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EFFICIENCY OF DIFFERENT DRIVES AND TRANSMISSIONS

Based on the results of tests conducted by the independent Swedish research institute Rototest, this study provides a comprehensive statistical assessment of torque losses in automobile transmissions of various types and configurations. The analysis relies on an extensive dataset comprising over 600 vehicles produced between 1993 and 2010, including cars with manual and automatic transmissions and different types of drivetrain layouts (FWD, RWD, AWD). Measurements were obtained using hub-mounted dynamometers, which allow for direct torque evaluation at the wheel hubs and eliminate typical errors associated with traditional chassis dynamometers, such as tire slippage and rolling radius uncertainties.

The results show a noticeable difference in transmission efficiency depending on transmission type and production year. For mechanical transmissions, the average efficiency before 2004 is estimated at approximately 0.91, whereas for vehicles produced after 2005 it reaches up to 0.96—suggesting significant advancements in design precision, materials, and lubrication systems. Automatic transmissions, on the other hand, exhibit relatively stable efficiency levels around 0.89, with losses generally higher than in manual systems, regardless of drive layout.

The study also explores the modal and average values of power losses across different configurations, highlighting that front- and rear-wheel-drive vehicles with manual gearboxes exhibit lower losses compared to their automatic counterparts. Despite ongoing development in automatic systems, such as torque converter lock-up mechanisms and multi-speed designs, their efficiency gains remain limited in practice.

These findings emphasize the importance of statistically grounded, independent testing for evaluating drivetrain performance and provide valuable insights for manufacturers, engineers, and policymakers focused on improving vehicle energy efficiency.

Key words: transmission, car, manual transmission, automatic transmission, wheel, front wheel drive, rear wheel drive, full wheel drive.

INTRODUCTION

The automobile transmission is a fundamental component of the powertrain, responsible for transmitting torque from the engine to the drive wheels. It plays a critical role in determining not only the vehicle's dynamic performance but also its overall fuel consumption and environmental impact. As global regulatory standards for fuel economy and emissions become increasingly stringent, improving the efficiency of drivetrain systems—including the transmission—has become a central focus for both automotive manufacturers and researchers [1].

One of the primary metrics used to evaluate the performance of a transmission system is the efficiency coefficient (EC), which expresses the ratio of useful mechanical power delivered to the wheels to the total power output of the engine. In other words, the EC reflects how much of the engine's energy is preserved and used for propulsion, rather than being lost due to internal resistance, friction, fluid dynamics, and other parasitic effects within the transmission.

Transmission efficiency is influenced by a wide range of factors, including:

- Type of transmission (manual, automatic, CVT, dual-clutch),
- Drive configuration (front-wheel drive, rear-wheel drive, all-wheel drive),
- Mechanical design and component precision,
- Lubrication quality and oil viscosity,
- Load conditions, gear ratios, and driving modes,
- Thermal conditions and wear over time.

Traditionally, values for transmission efficiency have been based on standardized estimates or manufacturer data, often ranging from 85% to 97% depending on the configuration [2]. However, many of these figures lack transparency and may not reflect real-world conditions. In some cases, values reported by automakers are optimized for marketing purposes and do not account for variations due to aging, wear, or temperature-dependent fluid losses.

To address this, researchers have increasingly turned to statistical evaluation methods, which allow for the analysis of large data sets collected from laboratory tests and real-world vehicle measurements. These methods provide a more objective and reliable assessment of transmission efficiency, as they can reveal distributions, identify average losses across different vehicle types, and expose outliers that might indicate mechanical faults or data inconsistencies (Fig.1).

