inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 7.9

IDENTIFICATION OF MOTORCYCLE INJECTOR NOISE BY SOUND QUALITY ANALYSIS

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Keywords:
SOUND QUALITY, BINAURAL ANALYSIS, IDLE ANNOYANCE

ABSTRACT
This paper focused on the identification of the frequency areas of a low sound pressure level but very annoying idle "Dya-Dya" noise of a motorcycle. The procedure of the sound quality analysis employed to solve this NVH problem was presented. We used a binaural analysis system, headphone playback system and spectrum analyzer to identify the idle noise. The measurement quantities included the injector surface vibration, near field and far field noise. By using the analysis techniques of artificial band-stop filter and spectrum comparison, we found that the major frequency of "Dya-Dya" was located above 4kHz. Further subjective assessment and objective data analysis verified that the proper insulation of injector could reduce the "Dya-Dya" sound, and it also revealed that the psychoacoustic sound quality "sharpness" was the main quality feature of injector idle noise.

1 - INTRODUCTION

Sound quality has become one of the major targets to assist in marketing and sales for vehicle industry. Therefore, the application of sound quality analysis at all phases of vehicle design stage is necessary and very important [1]. A perceivable injector noise during idle condition was reported for the new developed 125 c.c. injector motorcycle engine, which did not occur in the original carburetor engine. There is an NVH concern on this unpleasant injector sound of "Dya-Dya". This paper will focus on the identification of the frequency areas of this annoying sound and the procedure of the sound quality analysis employed.

2 - DIAGNOSIS PROCEDURES

2.1 - Objective

The objectives of this work are the identification of the unpleasant idle noise frequency of a target motorcycle by the subjective and objective sound quality evaluations and the proposal of the possible solutions.

2.2 - Diagnosis process

In order to investigate the difference of sound characteristics between injector and carburetor engine, we used the pair comparison approach. We denoted the motorcycle with injector engine as S2, whereas the other one with carburetor engine was denoted as S1. The first step is to measure the far field (around the rider's ear position) idle noise for two motorcycles. Then, we removed the seats, and measured the far field noises, injector or carburetor near field noises and injector or carburetor surface vibrations for S2 and S1. By comparing the sound characteristics' differences between S2 and S1, the potential candidates for the annoying idle noise "Dya-Dya" were roughly identified. After that, we emphasized our efforts on the subjective and objective sound evaluations for S2 only to further locate the major frequency of "Dya-Dya". During the subjective sound evaluation process for S2, we used the fiberglass and lead cladding to investigate the effects for sound absorption and insulation. For objective spectrum analysis, we used the artificial band-stop filter technique to identify the major frequency of annoying idle noise. In

this work, we also performed the sound quality parameter analysis to evaluate the main quality features of the annoying idle noise "Dya-Dya".

2.3 - Tests set-up

The instrumentation for this diagnosis included the sensors (microphones and accelerometers), the signal conditioners, a digital data recorder, a binaural analysis system, a headphone playback system and a spectrum analyzer. The measurement quantities included the injector surface vibration, near field and far field noise. The set-up for the far field and near field noise measurements for S2 (with seat removed) is shown in Figure 1. Figure 2 is a closed-up photo for the set-up of near field noise and injector surface vibration measurements of S2.

Figure 1: The set-up for the far field and near field noise measurements for S2.

Figure 2: The set-up for the near field noise and injector surface vibration measurements for S2.

3 - RESULTS AND DISCUSSION

3.1 - Near field noise and vibration spectra comparison of S2 and S1

As shown in Figure 3, with the seat removed, the near field noise spectra showed that the major sound pressure level difference for S2 and S1 occurring at 815Hz, 1752Hz and 4kHz∼5.3kHz. The surface vibrations of the injector (S2) and the carburetor (S1) were shown in Figure 4. By calculating the corresponding frequency for the idle engine speed, it was found that the dominant peaks in the vibration spectra were first order for both S2 and S1. However, comparing Figure 3 and Figure 4, it was concluded that there were no link between the near field noise and surface vibration, and it was thought that the idle noise was not caused by surface vibration of the injector or carburetor.

3.2 - Investigation of effects of noise absorption/insulation of S2

The fiberglass and lead were used to clad the injector. Figure 5 showed the effects of noise absorption/insulation on the near field injector noise. The spectra showed that there were an apparent noise reduction at 4.5kHz∼5.3kHz for applying the noise absorption/insulation. Besides, the results of subjective assessment confirmed that the annoying idle "Dya-Dya" noise was effectively suppressed by cladding the injector.

3.3 - Binaural analysis and band stop filter technique applied to S2

To further confirm the frequency range of the annoying idle "Dya-Dya" noise of S2, We used an artificial band stop filter built inside the binaural analysis system. We set the lower and upper cut-off frequencies

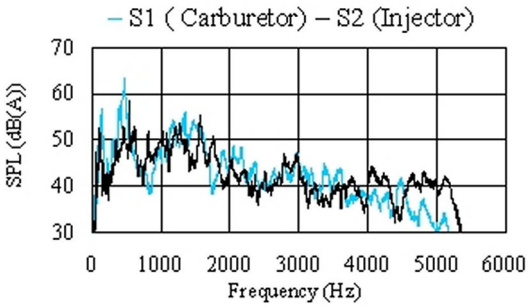

Figure 3: Near field noise spectra comparison of S1 and S2 with seats removed.

