The vision for a Carbon Neutral Scenario and Contributions to the Automotive Industry by TRAMI （Transmission Research Association for Mobility Innovation）

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ABSTRACT: Due to the worsening environmental issues on Earth, the importance of reducing CO2 emissions from automobiles has increased more than ever, and the expansion of electric vehicles is urgently needed. In TRAMI's carbon-neutral scenario, we emphasize research on the technology of miniaturizing and lightweighting electric drive systems through ultra-high-speed motors to simultaneously address the shortage of material resources for vehicle drive motors and the increase in CO2 emissions during manufacturing. Additionally, the miniaturization of electric drive systems enhances the design flexibility in electric vehicle development, leading to the creation of new attractions for electric vehicles. TRAMI aims to contribute through research activities to ensure that Japan's automotive industry leads the expansion of electric vehicles in the future.

1. WHAT IS TRANSMISSION RESEARCH ASSOCIATION FOR MOBILITY INNOVATION “TRAMI”

TRAMI is one of the organizations established with the approval of the competent minister to overcome challenges that cannot be solved individually by conducting joint research among multiple companies, universities, and incorporated administrative agencies, aiming for the practical application of technology. It was established in April 2018 (https://trami.or.jp). Currently, the members consist of 12 organizations, including major automobile manufacturers, transmission manufacturers, and general incorporated foundations primarily focused on testing and research (Figure 1). Additionally, there are currently 31 supporting member companies that agree with TRAMI's activities and support its initiatives. These supporting members also participate in TRAMI's research as joint research companies.

The philosophy of TRAMI is to provide an environment for the development of drive system technology in Japan and the development of human resources that support it through industry-academia collaboration. Under this philosophy, the following projects are being carried out:

-Fundamental research on the transmission efficiency, noise and vibration reduction, lightweight technology, and electrification of automotive drive systems
-Joint investigations related to automotive drive systems
-Modeling of automotive drive systems to promote Model Based Development (MBD)

Figure 1. Members of TRAMI

The technical scope handled by TRAMI (Figure 2) relates to vehicle drive system technology, encompassing all elements and integrated systems involved in the transmission of power/energy from the vehicle's power source (engine) to the tires. By promoting further development of this technical scope and reducing energy losses, TRAMI contributes to achieving carbon neutrality while also pursuing technologies to suppress noise and vibration. The

acquired technologies are modeled to accelerate the establishment of MBD environments, aiming for their application in rapid and optimal design in research institutions and each company.

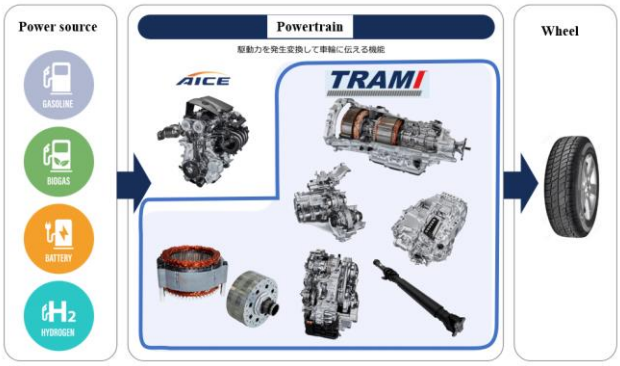

Figure 2. Technical research scope of TRAMI

In the initial three years after its establishment, TRAMI primarily focused on researching drive system technology related to internal combustion engines and hybrid systems. However, in anticipation of an increased adaptation of electric motors as power sources for vehicles to achieve carbon neutrality, TRAMI has actively taken on issues related to powertrains including motors as a primary research theme starting from the fiscal year 2022. As a result, the number of research themes, which were initially around 25, is expected to expand to 40 themes (plus investigations on electric vehicles and the establishment of MBD) by the fiscal year 2024. This paper introduces the carbon neutrality scenario envisioned by TRAMI and its contributions to the automotive industry.

2. The Environment Surrounding Carbon Neutrality

Automobiles are transportation machines that carry people and goods, requiring various natural resources and energy during manufacturing, as well as consuming a significant amount of energy during driving. If this energy is derived from fossil resources such as oil, it results in CO2 emissions during vehicle driving.

Figure 3 shows the breakdown of CO2 emissions by sector in Japan for the fiscal year 2022. Most CO2 emissions are attributed to energy transformation (such as power generation), industrial and transportation sectors. Among these, CO2 emissions from the transportation sector account for about 18% of the total, varying with changes in energy consumption methods, such as the type of power source and its efficiency.

