Dear readers,

As the automotive industry professional journal, GRC Newsletter is going to meet with you again after our efforts from all sides.

As the world's largest automobile production and marketing country now, Chinese automotive industry plays an important role at the world's automotive industry and it is estimated that Chinese car sales will reach to 30 million by 2020. The prospect of automotive market is very promising.

The new issue focuses on the introduction to gear shifting performance of transmission and NVH testing. Nowadays, consumers have high requirement on automobile gear shifting, so our experts have a detailed introduction to GSA technology application and gear shifting optimization.

NVH has become a key performance indicator that customers are more concerned, and passengers and drivers are more inclined to buy a vehicle with quiet and comfortable driving space. GRC experts can measure, analyze and optimize NVH by high-tech software and techniques. In the latter half of this issue, our experts have a detailed introduction to NVH Test Program and optimization process.

I am particularly grateful to all the colleagues for editing this issue, and hope that all readers will enjoy our content. Look forward to seeing you soon.

Kind Regards!

Wolfgang Schmitz, CEO
The GSA system consists of 4 hardware and software parts: the GSA Hardware, the GSA Data Recorder, the GSA Data Recorder Software and the GSA Analyzing Software (see Figure 1).

GRC has developed special measurement procedures and equipment appropriate to the shift characteristics of manual transmission vehicles. See Figure 2. Different types of sensors are used for the measurements, as follows:

- 3-axial force sensor
- 3-plan angle sensor
- Displacement sensor
- Two rotational speed sensors
- TTL converter and cable
- Two temperature sensors (K type)

In recent years, with the development and application of manual transmission, shift quality analysis has become more and more important. GRC’s Gear Shift Analysis (GSA) vehicle gear shift quality analysis system analyzes vehicle gearbox shift performance conveniently and flexibly without requiring big changes to the vehicle, and makes it unnecessary for the test to be conducted on the test bench. Analyzing gearshift performance within the whole vehicle is also closer to the driver’s operation in real life.
Main function of GSA vehicle gear shift quality analysis system

**Main testing parameters of the GSA system**
- Select force
- Shift force
- Select stroke
- Shift stroke
- Clutch stroke
- Transmission input shaft speed*
- Transmission output shaft speed*
- Vehicle velocity*
- Engine speed*

(*appropriate sensors must be installed at the transmission)

**Main functions of the GSA system**
- Comparison of different vehicle shift performances
- Evaluation of competitors’ shift quality
- Comparison of performance before and after design modifications
- Performance evaluation of internal and external shift transmission mechanisms, including efficiency, rigidity etc.
- Evaluation of the transmission’s shift impulse
- Evaluation of the transmission’s double bump
- Evaluation of the effect of clutch action on gear shift performance
- Evaluation of the transmission in different stages of its life cycle

Software features

**GSA software functions**
GSA software is divided into two parts, a data acquisition system and a data analysis system, making for flexibility according to requirements. The software can be operated in a Microsoft Windows environment, and does not need any other special environment like MATLAB. The system can also analyze data offline. The system can fully reflect the driver’s behavior; for example, if the driver deliberately engages in some special shift behavior, the GSA will reflect these special actions. The GSA system can if necessary be directly connected to GRC’s professional test rig operating system PDES. The system can export data in many different formats, such as Excel files, JPG, etc. Customers also can order special file formats to make comparisons with other data easier. Users can set the content of output data in whatever way suits their needs, such as shift force against shift time, shift force against shift stroke, etc.

**Summary**
The GSA vehicle shift quality analysis system can be used for detailed testing and analysis of such features of manual transmissions in an assembled vehicle as the shift and select forces, select and shift stroke, synchronization time and double bumps. The use of a GSA system helps transmission development engineers during the development of a new transmission, during design changes of a transmission, for benchmarks against other transmissions, and during design optimization. Because the shift procedure of a manual transmission can only be analyzed statistically, many shifts must be performed to get approvable results. The measurement results also have to be evaluated by experienced transmission engineers, so that potential variations of the synchronization time, shift time or double bump behavior are interpreted correctly. In addition, test engineers need a deep understanding of the working principles of manual transmission in general (e.g. synchronizer or detent system) and interface components like the clutch.
Manual Transmission Shiftability Optimization

Manual transmission shiftability optimization, is a combination of shiftability measurements and shift systems design optimizations. GRC is capable of delivering in both aspects on the basis of long term experience and continuous improvement of the corresponding software and hardware tools.