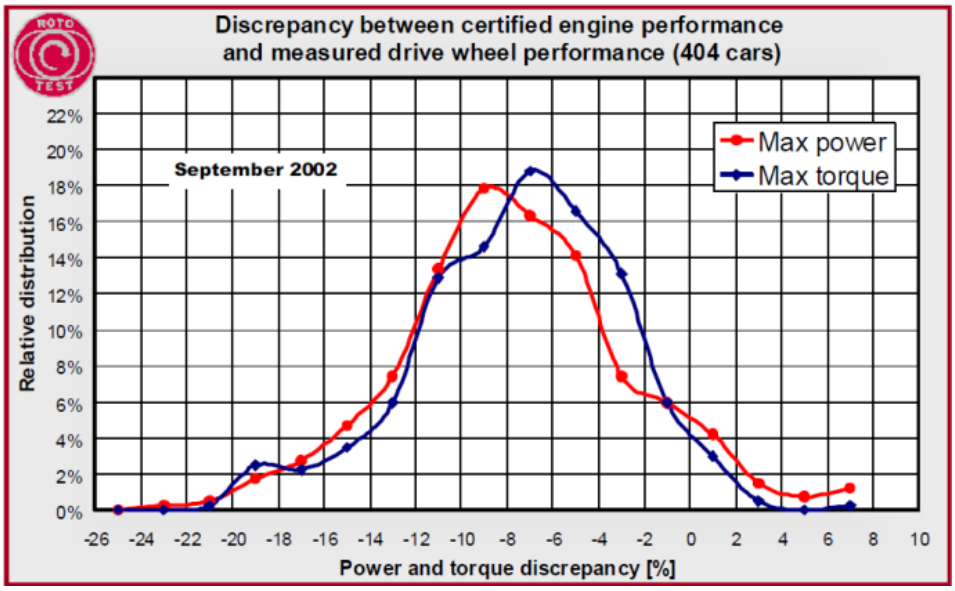

Fig. 1. Discrepancy between the passport performance indicators and the values dependent on the drive wheels [4].

One of the most notable contributors to independent transmission testing is the Rototest Research Institute, which has developed specialized dynamometer stands capable of measuring power output directly at the wheel hubs [3]. This testing approach eliminates many of the variables and inaccuracies associated with traditional chassis dynamometers, such as tire slip or unknown rolling radius, thereby allowing for more accurate isolation of transmission losses.

This paper aims to explore the principles of statistical evaluation of transmission efficiency, drawing upon publicly available data and independent testing methodologies. It also seeks to investigate how different design configurations and operational parameters affect efficiency, and what insights can be drawn to support future improvements in transmission design and control strategies.

Ultimately, understanding the real-world efficiency of transmissions is essential not only for engineers involved in powertrain optimization but also for policy-makers, fleet operators, and environmentally conscious consumers who seek to reduce energy consumption and emissions across the transportation sector.

ANALYSIS OF LITERARY DATA AND PROBLEM STATEMENT

The study of resistance forces in automobile transmissions has a long history: as early as the 1930s and 1940s [1], the first generalized estimates of the efficiency of mechanical transmissions were formulated. According to these data, for cars with one driving axle, the efficiency was from 0.9 to 0.95, and for cars with two and three driving axles - from 0.85 to 0.9. These values are still cited in educational literature and used in engineering calculations.

Modern sources, especially publications of automobile manufacturers, often report higher efficiency values - up to 0.97, in particular, for dual-clutch transmissions. However, such data are often of an advertising nature and are not always confirmed by independent measurements. This creates the problem of objectively assessing the real efficiency of modern car transmissions.

One of the few independent sources of reliable information is research conducted by the Swedish research institute Rototest Research Institute. This organization uses specially designed dynamometer stands that allow precise measurement of torque without the use of tires and rollers, eliminating common errors in traditional measurements. This allows us to obtain data on losses specifically in the transmission, without the influence of other factors.

AIM AND TASKS OF THE RESEARCH

The objective of this study is to statistically evaluate the efficiency of automobile transmissions based on data obtained by bench testing.

To achieve this goal, the following tasks were set:

- to conduct a literature review and evaluate existing data on transmission efficiency;
- to analyze an array of open data collected by the Rototest Research Institute in order to identify average and most probable values of transmission losses;
- to evaluate the differences in efficiency depending on the transmission type (manual, automatic), as well as the type of drive (front, rear, all-wheel drive);

- to analyze the dynamics of changes in transmission efficiency depending on the year of vehicle production.

RESEARCH RESULTS

During the statistical processing of the data collected by Rototest, the characteristics of more than 600 cars manufactured between 1995 and 2010 were analyzed (Fig.2). The results reflect the real losses in the drivetrain, defined as the difference between the rated engine power and the power transmitted to the wheels.

