Leveraging Strengths in Engaging in Diverse Businesses to Raise the Competitiveness of Products Capturing a World-Leading Market Share*

Toyota Industries engages in a diverse range of businesses, including car air-conditioning compressors, vehicles, engines, electronics, materials handling equipment and textile machinery. While striving to develop and produce highly competitive products in each business, we generate new added value and synergies through collaboration across business domains. Such cross-business efforts have enabled us to garner the world's No. 1 share for car air-conditioning compressors, lift trucks and air-jet looms. We meet customers' expectations with our diverse businesses and technologies.

* Survey by Toyota Industries Corporation

The World's No. 1 Share Products

Car Air-Conditioning Compressors

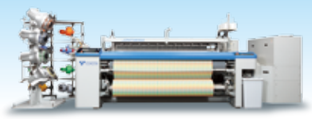
Toyota Industries' car air-conditioning compressors are highly acclaimed in terms of their reliability at high operating speeds and quiet operation in addition to such excellent environmental performance features as compactness, lighter weight and fuel efficiency, and have been adopted by the world's leading automakers.

Lift Trucks

Toyota Industries contributes to the optimization of customers' logistics operations mainly by providing a broad lineup of high-quality lift trucks and through various logistics solutions.

Air-Jet Looms

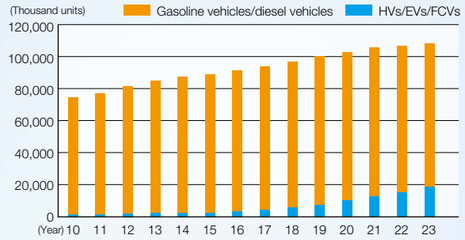
Backed by fully integrated operations from development and production to sales and after-sales services, Toyota Industries' air-jet looms have won extensive acclaim from customers around the globe thanks to superb reliability and high productivity.



Our Strengths in the Compressor Business

Toyota Industries' car air-conditioning compressors have earned a high level of trust from our customers, namely the world's leading automakers, for their superior fuel efficiency and stable quality, and have captured the No. 1 share in global unit sales. In addition to car air-conditioning compressors for conventional vehicles, needs for electric compressors for hybrid vehicles (HVs), plug-in hybrid vehicles (PHVs), electric vehicles (EVs) and fuel cell vehicles (FCVs) have recently been growing in step with advances in the electrification of vehicles.

■ Global Automobile Market Forecast (Based on Production)



Source: February 2016 data, IHS database

Overwhelming Competitiveness of Electric Car Air-Conditioning Compressor Created through Cross-Business Synergies

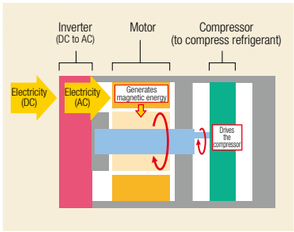
Since we developed the world's first mass-produced electric car air-conditioning compressor (electric compressor) in 2003, we have always remained at the forefront of the global electric compressor industry. In the meantime, we have developed more efficient, quieter and more compact compressors and greatly contributed to the improvement of automobiles' fuel efficiency and interior comfort. The Compressor Division and Electronics Division collaborated early on from the initial development stage in the development of a new electric compressor, as it needed an inverter that performs drive control of its internal motor.

ESB20 electric compressor mounted in the new Prius

The resulting compressor, the ESB20 mounted in the new Prius released by Toyota Motor Corporation (TMC) in December 2015, is a culmination of our collaborative efforts across business domains, and its performance and quality are already receiving high acclaim.

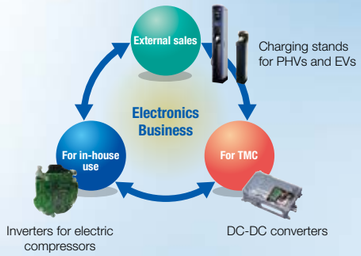
Inverter, a Key Component to Control an Electric Compressor

Compressors for conventional vehicles use power fed from the vehicle's engine to run the air conditioner. In HVs and other similar vehicles, these compressors cannot operate the air conditioner when the vehicle uses eco-friendly features that stop the engine, such as an idling stop system and electric drive mode. Electric compressors, on the other hand, are driven by a motor that uses power from the vehicle's main battery and can run the air conditioner even when the engine is not operating. An inverter is a key component that performs drive control of this motor. It enables the operation of the air conditioner during an idling stop in traffic congestion or when the vehicle runs in electric drive mode, helping to ensure a more comfortable vehicle interior and better fuel economy at the same time.



