Aggregation of Tyre Studies – ACEA & ETRTO
CONTENTS

• Executive summary

• Reminder & context

• Data Base & Aggregation frame work

• Statistical Analysis

• Conclusion
EXECUTIVE SUMMARY
EXECUTIVE SUMMARY

• Background
  • Two studies to assess the interdependency of tyres' parameters on each other.
  • ACEA: GRBP-70-25 and GRBP-74-09,
  • ETRTO: GRBP-73-11.
  • One laboratory

• Objectives
  • Assessment of any improvement/deterioration of noise performance in regard to the other tyres' parameters
  • Rationalization of both studies as requested by the GRBP experts:
    • Larger sample of tyres
    • Confirmation of the main the conclusions

• Conclusions
  • Confirmation of ACEA and ETRTO studies conclusions:
    • Conflict between rolling sound and safety performance
    • Better Handling performance is linked to an increase of the Rolling Sound
    • Undefined relation between rolling sound and CO2-emission
REMINDER & CONTEXT
The goal of this aggregation study, is to analyse the influence of the noise reduction of the tyres regarding their essential characteristics.

• UTAC performed two separate tyre studies by the past:
  • 2019 the ACEA Tyre Study
  • 2020 ETRTO Tyre Study

• We use here only the data which can be brought in a comparable state from both studies (7 parameters)
  • Rolling Sound,
  • Rolling Resistance,
  • Wet Grip,
  • Flat Trac (80%, 50% LI)
  • Longitudinal Aquaplaning,
  • Lateral Aquaplaning,
  • Weight.
DATABASE & AGGREGATION FRAMEWORK
Parameters retained for this aggregation study:
- Rolling Resistance, Wet Grip, Flat Track 80%, Flat Track 50%, Longitudinal & Lateral Aquaplaning, Weight (to evaluate tyre’s mass influence, if any)

### Test

<table>
<thead>
<tr>
<th>ID</th>
<th>Origin ID</th>
<th>DOT</th>
<th>Rolling Resistance</th>
<th>Rolling Sound</th>
<th>Flat Trac</th>
<th>Wet Grip</th>
<th>Longi. Aqua.</th>
<th>Lateral Aqua.</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A-ETRTO</td>
<td>n/a</td>
<td>8.686</td>
<td>6.12</td>
<td>6.77</td>
<td>61.8</td>
<td>61.8</td>
<td>1530</td>
<td>1462</td>
</tr>
<tr>
<td>2</td>
<td>C-ETRTO</td>
<td>2418</td>
<td>10.084</td>
<td>63.3</td>
<td>70.6</td>
<td>67.2</td>
<td>63.4</td>
<td>1500</td>
<td>1127</td>
</tr>
<tr>
<td>3</td>
<td>M-ACEA</td>
<td>4716</td>
<td>8.389</td>
<td>66.0</td>
<td>71.6</td>
<td>69.0</td>
<td>66.9</td>
<td>1294</td>
<td>1126</td>
</tr>
<tr>
<td>4</td>
<td>B-ETRTO</td>
<td>n/a</td>
<td>6.663</td>
<td>62.6</td>
<td>69.2</td>
<td>63.5</td>
<td>63.4</td>
<td>1718</td>
<td>1618</td>
</tr>
<tr>
<td>5</td>
<td>D-ETRTO</td>
<td>0716</td>
<td>7.985</td>
<td>65.3</td>
<td>73.6</td>
<td>66.4</td>
<td>65.8</td>
<td>1576</td>
<td>1304</td>
</tr>
<tr>
<td>6</td>
<td>E-ETRTO</td>
<td>3218</td>
<td>8.011</td>
<td>64.1</td>
<td>70.9</td>
<td>67.0</td>
<td>65.2</td>
<td>1297</td>
<td>1089</td>
</tr>
<tr>
<td>7</td>
<td>F-ETRTO</td>
<td>1818</td>
<td>9.171</td>
<td>63.8</td>
<td>70.8</td>
<td>66.1</td>
<td>64.9</td>
<td>1647</td>
<td>1346</td>
</tr>
<tr>
<td>8</td>
<td>G-ETRTO</td>
<td>3218</td>
<td>8.439</td>
<td>62.9</td>
<td>69.2</td>
<td>66.9</td>
<td>64.0</td>
<td>1427</td>
<td>1134</td>
</tr>
<tr>
<td>9</td>
<td>H-ETRTO</td>
<td>3118</td>
<td>7.914</td>
<td>63.0</td>
<td>69.7</td>
<td>65.5</td>
<td>64.2</td>
<td>1519</td>
<td>1238</td>
</tr>
<tr>
<td>10</td>
<td>A-ACEA</td>
<td>2218</td>
<td>8.985</td>
<td>64.8</td>
<td>71.7</td>
<td>66.3</td>
<td>65.5</td>
<td>1417</td>
<td>1286</td>
</tr>
<tr>
<td>11</td>
<td>B-ACEA</td>
<td>4318</td>
<td>9.949</td>
<td>64.9</td>
<td>71.3</td>
<td>66.4</td>
<td>65.7</td>
<td>1387</td>
<td>1080</td>
</tr>
<tr>
<td>12</td>
<td>C-ACEA</td>
<td>4818</td>
<td>8.142</td>
<td>65.0</td>
<td>71.8</td>
<td>66.9</td>
<td>66.1</td>
<td>1265</td>
<td>1099</td>
</tr>
<tr>
<td>13</td>
<td>D-ACEA</td>
<td>1119</td>
<td>8.444</td>
<td>65.1</td>
<td>72.1</td>
<td>67.1</td>
<td>66.4</td>
<td>1470</td>
<td>1206</td>
</tr>
<tr>
<td>14</td>
<td>E-ACEA</td>
<td>2818</td>
<td>8.117</td>
<td>65.8</td>
<td>73.4</td>
<td>67.4</td>
<td>66.8</td>
<td>1669</td>
<td>1507</td>
</tr>
<tr>
<td>15</td>
<td>F-ACEA</td>
<td>3618</td>
<td>8.953</td>
<td>64.7</td>
<td>71.3</td>
<td>66.4</td>
<td>65.4</td>
<td>1500</td>
<td>1294</td>
</tr>
<tr>
<td>16</td>
<td>K-ACEA</td>
<td>4518</td>
<td>7.075</td>
<td>65.1</td>
<td>72.0</td>
<td>66.9</td>
<td>66.6</td>
<td>1351</td>
<td>1232</td>
</tr>
<tr>
<td>17</td>
<td>L-ACEA</td>
<td>4218</td>
<td>6.449</td>
<td>63.9</td>
<td>70.7</td>
<td>65.9</td>
<td>65.0</td>
<td>1326</td>
<td>1126</td>
</tr>
<tr>
<td>18</td>
<td>M-ACEA</td>
<td>7718</td>
<td>7.666</td>
<td>65.1</td>
<td>71.9</td>
<td>67.2</td>
<td>66.0</td>
<td>1618</td>
<td>1271</td>
</tr>
<tr>
<td>19</td>
<td>N-ACEA</td>
<td>2718</td>
<td>7.175</td>
<td>63.6</td>
<td>70.2</td>
<td>65.8</td>
<td>64.7</td>
<td>1382</td>
<td>1168</td>
</tr>
<tr>
<td>20</td>
<td>P-ACEA</td>
<td>4318</td>
<td>8.336</td>
<td>63.9</td>
<td>70.7</td>
<td>66.0</td>
<td>64.9</td>
<td>1505</td>
<td>1351</td>
</tr>
</tbody>
</table>

