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APPLICATION OF AN ARTICULATION INDEX FOR THE EVALUATION OF A TYRE NOISE

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ABSTRACT
One of the important characteristics of the tyre is the quality of the vehicle interior noise. For an effective control of the tyre noise, it is necessary to define the relationship on the subjective rating and the objective measurement. In this study, the articulation index method is applied to evaluate a tyre noise from objective measurements. The measurement system is built to calculate an articulation index from vehicle interior noise due to a tyre only. An articulation index rating (AI rating) is newly set up to correlate subjective feeling rate by test drivers on the test track and the articulation index measured in the Lab. The results show that AI rate and subjective rating have a good correlation. AI rating can be used for the effective control and the evaluation of the tyre noise

1 - INTRODUCTION

As the passenger cars have been luxurious and light, many engineers have studied on the development of quieter vehicle than before. The main sources of the vehicle interior noise are the engine, the air intake system, the exhaust system, and the tyre. In recent works on the quantification of the noise sources, however noise components associated with engine are dominant in first and second gear, in third gear the two noise components, the tyre and the mechanical parts, are almost equal. This situation forces tyre noise components to be reduced to achieve a good noise quality in the vehicle cabin. The quietness of the vehicle interior is evaluated subjectively as well as objectively. The subjective sound quality is rated on a 1 to 10 point scale with the higher number being better. For the effective control of the tyre noise, it is necessary to define the correlation between subjective rates and objective measurements. Loudness, annoyance, speech interference, articulation index etc. are often utilized to evaluate quantitatively the nature of human response to noise. In this study, the articulation index was applied to correlate vehicle interior noise with subjective feeling rating.

2 - APPLICATION OF AI INTO TYRE NOISE EVALUATION

One of the harmful effects of noise is that it can cause speech interference. However, if it is used properly, noise can also be used to insure speech privacy. The degree of speech privacy or intelligibility for sentence communication can be determined by estimating Articulation Index (AI). Articulation index is defined in ANSI S3.5-1969 as below. "The AI is a weighted fraction representing for a given speech channel and noise condition, the effective proportion of the normal speech signal that is available to a listener for conveying speech intelligibility". Fig. 1 shows normal speech zone. In the vehicle cabin, the articulation index associated with the noise can be obtained by plotting the one-third octave band sound pressure level. If the measured sound level of car interior noise is lower then normal speech zone, it could not affect intelligibility for sentence communication. In this case, the AI is 1 or 100%. If the measured sound pressure level is located above speech zone, the AI is 0 or 0%. If the noise level of car interior is within the speech zone, the articulation index can be determined by the area occupied speech zone.

$$AI\,(\%) = \{(\text{uncovered part of the speech zone}) \,/\, (\text{speech area})\} * 100$$

Table 1 represents the limit values of noise levels and weighting factors in speech zone by each 1/3 octave. If the noise level in each band is higher than that of the higher limit of speech zone, weighting factors is '0'. In the case of the medium value between the upper and the lower limit, weighting factor has the value proportional to it. Therefore, AI can be calculated by summing the values in 1/3 octave

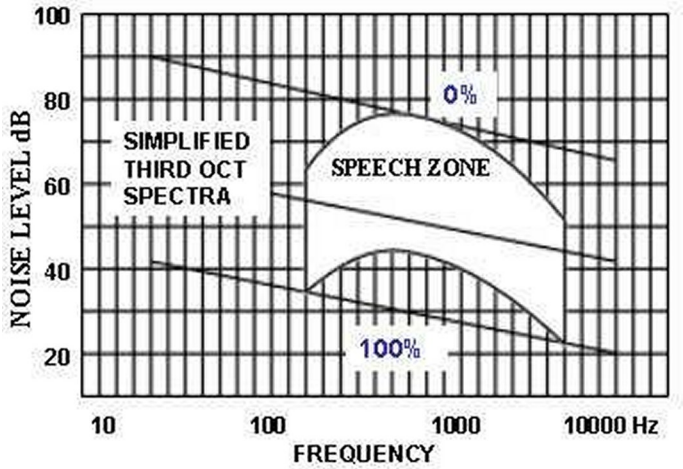

Figure 1: Graphical representation of normal speech level.

1/3 octave (Hz)	*200*	*250*	*315*	*400*	*500*	*630*	*800*	*1000*
Low limit dB	34	39	41	43	45	45	45	44
dB(A)	23.1	30.4	34.4	38.2	41.8	43.1	44.2	44.0
Weighting factor	1.0	2.0	3.25	4.25	4.5	5.25	6.5	7.25
1/3 octave (kHz)	*1.24*	*1.6*	*2.0*	*2.5*	*3.15*	*4.0*	*5.0*	*6.30*
Low limit dB	42	40	37	35	33	30	26	21
dB(A)	42.6	41	38.2	36.3	43.2	31	26.5	20.9
Weighting factor	8.5	11.5	11.0	9.5	9.0	7.75	6.25	2.5

Table 1: The limit values of AI & weighting factors.

3 - MEASUREMENT OF AI IN THE LAB

The measurement system is built using a sound level meter, B&K 2230 and a 1/3 octave band filter. Fig. 2 shows a flowchart of measurement of an articulation index.