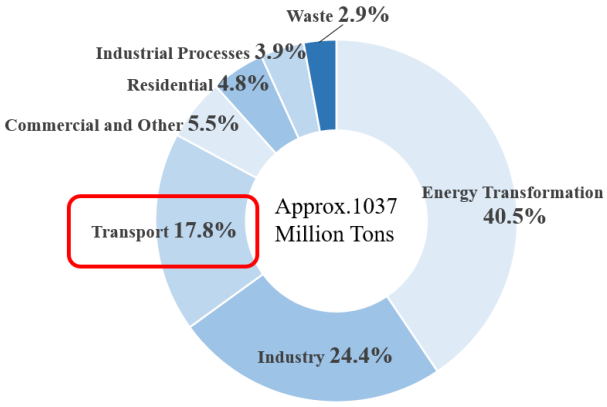

Figure 3. CO2 emissions by sector in Japan, FY2022
“Without allocation of CO2 emissions from power generation and steam generation to each sector”

Figure 4 compares CO2 emissions from different powertrains in the transportation sector. The CO2 emissions here include not only emissions during driving but also those generated during the manufacturing process, representing the total lifecycle CO2 emissions. Notably, the CO2 emissions associated with the production of energy sources (fuels, e.g. gasoline and electricity) required during driving can change significantly depending on the methods used to produce energy. This indicates that achieving carbon neutrality requires selecting powertrain systems that align with the energy circumstances of each country, while also recognizing that the potential for powertrains to contribute to CO2 emissions reduction is broad, regardless of the chosen powertrain system.

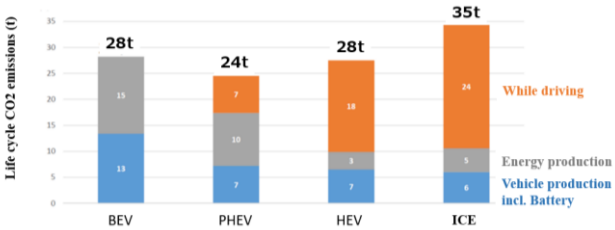

Figure 4. CO2 Emissions per Powertrain in the Transportation Sector (LCA)

3. TRAMI's Carbon Neutrality Scenario

From the perspective of lifecycle assessment, contributions to carbon neutrality need to be considered from two viewpoints:

(1) Reducing CO2 emissions during vehicle driving
(2) Reducing CO2 emissions during the manufacturing process, including materials, parts, and vehicle production, as well as resource circulation.

It is expected that the share of electricity supplied by carbon-free power plants and renewable energy will increase in the future. In this case, the CO2 emissions of BEVs, as shown in Figure 4, are anticipated to be greatly reduced. Based on this, enhancing foundational and fundamental research on powertrains associated with EVs is an urgent issue for our country.

Considering this, TRAMI has analyzed research themes it should tackle (Figure 5). This is a flowchart of vehicle manufacturing that takes lifecycle assessment into account. Recycling and reuse involving vehicle users, as well as parts manufacturing and vehicle manufacturing processes, and material development, are already being advanced by each company. Therefore, these areas are temporarily excluded from TRAMI's research focus on common problem-solving. However, delays in efforts toward resource conservation and material substitution through miniaturization, can be a significant setback for resource-scarce Japan, making it a common issue to address.

In fact, advancing miniaturization is expected to not only reduce resource usage but also facilitate modularization, expanding the number of installations and the range of applications. As a result, costs are also to decrease. Furthermore, if material substitution for general-grade components and new structures like magnet-less motors progresses, it could lead to a positive cycle of reduced procurement risks and costs. This would promote the proliferation of electrical vehicles. Therefore, resource conservation and material substitution are considered important angles for research themes.

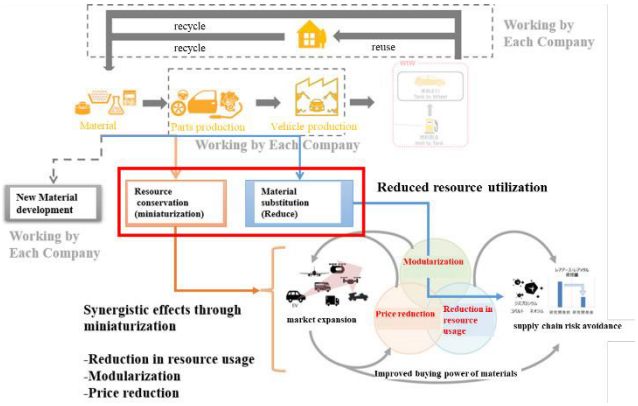

Figure 5. Angles of research themes in TRAMI

To achieve carbon neutrality, it is essential to promote excellent electrical vehicles in society. The means to contribute to carbon neutrality are as follows:

(1) Reducing CO2 emissions during driving: Aim for high efficiency of the electric powertrain system.
(2) Reducing CO2 emissions during manufacturing: Aim for resource conservation and material substitution by miniaturization of the powertrain.

In general, the motor power is the product of torque and rotation speed, and torque is proportional to the volume of the motor. Therefore, when designing a smaller motor with equal motor power, a technique to reduce torque by increasing rotation speed is used.

TRAMI, which handles powertrains including motors for vehicle drive, think that research on miniaturization of electric powertrains should be promoted through ultra-high rotation of motors in order to reduce CO2 emissions in the manufacturing process. Regarding the reduction of CO2 emissions during driving, there is a possibility that losses may increase due to ultra-high-speed operation, and TRAMI aims to deepen its countermeasures in this regard.