For tyres which were part of both ACEA & ETRTO studies, only one of them has been considered.
- Tyres 1, 2 and 3 are 3PMSF, tyres 1 and 4 are plain tread, the sequence of the list is randomly chosen.
- As the goal of the study is to analyse the influence of the noise reduction of the tyres regarding their essential characteristics, tyre were chosen for the purpose to analyse the interdependencies with a wide spread of parameters
- For each column the best result within the group of tyres and the worst are highlighted from green to red
STATISTICAL ANALYSIS
The radar charts provide a vision for a given performance a potential correlation with any other characteristics

- No correlation highlighted
- Reminder: tyres 1 and 4 are plain tread tyres
• Rolling Sound Correlation

• Radar chart of all rolling sound tests according to each tyre.

• The majority of the tests follow the same trend for the entire batch. → the shape of each « circle » shows a good correlation between noise performances

• To be noted that this correlation is a linear statistical correlation and not deterministic rule.

• Only one representative characteristic among them is kept for the next steps of the study.
• Further analysis to find correlation between parameters: bivariate analysis

• Red boxes enlighten significant correlation between two characteristics (p-value* <0.05).

*The P-value or probability value is, for a given statistical model, the probability that, when the null hypothesis is true, the statistical summary would be greater than or equal to the actual observed results.
• **How:**
  - factor analysis method that allows multivariate analyses between quantitative variables

• **Purpose:**
  - to reduce the number of 7 parameters

• The first 3 axes represent 91% of cumulative inertia.
STATISTICAL ANALYSIS - Principal Component Analysis

• **Axis 1**
  - Wet Grip, Lateral and Longitudial Aquaplaning and Flat Trac (negative).
  - This axis is the most representative for **Safety**

• **Axis 2**
  - Rolling Resistance & Weight.
  - This axis is representative for **CO2 Emissions**.