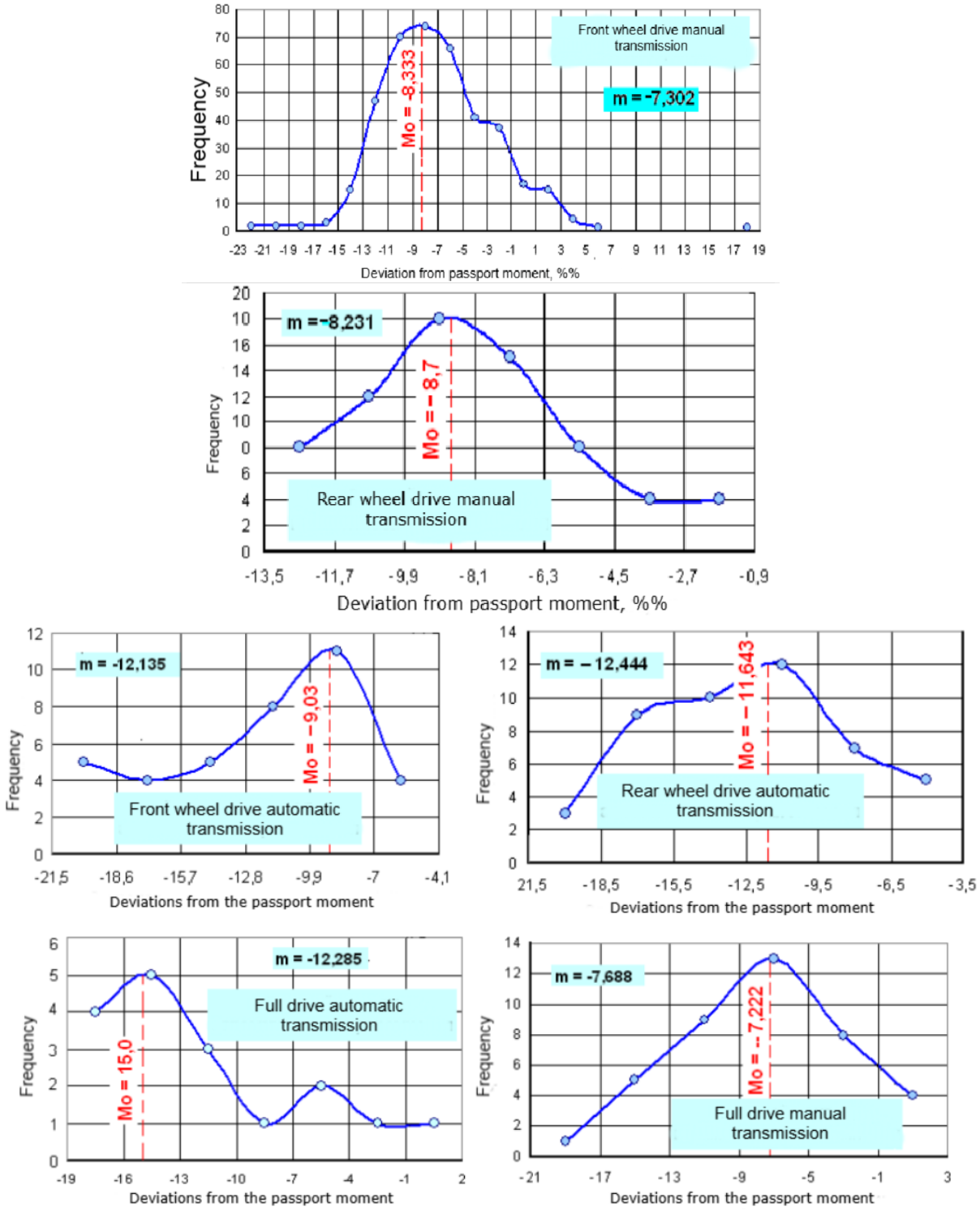

Fig.2. Distributions of deviations of measured torque values from the passport values

Key quantitative results:

- The average level of losses in the drivetrain was about 7-9% of the rated power.
- The most probable values of losses (mode) are 7% for torque and 9% for power.

- Automatic transmissions show an average loss of 12.3%, and a mode of 10.75%.
- Manual transmissions generally show lower losses, especially in newer cars.
- The type of drive (front or rear) has a minor effect on efficiency; the differences between them are within the statistical error.
- All-wheel drive has higher losses, but the sample size is insufficient for reliable conclusions (Tab. 1).