It is evident that ultra-high-speed operation of motors is not the sole solution to achieve the above objectives. However, two reasons can be cited for why this should be led as TRAMI rather than individual companies:

-Achieving ultra-high-speed operation exceeding 50,000 rpm has extremely high technical difficulty, necessitating breakthroughs in existing technologies.
-Innovative research is required not just for the motor alone but for the electric drive system.

Figure 6 illustrates the "benefit" and "research direction" resulting from ultra-high-speed operation. The horizontal axis represents motor speed, and the vertical axis indicates size and weight as an electric drive system with lower values indicating better characteristics.

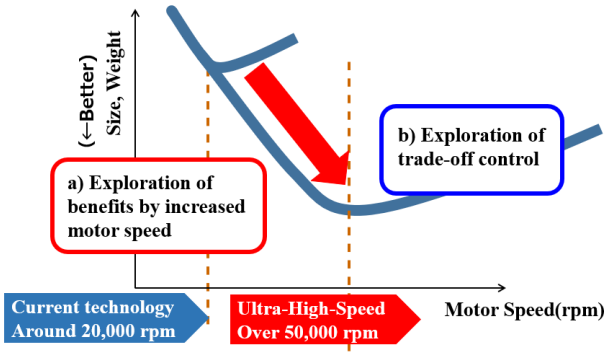

Figure 6. Exploration Image of benefits and trade-off by Ultra-High-Speed technical research

Up to around 20,000 rpm, it seems feasible to address this range by extending existing technologies. Generally, within this range, as motor speed increases, the "benefit" obtained from the motor alone improves. However, beyond a certain speed, it can be imagined that conflicts as a drive system may increase, particularly in the gearbox portion after the motor, potentially reducing overall “benefit”. TRAMI will promote a) Exploration of benefits by increased motor speed and b) Exploration of trade-off control with ultra-high-speed operation.

As a reference, the following are examples of outcomes expected from exceeding 50,000 rpm. According to forecasts for the number of electrical vehicles by 2040, a total reduction of about 30 million tons in CO2 emissions during manufacturing is anticipated. As an example of resource conservation, it is estimated that the use of electrical steel sheets could be reduced by about 1.5 million tons based on the forecast for the number of electric vehicles in 2027, bringing TRAMI one step closer to contributing to carbon neutrality.

4. Contribution to the Automotive Industry

TRAMI is promoting technical research on the entire ultra-high-speed (over 50,000 rpm) electric powertrain to accelerate electrification. The ultra-high-speed operation of motors requires extensive and critically important research to suppress iron losses, respond to increased centrifugal forces, and address high-frequency vibrations. Additionally, for practical application, it is necessary to ensure that the entire electric powertrain functions effectively. Even if the rotational speed of the power source reaches 50,000 rpm, the vehicle speed will not change significantly from the current state. The tire rotational speed of the vehicle is approximately 1,600 rpm at maximum speed, meaning it must be reduced from 50,000 rpm to this speed. In other words, the reduction ratio will be around 30, which will significantly alter the applicable range and means of existing mechanical element foundation technologies.

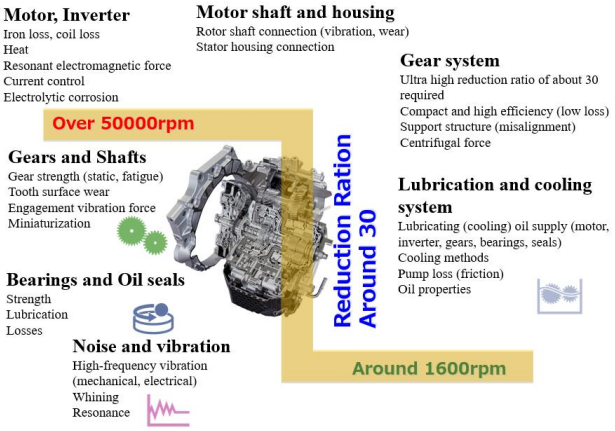

Figure 7. Essential technologies for Ultra-High-Speed electric powertrain system

Currently, the reduction ratio of electric powertrains is around 10 to 15, and proposals for gear trains that can expand the reduction ratio to 30 while maintaining or improving existing transmission efficiency are needed. Various technical studies are required, including lubrication and cooling methods at ultra-high speeds, bearing support structures, and stress analysis of gear tooth surfaces.

TRAMI's research on miniaturization, lightweighting, and efficiency improvement through ultra-high-speed operation (over 50,000 rpm) will accelerate innovation in related essential technologies (Figure 7). This new technology will be widely adopted in the diverse mobility and powertrains developed by each company, significantly enhancing the competitiveness of Japanese automobiles.

Furthermore, through this ultra-high-speed research, TRAMI will play a role in strengthening collaboration between industry and academia and bridging the gap between them, contributing to further revitalization of Japan's automotive industry.

5. Conclusion

As mentioned at the beginning of this document, TRAMI's philosophy is “to provide an environment for the development of our country drive system technology and the development of human resources who will carry it forward through industry-academia collaboration,” and industry-academia collaboration is the basis of TRAMI's activities. We hope that industry and academia will recognize the importance of this field and develop its basic studies and human resources through industry-academia cooperation.

References

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