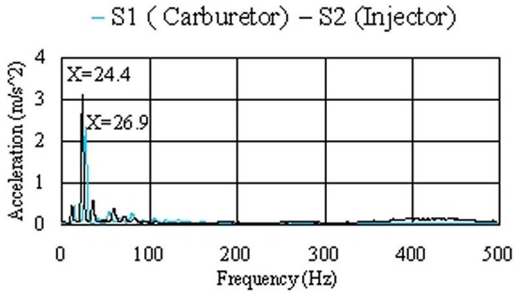

Figure 4: The surface vibration spectra of injector of S2 and the carburetor of S1.

of band stop filter as 4200Hz and 6250Hz, respectively. The headphone playback system was used to playback the filtered near field injector noise after band stop filter. By subjective evaluation, it was found that the "Dya-Dya" noise was removed.

3.4 - Far field noise spectra comparison of S2 and S1

Although, at the first sight, it seems that the dominant frequencies of far field noise of S2 and S1 occurring below 1200Hz. Those frequencies were proven later not correlated with the annoying "Dya-Dya" noise. Figure 6 shows the comparison of far field noises of S2 and S1 above 3kHz. It was found that there was an obvious difference between two spectra above 4kHz, although the sound pressure level was very low (below 30 dB(A)). After the binaural analysis and band stop filter technique, it was confirmed that the low-level noise above 4kHz was responsible for the idle annoyance.

3.5 - Objective sound quality parameter analysis

We used the binaural analysis system to perform the sound quality parameter analysis, and the results for near filed noise were shown in Table 1. Although the sound pressure level (L) and loudness (N) [2] of S2 were lower than those of S1 were, it was found that the sharpness (S) of S2 was 21% higher than that of S1. After fiberglass and lead cladding of S2, the sharpness was improved, and it was only 2% higher than that of S1 was. Using the artificial band stop filter to simulate the effects of noise absorption/insulation, it was found that the improvement of sharpness was 14%. Table 1 also shows the results for far field noise. It was found that the sharpness of S2 was originally 5% higher than that of S1. After band stop filter, the sharpness of S2 was 1.4% lower than that of S1. Also shown in Table 1, although the roughness (RGH) and impulsivity (IMP) of near field noise of S2 were improved by insulation or band stop filter, there was no improvement on the far field noise. From the results, it was concluded that the sharpness was the main sound quality feature of injector idle noise.

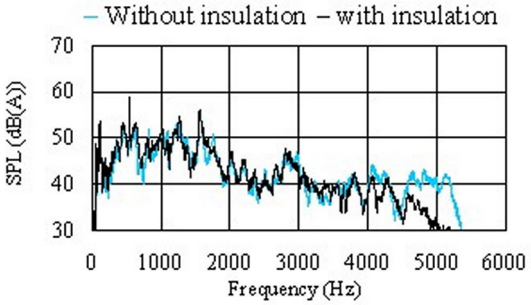

Figure 5: The effect of noise absorption/insulation on the near field injector noise of S2.

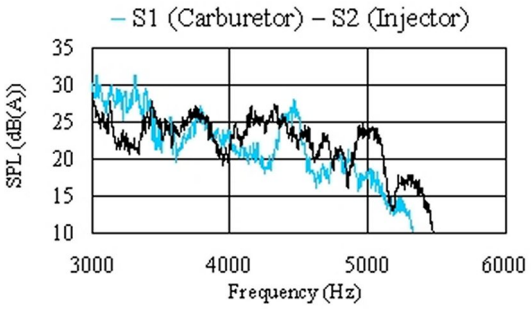

Figure 6: Far field noise spectra comparison of S1 and S2 above 3kHz, with seats removed.

		L dB(A)	N soneGF	S acum	TON tu	RGH as-per	FLS vacil	PRM dB	IMP iu
Near field noise of carburetor (S1) or injector (S2)	S1 without insulation	77.9	44.8	2.58	0.022	3.17	2.15	8.7	0.541
	S2 without insulation	75.9	41.1	3.13	0.028	4.15	2.23	6.9	1.29
	S2 with insulation	76.2	40.4	2.64	0.029	3.33	2.21	6.0	0.766
	S2 with band stop filter (cut-off freq. are 4200Hz & 6250Hz)	75.5	38.9	2.68	0.029	3.60	2.20	6.0	1.13
Far field noise (around rider's ear height)	S1 without insulation	63.3	18.2	1.48	0.024	0.596	1.65	6.7	0.372
	S2 without insulation	62.8	17.8	1.56	0.027	0.662	1.65	5.1	0.423
	S2 with band stop filter (cut-off freq. are 4200Hz & 6250Hz)	62.8	17.4	1.46	0.027	0.658	1.61	5.1	0.421

Table 1: The results of sound quality parameter analysis.

4 - CONCLUSION

By using the analysis techniques of artificial band-stop filter and spectrum comparison, we found that the major frequency of annoying idle noise "Dya-Dya" was located above 4kHz. Further subjective assessment and objective data analysis verified that the proper insulation of injector could effectively suppress the "Dya-Dya" sound, and it also revealed that the psychoacoustic sound quality "sharpness" was the main quality feature of injector idle noise. Based on the analysis results, the possible countermeasures were proposed to improve the injector sound quality in the next development stage.

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