Table 1 Average differences between measured and passport torque values for different categories of passenger cars

Transmission Type	Drive Type	Sample Size	Mean Loss (%)	Mode Loss (%)
Manual	Front-wheel drive (FWD)	396	-7.302	-8.333
	Rear-wheel drive (RWD)	69	-8.231	-8.7
	All-wheel drive (AWD)	40	-7.688	-7.222
Automatic	Front-wheel drive (FWD)	37	-12.135	-9.03
	Rear-wheel drive (RWD)	46	-12.444	-11.643
	All-wheel drive (AWD)	17	-12.285	-15

- When comparing vehicles by year of production, a reduction in losses was found only for mechanical transmissions.

DISCUSSION OF THE RESEARCH RESULTS

The results of the analysis confirm that real losses in the transmission depend significantly on its design and technical condition. The data obtained cast doubt on the overly optimistic efficiency values stated in advertising materials.

Despite the active introduction of torque converter locking technologies, automatic transmissions are, on average, inferior to mechanical ones in terms of efficiency. This is explained by a more complex design, the presence of hydraulic systems and additional internal friction.

Interestingly, mechanical transmissions have shown a steady trend towards reducing losses over the past decades. This is probably due to the use of more advanced bearings, improved manufacturing accuracy, the use of low-viscosity transmission oils and the introduction of new-generation synchronizers.

It is also worth noting that the spread of losses among different car models can reach 25%, which is due to both design features and the condition of the transmission units. This emphasizes the need for an individual approach when assessing the efficiency of a particular vehicle.

CONCLUSIONS

Thus, based on the modal values of losses, the following transmission efficiency values can be considered the most probable:

- manual transmission, front and rear wheel drive, cars produced in 1995-2004 - 0.91; cars produced in 2005-2010 - 0.96;
- automatic transmission, all types of drive - 0.89.

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Ю.В. Зибцев, П.А. Ворошилов. **Ефективність різних приводів трансмісій.**

На основі результатів випробувань, проведених незалежним шведським дослідницьким інститутом Rototest, це дослідження дає комплексну статистичну оцінку втрат моменту, що крутить, в автомобільних трансмісіях різних типів і конфігурацій. Аналіз ґрунтується на великому наборі даних, що включає понад 600 транспортних засобів, випущених у період з 1993 по 2010 рік, включаючи

автомобілі з механічною та автоматичною трансмісією та різними типами схем трансмісії (FWD, RWD, AWD). Вимірювання були отримані за допомогою динамометрів, встановлених на маточині, які дозволяють безпосередньо оцінювати крутний момент на маточках коліс і усувають типові помилки, пов'язані з традиційними динамометрами шасі, такими як прослизання шин і невизначеність радіусу кочення. Результати показують помітну різницю в ефективності трансмісії в залежності від типу трансмісії та року випуску. Для механічних трансмісій середній ККД до 2004 року оцінюється приблизно в 0,91, тоді як для транспортних засобів, випущених після 2005 року, він досягає 0,96, що свідчить про значний прогрес у точності проектування, матеріалах та системах мастила. З іншого боку, автоматичні трансмісії демонструють відносно стабільні рівні ефективності близько 0,89, причому втрати зазвичай вищі, ніж у ручних системах, незалежно від схеми приводу.

Дослідження також вивчає модальні та середні значення втрат потужності у різних конфігураціях, підкреслюючи, що автомобілі з переднім та заднім приводом та ручними коробками передач демонструють нижчі втрати в порівнянні з їх автоматичними аналогами. Незважаючи на розвиток автоматичних систем, таких як механізми блокування гідротрансформатора і багатошвидкісні конструкції, їх приріст ефективності залишається обмеженим на практиці.

Ці результати наголошують на важливості статистично обґрунтованого незалежного тестування для оцінки продуктивності трансмісії та надають цінну інформацію виробникам, інженерам та політикам, зосередженим на підвищенні енергоефективності транспортних засобів.

Ключові слова: трансмісія, автомобіль, ручна КПП, автоматична КПП, колесо, передній привод, задній привод, повний привод.

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