Electronics Business Supporting Our Global Top-Share Products

■ Honing Technological Capability by Developing Products for TMC, External Sales and In-House Use



Toyota Industries' Electronics Business provides DC-DC converters, AC inverters, rear inverters for four-wheel drive (4WD), cooling devices, on-board chargers, charging stands and other car electronics products to TMC. Based on the experience we have gained in responding to TMC's stringent demand for higher quality and selling products to many automakers in addition to TMC, we utilize accumulated technologies and expertise in our products developed in-house, including electric compressors.

We aim to enhance our total strengths and the competitiveness of our products that capture the world's No. 1 share in their respective markets by refining our proprietary technological capability and leveraging synergies across business domains.

Discussion

Project Members Talk about the Outcome of Collaboration between the Compressor Business and Electronics Business

The ESB20 electric compressor, which is mounted in the new Prius to contribute to higher environmental performance and vehicle comfort, integrates synergies between the Compressor Division and Electronics Division from product development to production and quality assurance. In this section, project members from these two divisions talk about the outcome of their collaboration.

Challenges Faced with the Development of the ESB20 Electric Compressor

In developing the ESB20, one of the tasks assigned to the project team was to contribute to achieving the world's highest-level fuel economy and interior comfort in the new Prius. Higher performance was thus required in every aspect of the compressor, such as raising the air-conditioning function without increasing its volume, making it quieter, improving its vibration resistance and reducing power consumption. "At the same time, we had to think about future models to be derived from the ESB20 and ensure their easier development and production through the use of a common structure and production method," notes Tatsuya Koide of the Compressor Division.

To achieve these goals, a higher level of collaboration and greater synergies were called for between the Compressor Division and the Electronics Division, which is in charge of development and production of inverters, during concept formulation in the initial development stage.

Tatsuya Koide
Group manager, Engineering Dept.
Compressor Div.

Inverter for electric compressors

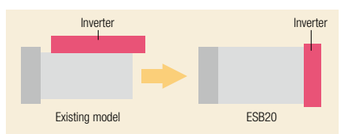
ESB20 electric compressor

Positive Outcome Derived from Collaboration by Surmounting Development Challenges

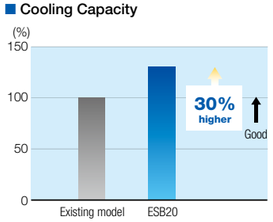
In order to both improve performance and make components more compact, efforts had to be made in various aspects. One is finding the best structure-performance balance in a scroll, which compresses refrigerant, and such key components as an inverter, which controls the motor that rotates the scroll, as well as in the shape of the compressor itself. Another is seeking total optimization in the resulting electric compressor.

Koide explains: "To make the compressor fit more easily in the narrow engine room, we first moved the inverter, which was previously positioned on top of the compressor, to the rear end of the compressor. We also made the shape of the compressor cylindrical by eliminating surface irregularities as much as possible. We selected a thin cylindrical shape for the inverter so as not to add much to the compressor's total length and needed to integrate all its functions into this small space. The compressor team and the inverter team worked together and found the optimum solution by utilizing computer aided engineering (CAE) analysis*1 on the structural design and the cooling performance design."