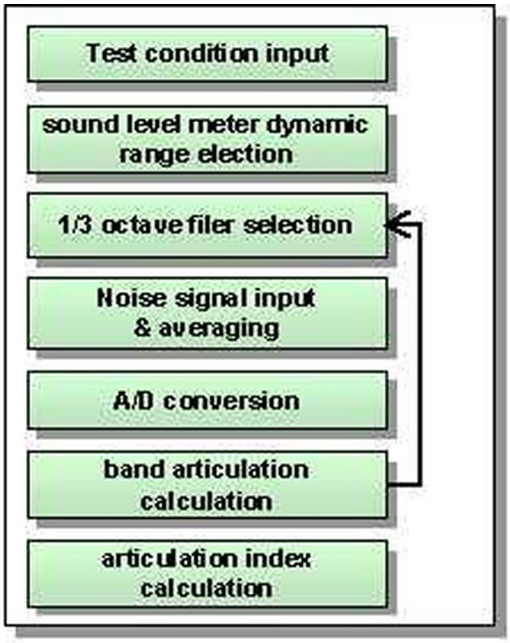

Figure 2: Measurement procedure of AI.

To measure the articulation index, the chassis dynamo was used to rotate the tyre. The microphone was located at the driver ear position. 12 different types of tyre were chosen as shown in Table 2. After

warming up the tires at the speed of 60km/h for 20 minutes, Articulation index were estimated at the speed of 100, 120, and 140 km/h from the measured sound pressure level in 1/3 band.

TEST TIRE	**SIZE**
A	175/70R13
B	P175/70R13
C	P175/70R13
D	175/70R13
E	175/70R13
F	185/60R14
G	185/60R14
H	185/60R14
I	175/70R13
J	175/70R13
K	185/60R14
L	185/60R14

Table 2: The test tyres and their size.

4 - AI RATING

From the measured results of articulation index, It was observed that there were a 10% different gap between the most superior tire and the most inferior tire, which was corresponding to 4 grades of subjective rating (table 3). When the driving speed increase from 100 km/h to 120 km/h, AI is reduced 10% on average and driving speed increase 120 km/h to 140 km/h, AI is reduced by 7.16% on average. For the correlation between subjective feeling and AI, AI rating is newly set up in the range of 0 to 10. Table 4 shows relationship between the AI and AI rating. When articulation index increased as much as 1.5%, AI rating increase by 0.5 rating. Table 5 and Fig 3 show relationship of AI rating and subjective rating. They show the good correlation.

TIRE	**100 km/h**	**120 km/h**	**140 km/h**	**feeling rating**
A	81.48	73.60	66.60	7.0
B	79.66	71.69	65.36	6.5
C	77.78	69.99	64.60	6.5
D	80.30	68.30	61.49	6.0
E	77.28	68.00	60.48	6.0
F	74.58	67.49	61.90	6.0
G	79.60	66.00	56.89	5.5
H	79.28	66.37	57.40	5.5
I	73.28	66.19	60.68	5.5
J	74.98	65.69	59.37	5.5
K	73.27	64.89	56.26	4.0
L	74.29	62.50	53.68	4.0

Table 3: Articulation index rating.

speed	AI & AI rating								
100km/h	70.5	72.0	73.5	75.0	76.5	78.0	79.5	81.0	82.5
120km/h	60.9	62.4	63.9	65.4	66.9	68.4	69.9	71.4	72.9
140km/h	53.7	55.2	56.7	58.2	59.7	61.2	62.7	64.2	65.7
rating	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	

Table 4: Relationship between articulation index and AI rating.

TIRE	100 km/h	120 km/h	140 km/h	feeling rating
A	7.50	8.00	8.00	7.00
B	7.00	7.50	7.50	6.50
C	6.00	7.00	7.50	6.50
D	7.00	6.00	6.50	6.0+
E	6.00	6.00	6.00	6.00
F	5.00	6.00	6.50	5.50
G	7.00	5.50	5.00	5.00
H	6.50	5.50	5.00	5.50
I	4.50	5.50	6.00	5.50
J	5.00	5.50	5.50	5.50
K	4.50	5.00	4.50	4.50
L	5.00	4.50	3.50	4.00

Table 5: Relationship between articulation index rating and feeling rating.

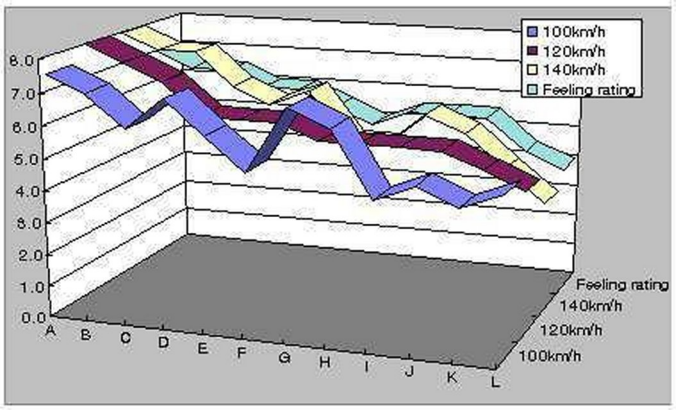

Figure 3:
A graph representing the correlation between feeling rate and AI.

5 - CONCLUSIONS

For the effective control of noise, it is required to find the relationship between objective measurement and subjective feeling rating. In this study, Articulation index rating is developed to correlated Lab noise test to subjective feeling. AI rating is set up in the range of 0 to 10 such as articulation index increased as much as 1.5%, AI rating increase by 0.5 rating. From the measurement results, AI rating in the Lab and subjective rating on the field are very good relationship and can be used to control of tyre noise quality improvement.

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