The shiftability optimization process

Shiftability optimization approach (see Figure 1) is a continuous cycle of the below stages:

- Subjective evaluation of shiftability
- Measurement of gear shift behavior
- Design review
- Improvement proposals
- Change construction
- Management of prototyping process

Subjective evaluation on shiftability

Subjective evaluation requires a driver with rich driving experience. The evaluation comprises the following aspects:

- Shift knob ergonomics
  - Knob position
  - Knob touch / shape
- Static shiftability
  - Select and shift force
  - Select and shift travel
  - Shift snap-in
  - Shift friction
  - Shift noise
  - Cross shift
- Dynamic shiftability
  - Shift vibration / noise
  - Engagement performance
  - Disengagement performance
  - Shift double bump
- Idle shiftability
  - 1 gear shiftability
  - R gear shiftability
- Clutch characteristics
  - Clutch position
  - Maximum force
  - Clutch travel

On the basis of the subjective evaluation a radar chart can be created, which reflects a kind of fingerprint of the vehicle’s shiftability and allows clear comparisons between different vehicles (see Figure 2).
Measurement of gear shift behavior

Almost all of the subjective evaluation terms can be objectively quantified through GSA measurements. Then GRC engineers compare them with GRC / ATESTEO criteria to provide quantitative data for the following optimization. The following content is just a brief introduction of the GSA system, for more details please refer to the GSA articles. Figure 3 shows the GSA measurement and results example.

Figure 3: GSA Measurement and Results Example

Design review / improvement proposals

According to the subjective evaluation results and objective data of GSA measurement, GRC can define which items need to be optimized and the corresponding target. Then, according to the defined target, GRC can process the shift subsystems optimization, by (for instance) tolerance stack up calculations, detent force-travel curve simulation, or cross shift route simulation.

Tolerance stack up calculation

Tolerance stack up calculation can review and optimize the following shiftability items:

- Free play
- Shift travel
- Select travel

Detent force-travel curve simulation

ATESTEO DETENT CALCULATOR can simulate each detent’s force-travel curve independently; it comprises the main detent, shift rod detent and synchronizer detent. Then integrates all the curves depending on their relationships. Figure 4 shows the customer interface and the parameters needed to be input.

Figure 4: DETENT CALCULATOR Customer Interface
When we get the integrated curve we can get the shift knob force-travel curve (as Figure 5).

From the shift knob force-travel curve we can get the following information:
- Shift force
- Shift snap-in
- Shift friction

So we can process the specific adjustment to detent contour, or their position relationships to reach the criteria. Figure 6 shows the idle shift force curve.

Cross shift route simulation

To figure out the cross shift performance, GRC needs to simulate the cross shift route (as Figure 7).

The poor positions can be found out from the simulated route, so GRC can process the specific optimization to the related parts, to get the optimum cross shift performance (as Figure 8).

Change construction/management of prototyping process

After the customer gets the improvement proposals, the customer is in charge.

The involvement of the customer in the GRC/ATESTEO shiftability approach, is an important aspect of the process. The advantage for the customer is that the customer is directly involved in the improvement process. It also makes the approach more efficient because the customer keeps the know-how about manufacturing and processing, right from the beginning of the improvement implementation. GRC/ATESTEO also supports customers during this phase of the process. After the optimized vehicle is available, the subjective evaluation and GSA measurement need to be repeated to verify the optimized effects. If the optimization is satisfying for the customer, the process is concluded.
Introduction to NVH Vehicle Measurement

NVH is the abbreviation of three words that are Noise, Vibration and Harshness. In most cases noise exists with vibration, because noise is caused by vibration. By analyzing the NVH model, NVH is a system composed by excitation source (such as engine, transmission, etc.), channel of vibration transmission (suspension system, body) and acceptor (human).

NVH is becoming a key performance indicator for customers concerned, and more and more customers tend to buy a vehicle with a quiet and comfortable passenger compartment.

NVH measurement facility

Most OEMs implement the NVH verification and development with the NVH laboratory (example as Figure 1), namely, anechoic chamber. The laboratory is suited for vehicle measurement and assessment because of the large investment amount, long construction cycle and large maintenance and usage cost.

