

Table. Performance test results of test condition 1 with Pd/Ps = 1.5/0.3

Condition	Pd/Ps (Mpa)	Nc(RPM)	Cooling Capacity Q (KW)	Power L (kW)	COP	Discharge T(°c)
S/H 10K S/C 5K	1.5/0.3	2000	1.484	0.67	2.215	<120
		4000	3.062	1.34	2.285	<120
		6000	4.239	2.01	2.109	<120

The cooling capacity (Q) of the compressor also increases from 1.484kW to 4.239kW (Fig.) with higher rotational speeds. This is expected, as a faster rotation allows the compressor to remove more heat from the system, resulting in increased cooling capacity. The Coefficient of Performance (COP) provides insights into the efficiency of the compressor. While there is a slight decrease in COP from 2.215 to 2.109 (Fig.) as rotational speed increases, the values remain relatively close. This indicates that, despite higher power consumption at higher speeds, the compressor is still effective in producing cooling capacity.

In test condition 2 as shown in table the Pd/Ps ratio(Pressure Ratio) is taken as 2.1/0.4. This indicates a positive correlation between rotational speed and power consumption, suggesting that higher speeds demand more electrical power for compressor operation.

Inferences:

As shown in Fig. the evaluation of the Coefficient of Performance (COP) underscores the consistent superiority of the electrically driven compressor. The COP values with compressor speed range of 2000 to 6000 RPM for the electrically driven compressor range from 1.904 to 2.062, outperforming the conventional compressor with compressor speed range of 2000 to 6000 RPM with COP values ranging from 1.313 to 1.632. This signifies the electrically driven compressor's more effective conversion of electrical input into cooling output, emphasizing its enhanced energy efficiency. The discernible advantage in COP strengthens the case for considering the electrically driven compressor as a preferable option, particularly in applications prioritizing energy efficiency and operational cost-effectiveness.

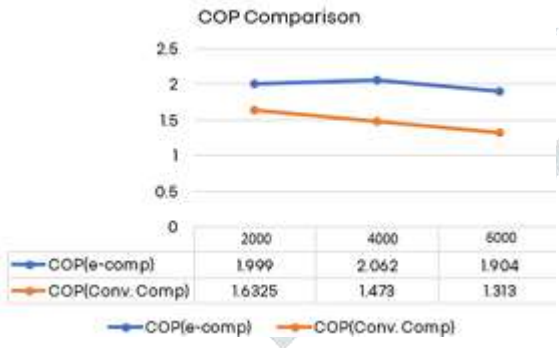

Fig.table
COP comparison between e-compressor and belt driven compressor

Cost Analysis

Comparing the integration of an e-compressor in the entry segment vehicle with the conventional belt driven compressor, there is a cost increase of approximately 63% when e-compressor is integrated. This marginal increase in the cost is mainly on the part cost. In conclusion, while the upfront cost difference between e-compressors and traditional belt-driven compressors is evident, it is essential to consider the broader spectrum of advantages associated with adopting cutting-edge e components. Though the Cost up Value is higher for any Entry Segment Vehicle, in terms of long-term cost efficiencies to technological advancements, these factors collectively contribute to the overall value proposition of Replacing electric Compressor in entry Segment vehicles.

Conclusion

This study delves into the meticulous selection of compressors, examining their seamless integration into entry-level vehicles. The architecture packaging status indicates a strategic inclusion of the belt-driven compressor within the powertrain unit to optimize assembly feasibility. Conversely, the e-compressor is mounted on the Body in White (BIW) to alleviate potential NVH (Noise, Vibration, and Harshness) concerns that could affect performance. The transition from a belt-driven to an e-compressor necessitates notable modifications, incorporating advanced electrical components like the DC-DC inverter and the belt-driven starter generator. This replacement of conventional compressor by e-compressor can be a potential USP and could further help in

contributing to the recent trends in global EV market. This study recommends ongoing research and analysis to address efficiency challenges, particularly at higher rotational speeds, and to enhance the overall performance of compressor systems in diverse automotive applications.

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