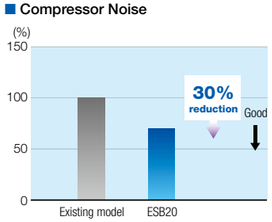
Takeshi Harasawa of the Electronics Division observes: "For this inverter, we needed to reduce its size and house everything in the cylinder while at the same time ensuring the ease of production. So, we totally revamped the size and layout of the components. One of the most significant results of our collaboration was a method to ensure solid cooling



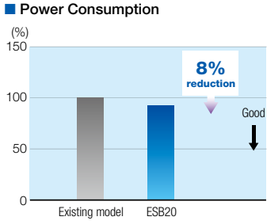
■ Cooling Capacity



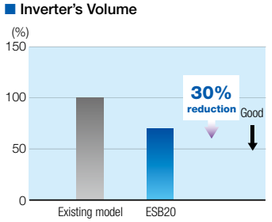
■ Compressor Noise



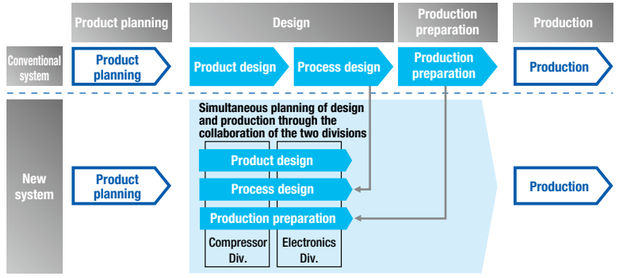
■ Power Consumption



■ Inverter's Volume



■ New Development and Production System for Generating Synergies



Takeshi Harasawa
Assistant General Manager,
Engineering Dept.
Electronics Div.

performance. Electronic circuits and components of an inverter generate heat when electricity flows through them. Reducing the size of an inverter makes it difficult to secure enough surface area needed to release that heat. The new cooling structure that has been developed is the result of true synergy between the two divisions." Koide adds: "The aluminum die-cast base of the inverter was designed by the Compressor Division. Because its thickness and shape determine the cooling performance of the compressor, the Electronics Division utilized its thermal simulation technology to identify the optimum shape under various design restrictions and succeeded in securing the required cooling performance."

As a compressor is mounted near the engine, an inverter integrated into the compressor is required to be heat- and vibration-resistant. Electronic components, in general, are rarely used in such harsh conditions, but the close collaboration of the two divisions made successful development of such an inverter possible.

The resulting ESB20 achieves a 30% higher cooling capacity, 30% reduction in compressor noise, and through improved efficiency, 8%*2 less power consumption. A 30% reduction in the inverter's volume also allows easier vehicle mounting. The ESB20 has been mounted in the new Prius as an electric compressor boasting the world's leading performance.

*1: A system to aid in product development using computers in the areas of design and numerical analyses
*2: Results of measurements under year-round use conditions

New Development and Production System Adding Greater Value to the Collaboration Outcome

Upon the development and production of the ESB20, we exercised our ingenuity in each stage from design to production preparation. Conventionally, we begin with product planning and then proceed to product design, process design and finally to production preparation. This time, we conducted product design, process design and production preparation concurrently, sharing the simultaneous engineering approach between the two divisions to pursue higher quality, lower costs and ease of production for the product. The two divisions were mutually inspired by sharing knowledge and ideas with each other while promoting the project. "Continuously stable production of a quality product is difficult to manage and maintain. With the design team, we shared information from the product design stage on hundreds of issues that could occur in the mass production stage. Based on the information, the design team worked to modularize*3 components and simplify their structures," explains Daisuke Katayama of the Electronics Division, who is well-versed in compressors and was in charge of production engineering of the inverter. Energetic discussions among project members led to the completion of a new, simple, compact and highly efficient production line. The new line will make adding variations to the ESB20 easy and allow mixed production of these models at a consistently high quality level.

Inverter production line

Daisuke Katayama
Assistant manager,
Production Engineering Dept.
Electronics Div.

*3: A group of functionally associated components forming one larger functional component

Continued Cross-Business Collaboration to Enhance Synergistic Effects and Increase Product Appeal

At Toyota Industries, personal exchanges across different business domains have always been active, and our strengths stem from a corporate culture that proactively encourages cross-business collaboration. This time, the Compressor and Electronics divisions started working together from the concept development stage of the ESB20, which enabled the manufacture of a product that meets ambitious goals. We will continue to leverage the synergies from cross-business collaboration with a view to further increasing our competitive edge and delivering products needed by customers around the world.