GRC implements the NVH measurement and assessment by using convenient and fast facilities and software. The headset microphone could be used for acquiring sound pressure values (example as in Figure 2), and acceleration sensors & speed sensors which have a small size and high accuracy, are used for acquiring vibration parameters (example as Figure 3). The system tests and analyzes transmission noises, such as WHINE, RATTLE and CLUNK, mainly on the vocalism principle and transfer characteristics. With shielding other low influential factors which NVH causes, the facility’s testing and analyzing efficiency even higher.

Portable data acquisition equipments and laptops are used to record and analyze data.

NVH measurement of content

Portable data acquisition equipments are fast and convenient when installed on the vehicle to measure the below content:

- Sound pressure by the driver
- Rotation speed/angular acceleration of rotating elements in the transmission
- Vibration acceleration of transmission elements
- Vibration acceleration of mounts in the engine compartment

NVH procedure of measurement and analysis

NVH subjective assessment

The key objective is to find out and distinguish the excitation source during NVH measurement. The shaft speed and vibration tests are necessarily corresponding to the concerned gear, and then we can go on with the analysis based on the test result. First of all, GRC implements subjective measurement and assessment according to a strict specification. We should confirm if WHINE, RATTLE or CLUNK noise is existing. Assessment table is shown as Table 1.

<table>
<thead>
<tr>
<th>Item</th>
<th>Manoeuvre Description</th>
<th>Gear</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>@1500 rpm</td>
<td>Driving with target gear at target engine speed</td>
<td>1st</td>
<td>7</td>
</tr>
<tr>
<td>@2000 rpm</td>
<td>Fast tip in to WOT till the engine speed reaching 3000 rpm</td>
<td>1st</td>
<td>7</td>
</tr>
<tr>
<td>@1500 rpm</td>
<td>-</td>
<td>2nd</td>
<td>7</td>
</tr>
<tr>
<td>@2000 rpm</td>
<td>-</td>
<td>2nd</td>
<td>7</td>
</tr>
<tr>
<td>@1500 rpm</td>
<td>-</td>
<td>3rd</td>
<td>5</td>
</tr>
<tr>
<td>@2000 rpm</td>
<td>-</td>
<td>3rd</td>
<td>5</td>
</tr>
<tr>
<td>@1500 rpm</td>
<td>-</td>
<td>4th</td>
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<tr>
<td>@2000 rpm</td>
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<td>-</td>
<td>6th</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 1: Subjective Measurement Table
NVH measurement

• Confirming the gear which should be measured specifically according to the measurement result. Designing the installation positions of acceleration and speed sensors (based on layout of transmission), and then installing the sensors. Example in Figure 4.
• Fixing and connecting the data acquisition equipment with a laptop after the sensors are installed, and then configuring the data acquisition equipment channels.
• Measuring and recording the data on a straight testing road under different conditions according to the requirement, and then analyzing the data by software. Example in Figure 5.

Summary

Based on the measurement of sound pressure and acceleration of elements, GRC could provide comprehensive and objective data to design/optimization engineers. The measurement is used to establish finite element model of NTF, and is helpful to execute the optimization of noise source and transfer path by modified parameters.
Acoustic properties

Certification
- ISO 3745 class 1 (High precision method) ISO 3745

Cut-off frequency
- 250 Hz

Absorbers
- Wedge type
- Length: 340 mm

Background noise level
- 45 dB
- Electric machines located outside of the noise chamber

Decoupling
- Base plate made of concrete decoupled from the structure borne noise by elastomeric blocks

Natural frequency
- 6 Hz

Drive

Input
- 95 kW
- 300 Nm (nominal)
- 490 Nm (overload)

Output
- 100 kW
- 454 Nm (nominal)
- 640 Nm (overload)

Input driveline with rigid connection of motor and transmission via a CFK shaft.

NVH test program description

Description of gear rattle measurement

Preparation for gear rattle test
- The transmission is set to the test temperature before every test run
- The gear which will be tested is engaged
- The transmission is set to a required constant speed by the input motor
- A load of torque is applied by the output engine
- The frequency of the torsional acceleration is set to the corresponding 2nd engine order
- The torsion fluctuation is ramped up from nearly 0 to maximum acceleration
- The radiated noise is measured by 4 Microphones located 1 meter away from the test object (see Figure 4)
- The A-weighted sound pressure levels of the 4 microphones are averaged and are drawn vs. the torsion acceleration
- The torsional acceleration is calculated from input shaft speed
- The basic noises from oil pump, gear meshing and bearing noises are contained in the complete analysis

