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Sound Quality Enhancement with Exhaust Manifold and Hot-End Structure Optimization on H8 Engine Systems

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Abstract

Idle sound quality for motorcycles is very important to the customers [1,2]. People would like to have a strong individualized sound in idle, linear and smooth sound in the driving condition. Since the idle fluctuation noise is based on the engine firing sequence, the exhaust manifold structure and the idle frequency eight or six cylinders engine are really hard to get a real good fluctuated tailpipe sound in the idle condition compared to the two or three cylinders engines. However, some surrogate methodology can be applied to these engines. Based on the noise cancellation process in amplitude and phase in the exhaust manifold system, engineers can manipulate the noise with several lower peaks, and the other higher peaks can be perceived by the masking effect in the time domain. In this scenario, people only feel the big noise fluctuation peaks, even the smaller peaks are still there in the background. In addition, waves can be further improved by the Hot-End structure. The structure could provide more opportunities to separate and cancel the waves in the duct system by phase. In this paper, a special case is presented by these methodologies and techniques. An eight-cylinder horizontal engine with an uneven firing sequence makes very irregular tailpipe noise in the idle condition originally. By optimizing the exhaust manifold structures in shapes and lengths by the DOE method, and also applying the new H Type Hot-End structure with the active-controlled valve in the middle of the connecting pipe, the tailpipe noise is finally optimized successfully. Good idle impulsiveness and less half-orders tone in running up can be achieved simultaneously with these techniques.

Introduction

Impulsiveness is a kind of sound quality that describes the noise pulsation characteristics in the time domain. A good impulsive sound should have clear peaks, such as "Kong-Kong-Kong…. or Dong-Dong-Dong……" while you hear it. Compared to the two or three cylinders engines, eight-cylinders engines are even hard to achieve a good impulsiveness performance. The reason is that the tailpipe noise comes from the wave's summation in the exhaust duct system and the peak occurrence timings are controlled by the combustion frequency. For an eight-cylinder engine, its combustion frequency is four times faster than the two cylinders engine in idle condition. That means the pressure peaks occur 4 times more than the two cylinders engine in the same time period. That DNA drives the complexity to engineers to manage a good impulsiveness performance to the eight-cylinders engine for the idle sound quality. The other issue that affects impulsiveness performance is the firing sequence. That affects the timing of each wave that reaches the sum point in the duct system. A good firing sequence can effectively offset the pressure wave in the duct systems [3] by offsetting the amplitude and phase in different ducts that noise can be amplified or attenuated by the phase shift. The exhaust manifold optimization in geometry could improve the wave summation by manipulating the wave's amplitude and phase while it gets to the joining points [4]. It is discussed that exhaust manifold optimizations on a V6 engine that pursue enhanced impulsiveness by their subjective evaluation matrix [5, 6]. These improvements are based on the wave amplitude and phase summation principle that depends on the duct shapes variation and the length difference. The other way of noise improvement on noise frequency components is to mix the wave pressures between left and right banks while it gets into the exhaust Hot-End structure. The waves from the left and right banks can be canceled by the noise from the other side by the phase. In this paper, due to the H8 engine's odd firing sequence, the original pressure peaks are very chaotic in the duct system that is hard to give you a clear impulsiveness feeling in the idle condition and also hard to provide a clear tone in the running-up condition. Thus, the goal of this paper is to build a smooth vehicle with a special impulsive idle quality and fewer half-orders sound in the running.

TABLE 5 DOE Result of Setup #2

DOE Pipe 1357(mm)	*Cylinder 1*		*Cylinder 3*		*Cylinder 5*		*Cylinder 7*	
	d11	*d12*	*d31*	*d32*	*d51*	*d52*	*d71*	*d72*
Baseline	29		29		29		29	
DOE-Best	26.9733	32.9773	29.7311	31.2334	28.047	29.3358	32.6847	27.5566
Engineering 29-1	27	33	30	31.5	28	29.5	33	27.5
Engineering 29-2	27	33	30	31.5	28	29.5	32.5	28
DOE Pipe 2468(mm)	*Cylinder 2*		*Cylinder 4*		*Cylinder 6*		*Cylinder 8*	
	d21	*d22*	*d41*	*d42*	*d61*	*d62*	*d81*	*d82*
Baseline	29		29		29		29	
DOE-Best	27.1782	32.2884	30.382	26.6233	30.8273	30.5143	32.8886	32.4959
Engineering 29-1	27.5	32.5	30.5	27	31	30.5	33	32.5
Engineering 29-2	27.5	32.5	30.5	27	30.5	30.5	32.5	32.5

FIGURE 21 Baseline vs. Final Optimization Result in the Idle Condition

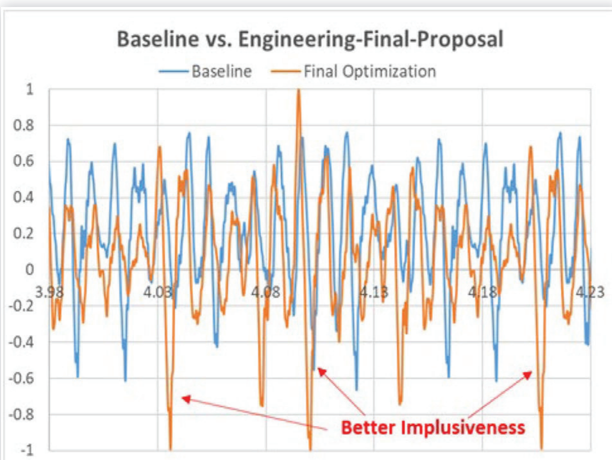
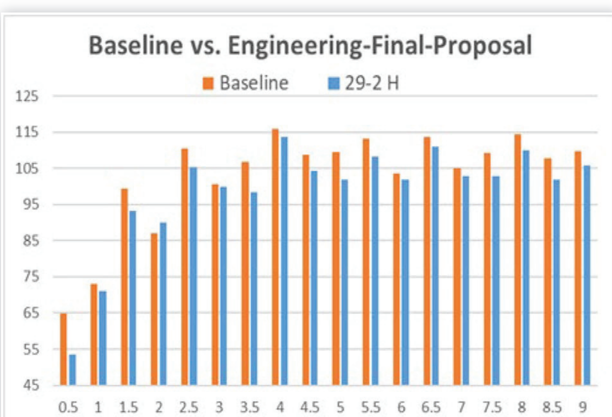


FIGURE 22 Baseline vs. Final Optimization Result in the Running-Up Condition



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There is no hesitation to answer your question. Thank you very much.

Definition and Abbreviation

DOE - Design of Experiment
DRE - Design Release Engineer
H6 - Horizontal Six-Cylinder Engine
H8 - Horizontal Eight-cylinder Engine
$\mathbf{P_r}$ - Rotational Inertial Force
$\mathbf{P_j}$ - Reciprocal Inertial Force
L - Rod Length
α - Crankshaft Angle
DNA - Deoxyribonucleic Acid
GT - GT Power

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