• **Axis 3**
  - Flat Trac (positive)
  - This axis is representative for **Handling**

<table>
<thead>
<tr>
<th>Part of inertia</th>
<th>48%</th>
<th>27%</th>
<th>16%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Axis 1</td>
<td>Axis 2</td>
<td>Axis 3</td>
</tr>
<tr>
<td>Rolling resistance</td>
<td>0.11447</td>
<td>0.88298</td>
<td>0.25046</td>
</tr>
<tr>
<td>Wet Grip</td>
<td>0.81409</td>
<td>-0.30913</td>
<td>0.25639</td>
</tr>
<tr>
<td>Flat Trac 80%</td>
<td>-0.68436</td>
<td>-0.00475</td>
<td>0.69410</td>
</tr>
<tr>
<td>Flat Trac 50%</td>
<td>-0.75908</td>
<td>-0.34619</td>
<td>0.50409</td>
</tr>
<tr>
<td>Longi aquaplaning</td>
<td>0.95221</td>
<td>0.06517</td>
<td>0.25576</td>
</tr>
<tr>
<td>Lateral aquaplaning</td>
<td>0.84282</td>
<td>-0.04507</td>
<td>0.45406</td>
</tr>
<tr>
<td>Weight</td>
<td>-0.14998</td>
<td>0.92685</td>
<td>0.04316</td>
</tr>
</tbody>
</table>

• These axes are slightly different from the 2 previous studies (due to other settings of parameters)
STATISTICAL ANALYSIS - Principal Component Analysis

- Axis 1 representative for **Safety**

  *the larger the size (quality score), the more the tyre is in line with the performance axis. axis characterises*

- Opposition between Rolling Sound and Safety performances.
STATISTICAL ANALYSIS - Principal Component Analysis

- Axis 2 representative for CO2 emission

- No clear correlation

*the larger the size (quality score), the more the tyre is in line with the performance axis. axis characterises*
• Axis 3 representative for **Handling**

*the larger the size (quality score), the more the tyre is in line with the performance axis. Axis characterises*

• Better Handling performance is linked to an increase of the Rolling Sound
• Letters correspond to the 20 tyres tested:
  • Red letters are noisy tyres,
  • Green are quiet tyres,
  • Blue are middle noise tyres.

• Reminder: tyres 1 and 4 are plain tread tyres
CONCLUSIONS
**CONCLUSIONS**

- **Test program conclusion**
  - It gives a comprehensive toolbox to evaluate the relationship and interdependency between Rolling Sound and other tyre’s performances using standard or regulatory measurement protocols.
  - Correlation of the four acoustic parameters regarding UN-R51.03 (Vehicle measurement) and UN-R117 (Tyre measurement) is good and can be chosen only one in this study (To be noted that this correlation is a linear statistical correlation and not deterministic rule).

<table>
<thead>
<tr>
<th>Tyres tested</th>
<th>ACEA study</th>
<th>ETRTO study</th>
<th>Aggregation Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>set/size</td>
<td>16 x 205/55 R16 91 H/ T/ V/W</td>
<td>10 x 205/55 R16 91/94 H/V/W</td>
<td>20 x 205/55 R16 91 H/V/W</td>
</tr>
<tr>
<td>dry grip</td>
<td>ECE13H Type 0</td>
<td>Similar to ECE R117 wet grip</td>
<td>-</td>
</tr>
<tr>
<td>dry handling</td>
<td>Flat trac bench</td>
<td>Flat trac bench</td>
<td>Flat trac bench</td>
</tr>
<tr>
<td>wet grip</td>
<td>ECE R117</td>
<td>ECE R117</td>
<td>ECE R117</td>
</tr>
<tr>
<td>aquaplaning</td>
<td>VDA methods (E08, E05)</td>
<td>VDA methods (E08, E05)</td>
<td>VDA methods (E08, E05)</td>
</tr>
<tr>
<td>vehicle noise</td>
<td>ECE R51 cruises and acceleration</td>
<td>ECE R51 cruises and acceleration</td>
<td>ECE R51 cruises and acceleration</td>
</tr>
<tr>
<td>tyre noise</td>
<td>ECE R117 – rolling sound</td>
<td>ECE R117 – rolling sound</td>
<td>ECE R117 – rolling sound</td>
</tr>
<tr>
<td>CO2</td>
<td>ECE R117 – RR weight, tread depth, void ratio</td>
<td>ECE R117 - RR weight</td>
<td>ECE R117 - RR weight</td>
</tr>
<tr>
<td><strong>Emission Related Tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSIONS

- **Statistical analysis**
  - The 7 parameters summarize in 3 axes with a good level of representativeness (part of inertia is 91%).
  - The radar charts and the Principal Components Analysis show a conflict between rolling sound (R117) and safety performances (wet grip, lateral aquaplaning).
  - **Simple conclusions regarding rolling sound, and other parameters**: rolling resistance, weight and safety performance (longitudinal aquaplaning) cannot be drawn.

<table>
<thead>
<tr>
<th>ACEA study</th>
<th>ETRTO study</th>
<th>Aggregation Study</th>
</tr>
</thead>
</table>
| summarize 8 characteristics to “safety”, “handling” and “CO2-emissions”:
  - conflict between rolling sound and safety performance
  - handling performance supports good rolling sound
  - undefined relation between sound and CO2-emission | summarize 7 characteristics to “wet safety”, “dry grip/CO2-emissions” and “flat trac 80% / dry grip”:
  - conflict between rolling sound and wet safety
  - plain tread tyres represent an asymptote for rolling sound at a forbidden stage of wet safety | summarize 7 characteristics to “safety”, “CO2-emissions” and “handling”:
  
  **Confirmation of both conclusions** |