Process of gear rattle test
- The transmission is set to the test temperature before every test run
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Figure 3: Positions of Microphones

Figure 4: Measuring Points

(a) Microphone Position
(b) Microphone Position
(c) Input Shaft Speed Sensor Position
(d) Input Shaft Speed Sensor and Vibration Sensor Position
Description of gear whine measurement

**Preparation for the gear whine test (layout see Figure 5)**

- The transmission is rigidly mounted to a fixture by the bell housing only
- The differential is blocked
- A short connection shaft with high torsional stiffness is used to connect the transmission input shaft via splines and a modified clutch hub
- A high stiffness and low inertia connection shaft is mounted to the load motor, and the shaft length is determined by the required motor position outside of the acoustic chamber
- A boost transmission is installed, because higher speed and higher torque are necessary
- Speed and torque transducers are mounted in front of and behind the transmission
- Four microphones are positioned about one meter away from the transmission sample (see Figure 3/Figure 6)
- One tri-axial accelerometer is installed (same position as in vehicle)
- Octobox and Artemis from HEAD acoustic are used for measuring and analyzing

**Process of gear whine test**

- The transmission is set to the test temperature before every test run
- The gear which will be tested is engaged
- The transmission is set to a required start speed by the output motor
- A constant load is applied by the input engine
- The speed is ramped up
- Every test run is repeated three times
- The overall values and the meshing orders of the engaged gear pairs are extracted from the A-weighted microphone signals
- The analysis settings in Artemis are as following:
  - Window: Hanning
  - Weighting: Fast
  - Resolution: 0.1 order
- The results are averaged over the three test runs and over the four microphones
- The values are drawn vs. the engine speed

Description of stiffness and free play measurement

**Preparation for stiffness and free play test (layout see Figure 5)**

- The transmission is rigidly mounted to a fixture by the bell housing only
- The differential is blocked
- A short connection shaft with high torsional stiffness is used to connect the transmission input shaft via splines and a modified clutch hub
- A high stiffness and low inertia connection shaft is mounted to the load motor, and the shaft length is determined by the required motor position outside of the acoustic chamber
- A boost transmission is installed, because higher speed and higher torque are necessary
- Speed and torque transducers are mounted in front of and behind the transmission
- One speed transducer is mounted on each input shaft, output shaft and differential
- Rotec is used for measuring and analysis

**Process of gear stiffness and free play test**

- The transmission is set to the test temperature before every test run
- The gear which will be tested is engaged
- The transmission is set to a required constant speed by the input motor
- A load is applied by the motor
- The torque is ramped up from positive torque to negative torque and back to positive torque (the measurement process is shown on Figure 7)
- The torque is drawn vs. the differential angle (see Figure 8)
**Fast and Accurate Whine Optimization Process**

**Fast and accurate whine optimization process (see Figure 1)**

Perfect international standard of “V” type whine optimization process, it can define accurately and is fast to solve systematic whine from the problem analysis to simulation.

**Whine optimization process explanation**

**Whine reason analysis**

**Whine principle**

Because the actual meshing gear cannot be carried out in accordance with the theory of involute meshing, it may cause the gear meshing transmission error, leading to gear vibration whine. Namely,

\[ \omega_1 \times R_1 \neq \omega_2 \times R_2 \]

**Whine transfer**

Generally falls into two kinds (see Figure 2)

- First is structure borne noise
- Second is air borne noise

Here we mainly discuss internal influence factors of transmission whine (see Figure 3 / Figure 4).

**Figure 1: Whine Optimization Process**

**Figure 2: Whine Analysis**

**Figure 3: Transmission Internal Whine Influential Factors**

**Figure 4: Transmission Hardware Design Whine Relative Parameters**
Whine test and analysis

To confirm the key factors affecting the whine generation and transfer through test of spectrum analysis. (see Figure 5)

Whine optimization scheme

According to the whine design standard and test spectrum analysis, we put forward the corresponding optimization scheme, such as requirement of contact ratio, structure layout, bearing clearance, gears order analysis, etc. (see Figure 6)

Whine simulation

Contact pattern analysis on different load, and define gear micro modification parameter (see Figure 7).

