Loudspeakers performance variance due to components and assembly process – Field assessment

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THE CASE STUDY

- This study is the continuation of the investigation presented at the past convention of AES in Berlin of this year
- The study was supported by a loudspeakers manufacturing company among the leaders of the automotive market
- It is an experimental study of the main causes of scrap during the production of a typical midrange loudspeaker
GOALS OF THE STUDY

1. Improve the quality of the transducer since the development phase reducing the variance and number of pieces which fail the End of Line test (EOL)

2. Investigate the influence of modification of components and assembly process in the working condition of a loudspeaker (i.e. inside a car)
• INTRODUCTION

• SECTION 1: Loudspeakers with modified components parameters

• SECTION 2: Loudspeakers with modified assembly process

• SECTION 3: Measurements set-ups

• SECTION 4: Measurements and data analysis

• SECTION 5: WoW loudspeakers – “Worst of the Worst”

• CONCLUSIONS
SUMMARY OF WORK

- 100 mm midrange loudspeaker (100Hz-12kHz)
- Two sets of different samples have been built, employing both input parts at tolerance limits and assembling mistakes
- Analysis of each deviation on components and assembly process by frequency response curve
SUMMARY OF WORK

- Two sets of experiments:
  - Components
  - Assembly Process

- Measurements:
  - Anechoic chamber
  - Real production line
  - Inside a production car

INTRODUCTION

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SECTION 1

Loudspeakers with modified components parameters
SECTION 1: Loudspeakers with modified components parameters

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- Selection of the most critical components parameters at the minimum and maximum tolerance values.
- Variation of the nominal value of the components parameters.
COMPONENT VARIATIONS

- Mass of cone
- Thickness of membrane edge
- Pulp quality of the membrane
- Electrical resistance of voice coil
- Stiffness of spider
- Mass and thickness of dust cap
SAMPLES

- For each parameter:
  - 3 modified samples at the maximum tolerance
  - 3 modified samples at the minimum tolerance
- 3 reference samples
- No samples with mixed flaws

TOTAL = 45 SAMPLES (42 modified + 3 reference)
SECTION 2

Loudspeakers with modified assembly process parameters

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GENERAL OVERVIEW

- The manufacturing process was simulated by using production tools and machines off-line
- Quantity of glue and position of voice coil have been altered
- Variation of the nominal value at the minimum and maximum tolerance approved for the production
ASSEMBLY VARIATIONS

- Gluing of moving part of speaker
- Gluing between dome and cone
- Black paint for damping on the cone
- Position of voice coil (coil IN and coil OUT)
For each variation:
- 5 modified samples at the maximum tolerance
- 5 modified samples at the minimum tolerance
- 5 reference samples
- No samples with mixed flaws

TOTAL = 45 SAMPLES (40 modified + 5 reference)
SECTION 3
Measurements set-ups

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ANECHOIC CHAMBER

- IEC/DIN baffle
- 1m distance of microphone
- Klippel Analyser
EOL MEASUREMENTS

- Klippel QC (Quality Control)
CAR MEASUREMENTS

- SpectraRTA software
- External amplifier
- A CD reproducing pink noise
- External sound card – “Roland – UA – 25EX”
- 2 microphones (17 cm horizontal distance positioned on the driver seat)
CAR MEASUREMENTS
SECTION 4

Measurements and Data analysis
GENERAL OVERVIEW

- For confidentiality reasons it is not possible to show the graphs legend
- All curves presented are the average for each modified component and modified assembly process
- Typical frequency band to evaluate a midrange in the automotive sector is 100 Hz – 12 kHz
- We will not show again the curves of EoL and anechoic chamber shown in Berlin
SECTION 4: Measurements and Data analysis

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Differences reference samples and modified samples
CONCLUSIONS
MODIFIED COMPONENTS

- The measurement lead to the same conclusions of the results obtained in laboratory and during the EoL:
  - Main variations in frequency response occur at high frequencies
  - There is a dispersion of at least of 7dB after the break up frequency
  - All measurements underlined the same critical components
ASSEMBLY PROCESS CAR

SECTION 4: Measurements and Data analysis

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Loudspeakers performance variance due to components and assembly process – Field assessment
Differences reference samples and modified samples
CONCLUSIONS
VARIATIONS ON ASSEMBLY PROCESS

- No process deviation influences in a significant way the performance of the samples
- Main differences between samples with deviating assembly parameters and the nominal one happen only at very high frequencies (10kHz), and they are not so relevant (less than 2dB in the car measurement)
SECTION 5

WoW loudspeakers – “Worst of the Worst”
GENERAL OVERVIEW

- WoW loudspeakers stand for “Worst of the Worst” ones
- Variations of components influence more the performance of loudspeakers rather than the assembly process
- To select the more critical components, a 1/6 octave averaging smoothing for the frequency response has been used
- Differences among reference samples and modified components have been calculated and then averaged on the entire frequency band of 100 Hz-12000 Hz
DIFFERENCES LAB-EOL-CAR