Whine contact pattern test

After all analysis has been finished, the gear contact pattern test needs to be implemented, and then validates if the gear modification is correct and reasonable (see Figure 8).
Whine bench test
Through the transmission bench test to verify the whine improvement effect, and according to the relevant whine evaluation standard, to evaluate whether it can meet customer requirements (test bench see Figure 9).

Whine optimization report
Combining the entire optimization process, the summary report will make the customer have the accumulation of experience and learning.

Whine vehicle test
If the whine bench test can meet customer requirements, the vehicle test does not generally have a problem; if the vehicle has the whine problem, it needs investigation and analysis from the related structure borne path, or resonance point of the vehicle.

Whine of transmission optimization example
The gear modification is the most common and effective method at present, to solve the whine problem from the source. For example, transmission has unacceptable coast whine on 2nd gear when the engine speed is at 1700 rpm~2300 rpm.

See left of Figure 10; interior noise of 2nd coast mode is dominated by 19 order noise of 2nd gear.

The gear modification significantly improved the gear order noise levels, reduced noise more than 10 dB(A) at 2nd gear, and reduced the vehicle noise level to an acceptable level (see Figure 10 / Figure 11).
News

• GRC and WLY Set Up a Joint Venture Company in China
• Shanghai Testing Expo
• TMC Keynote Speech

GRC and WLY Set Up a Joint Venture Company in China

ATESTEO Gear Research Center (China) Co., Ltd. (GRC), who has set up a joint venture named GRC Automotive Technology (Zhejiang) Co., Ltd. with Zhejiang Wan Li Yang Co., Ltd. (WLY) on December 15th, 2016. The joint venture mainly engages in engineering and technical development services pertaining to MT, AT, CVT, DCT, and PHEV transmission as well as NEV drivetrains. It will fully integrate WLY’s market resource and production experience with GRC’s advanced development technologies and experience. The joint venture aims to improve traditional drivetrain know-how and fill the gap of transmission technology in China, so as to satisfy the demand of OEMs in drivetrain systems for traditional and new energy vehicles. It also works closely with the OEMs and the component suppliers on research and development, to create a sound ecosystem for China’s automotive industry!

Shanghai Testing Expo

The 2016 Automotive Testing Exhibition was held on 27th to 29th of September in Shanghai. As the leader of automotive transmission industry, GRC’s products were displayed in Hall 3 Booth 11003 of the exhibition which was located in Shanghai World Expo Exhibition & Convention Center. In the exhibition, GRC presented a diverse range of high-tech products of transmission and vehicle testing, including torque measurement systems, shifting actuators, high-end equipment, and functional development and testing of drivetrain. The GRC booth with the measurement equipments attracted lots of visitors, and GRC experts gave professional explanations to them. During the exhibition, GRC got the information of over 80 customers who showed interest in our business. This achievement greatly promotes the expansion of our business, and builds up our professional and customer-oriented corporate image.

TMC Keynote Speech

The 8th TMC Seminar was held on 29th and 30th of April in Beijing. As the long-term and stable partner, GRC engineering manager, Mr. Yang Jiafeng made a technical speech titled “The Software Development of New Energy Automotive Driving System” in the first day of the seminar. After Mr. Yang had a brief introduction about the company’s rebranding, he elaborated GRC’s research and software development capabilities of the new energy automotive driving system, and GRC released the plan to promote and extend the testing technique of the driving system in the seminar.
## Upcoming Events in 2017

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<th>Event</th>
<th>Location</th>
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<td>20 – 21 April</td>
<td>TMC 2017</td>
<td>Shanghai, China</td>
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<tr>
<td>24 – 26 May</td>
<td>JSAE Automotive Engineering Exposition</td>
<td>Yokohama, Japan</td>
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<tr>
<td>20 – 22 June</td>
<td>2017 Testing Expo Europe</td>
<td>Stuttgart, Germany</td>
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<tr>
<td>05 – 06 July</td>
<td>VDI Tagung</td>
<td>Bonn, Germany</td>
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<tr>
<td>19 – 21 September</td>
<td>2017 Testing Expo China</td>
<td>Shanghai, China</td>
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<tr>
<td>20 – 22 September</td>
<td>CTI Symposium China</td>
<td>Shanghai, China</td>
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<tr>
<td>24 – 26 October</td>
<td>2017 Testing Expo North America</td>
<td>Novi, MI, USA</td>
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<tr>
<td>20 – 22 December</td>
<td>CTI Symposium Germany</td>
<td>Berlin, Germany</td>
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**Imprint**

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