The average of each curve is represented by a data point.
WOOW SAMPLES

- WOW samples have been built using a mix of such components
- Two types of WOW
- In total 10 samples
- WOW 1 \(\rightarrow\) Component 1 at its lower tolerance (C1-) and Component 2 at its higher tolerance (C2+)
- WOW 2 \(\rightarrow\) complementary components of WOW 1 (C1+ and C2-)
RESULTS OF MEASUREMENTS_CAR

SECTION 5: WoW loudspeakers – “Worst of the Worst”

Frequency Response Curve

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RESULTS OF MEASUREMENTS_CAR

SECTION 5: WoW loudspeakers – “Worst of the Worst”

Differences reference sample, WoW and modified samples

- WoW 1
- WoW 2
- Component 1
- Component 2
- Component 3
- Component 4

Decibel [dB] vs. Frequency [Hz]

100 1000 10000
Each modified component has been characterized by a percentage indicating its influence on WoW.
INFLUENCE OF COMPONENTS ON WOW 1

It is evident that the mixing of components does not increase significantly the average difference between reference and modified samples.

<table>
<thead>
<tr>
<th>Component</th>
<th>dB</th>
<th>LINEAR</th>
<th>% WOW 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>WoW 1</td>
<td>1.01</td>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td>C2 +</td>
<td>0.89</td>
<td>1.11</td>
<td>99 %</td>
</tr>
<tr>
<td>C1 -</td>
<td>1.06</td>
<td>1.13</td>
<td>101 %</td>
</tr>
<tr>
<td>WoW 1</td>
<td>1.34</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>C2 +</td>
<td>1.07</td>
<td>1.13</td>
<td>97 %</td>
</tr>
<tr>
<td>C1 -</td>
<td>1.29</td>
<td>1.16</td>
<td>99 %</td>
</tr>
<tr>
<td>WoW 1</td>
<td>1.55</td>
<td>1.20</td>
<td></td>
</tr>
<tr>
<td>C2 +</td>
<td>0.96</td>
<td>1.12</td>
<td>93 %</td>
</tr>
<tr>
<td>C1 -</td>
<td>1.18</td>
<td>1.15</td>
<td>96 %</td>
</tr>
</tbody>
</table>

- **dB**: average calculated from the differences between reference and flawed sample in the range 100Hz-12kHz
- **Linear**: conversion of the dB value
- **%**: ratio between linear value of each component and the linear value of WoW in which the component has been used
### INFLUENCE OF COMPONENTS ON WOW 2

<table>
<thead>
<tr>
<th></th>
<th>dB</th>
<th>LINEAR</th>
<th>% WoW 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAR</strong></td>
<td>WoW 2</td>
<td>0.65</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>C2 -</td>
<td>0.82</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>C1 +</td>
<td>0.95</td>
<td>1.12</td>
</tr>
<tr>
<td><strong>EOL</strong></td>
<td>WoW 2</td>
<td>0.60</td>
<td>1.07</td>
</tr>
<tr>
<td></td>
<td>C2 -</td>
<td>1.15</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>C1 +</td>
<td>0.74</td>
<td>1.09</td>
</tr>
<tr>
<td><strong>LAB</strong></td>
<td>WoW 2</td>
<td>1.12</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>C2 -</td>
<td>0.99</td>
<td>1.12</td>
</tr>
<tr>
<td></td>
<td>C1 +</td>
<td>0.80</td>
<td>1.10</td>
</tr>
</tbody>
</table>

- **dB**: average calculated from the differences between reference and flawed sample in the range 100Hz-12kHz
- **Linear**: conversion of the dB value
- **%**: ratio between linear value of each component and the linear value of WoW in which the component has been used

It is evident that the mixing of components does not increase significantly the average difference between reference and modified samples.
CONCLUSIONS

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CONCLUSIONS

• The measurements inside the car confirm the thesis already presented for the laboratory and production line analyses: the most critical elements are the single components rather than their assembling process.

• The modified components produce a dispersion of a max 7dB above the break up frequency, instead the variation of assembly process seems to be not so influential on the driver’s performance.
The relevance of the modified components is not perfectly coincident among laboratory, EoL and car; however a simple correlation analysis considering all modified parameters shows that a minimum Pearson coefficient of 0.73 exists among the three sets of measurements:

- **PEARSON CAR – EOL**: 0.73
- **PEARSON EOL – LAB**: 0.97
- **PEARSONS CAR – LAB**: 0.84
FUTURE WORKS

- The same study can be repeated for different type of transducers (tweeter and woofer) and materials (plastic cones)
- Deeper investigation of the possible correlations between mixed modified components
- The actual influence on human perception of measured differences in order to guide in a more efficient way the improved design of loudspeakers
THANKS FOR THE ATTENTION

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