VIBRATION

AND

PEAK VU ANALYSIS

ON

CATERPILLAR ENGINE

AT

ANALYTICAL ENGINEERING, INC

FOR

[redacted]

MASON, OH

17 JULY 2002

PREPARED BY:

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Introduction:

ARC Associates (ARC) was contacted to monitor the vibration on a Caterpillar engine at various speeds and loads before and after the introduction of a catalyst designed to improve engine performance. The purpose of ARC's portion of the test was to determine whether the introduction of the catalyst had an effect on the engine vibration.

The engine was instrumented and mounted in a test cell at Analytical Engineering, Inc., Columbus, IN. The load was provided by an electric DC dynamometer direct coupled to the engine.

Instrumentation:

In addition to the typical engine monitors provided by Analytical Engineering, the following instrumentation was used to collect the vibration data:

PCB Velocity transducers
PCB Accelerometers
MM Magnetic Proximity transducer
Caterpillar Torsional Demodulator
Sony PC208 Digital Data Recorder
CSI Model 2120 Data Collector
CSI Wavepak Two Channel Spectrum Analyzer
ARC Tach Signal Generator
Associated Power Supplies, cables, magnets, etc.

Data Collection:

Velocity vibration transducers were mounted in the horizontal and vertical directions at the front and the rear of the engine. In addition, one axial velocity measurement was taken at the front of the engine and vertical acceleration and high frequency peak hold measurements were made on the engine block at the number one cylinder.

The magnetic proximity transducer was mounted in the engine bell housing to sense the teeth on the engine ring gear. This pulse train was then frequency de-modulated to determine the torsional vibration.

All data was recorded using the Sony digital data recorder.

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1200 RPM - 25%

	OVERALL				THIRD ORDER			
LOCATION	NO CAT	W/CAT	DIFF	%	NO CAT	W/CAT	DIFF	%
EFH	0.270	0.261	0.009	3.333	0.146	0.125	0.021	14.384
EA	0.224	0.232	-0.008	-3.571	0.018	0.020	-0.002	-11.111
EFV	0.354	0.351	0.003	0.847	0.042	0.025	0.017	40.476
ERH	0.312	0.279	0.033	10.577	0.055	0.049	0.006	10.909
ERV-RT	0.407	0.416	-0.009	-2.211	0.113	0.097	0.016	14.159
ERV-LFT	0.388	0.390	-0.002	-0.515	0.079	0.066	0.013	16.456
BLOCK V	2.727	2.634	0.093	3.410	0.037	0.029	0.008	21.622
TORSION	0.086	0.083	0.003	3.488	0.054	0.055	-0.001	-1.852
TOTAL	1.955	1.929	0.026	1.330	0.453	0.382	0.071	15.673

A review of the vibration energy in the these tables at the engine speeds and loads of the test show that except for a few anomalies in the data, there was a reduction in engine vibration at all engine speeds and loads after the catalyst injection.

The AEI instrumentation indicated an increase in engine torque and horsepower after the injection of the catalyst. The third order vibration in a six cylinder, four stroke engine would normally increase with an increase in engine horsepower. However, the greatest reduction in engine vibration energy occurred at the third order of engine speed. This could be due either to more even fuel consumption or a longer burn in the power stroke.

The overall torsional vibration was dominated by the half order torsional resonance at engine speeds above 1600 RPM. However, the half order torsional was not the energy of interest in this test.

The third order torsional changed very little, or not at all, after the catalyst injection. With an increase in torque and horsepower after injection it appears that the expected increase in third order torsional was off set by something in the engine power stroke.

The following table is a summary of the vibration energy totals at each speed and load and also lists the grand total vibration energy summary for the entire test.

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SPEED	OVERALL				THIRD ORDER			
LOAD	NO CAT	CAT	DIFF	%	NO CAT	CAT	DIFF	%
1200 - 25	3.055	2.822	0.233	7.627	1.768	1.510	0.258	14.593
1200-50	2.447	2.196	0.251	10.257	0.986	0.908	0.078	7.911
1200-75	3.055	2.822	0.233	7.627	1.768	1.510	0.258	14.593
1200-100	4.169	3.201	0.968	23.219	2.722	1.521	1.201	44.122
1400-25	2.326	2.368	-0.042	-1.806	0.286	0.272	0.014	4.895
1400-50	2.374	2.258	0.116	4.886	0.707	0.511	0.196	27.723
1400-75	2.736	2.576	0.160	5.848	1.068	0.805	0.263	24.625
1400-100	3.696	3.163	0.533	14.421	2.248	1.582	0.666	29.626
1600-25	3.142	3.010	0.132	4.201	0.575	0.590	-0.015	-2.609
1600-50	3.140	3.068	0.072	2.293	0.513	0.482	0.031	6.043
1600-75	3.686	3.350	0.336	9.116	0.994	0.948	0.046	4.628
1600-100	4.419	4.152	0.267	6.042	1.456	1.324	0.132	9.066
1800-25	2.844	2.870	-0.026	-0.914	0.923	0.894	0.029	3.142
1800-50	3.182	2.888	0.294	9.239	0.702	0.568	0.134	19.088
1800-75	3.363	3.282	0.081	2.409	0.767	0.731	0.036	4.694
1800-100	4.230	3.958	0.272	6.430	1.030	0.889	0.141	13.689
1900-25	3.055	2.959	0.096	3.142	1.086	1.014	0.072	6.630
1900-50	3.432	2.966	0.466	13.578	0.831	0.702	0.129	15.523
1900-75	3.718	3.716	0.002	0.054	0.774	0.730	0.044	5.685
1900-100	4.088	3.949	0.139	3.400	0.934	0.885	0.049	5.246
TOT ALL	66.157	61.574	4.583	6.927	22.138	18.376	3.762	16.993

The total overall vibration energy taken at all engine speeds and loads was reduced by 7% and the total third order vibration energy taken at all engine speeds and loads was reduced by 17% as a result of the catalyst injection.

In addition to the low frequency velocity energy peak acceleration value data was also taken at each engine speed and load. In this case the low frequency energy is removed by a high pass filter and the incoming data is sampled at a high sampling rate. The peak accelerations and their repetition rate are captured and recorded.

High frequency accelerations are caused by metal stressing, rubbing, gas or fluid flow, high pressure leaks, etc. In the case of an internal combustion engine the most likely cause would be the normal flow of fuel mixture and exhaust gases through the valves.

Associates

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Engine faults such as blow by or scuffing of the cylinder wall would also show up in the high frequency acceleration data. However, for this test it can be concluded that if a fault were present in an engine cylinder it would result in the same data both before and after catalyst injection.

The following table lists the peak acceleration energy values both before and after catalyst injection as well as the difference in magnitude and percent:

ENGINE		PEAK VALUE			
SPEED	LOAD	BEFORE	AFTER	DIFF	%
1900.00	100.00	3.05	3.91	0.86	28.20
1900.00	75.00	3.42	4.68	1.26	36.84
1900.00	50.00	3.76	6.33	2.57	68.35
1900.00	25.00	4.36	4.66	0.30	6.88
1800.00	100.00	2.94	4.31	1.37	46.60
1800.00	75.00	2.45	3.76	1.31	53.47
1800.00	50.00	3.41	4.31	0.90	26.39
1800.00	25.00	4.51	5.40	0.89	19.73
1600.00	100.00	2.19	2.66	0.47	21.46
1600.00	75.00	2.27	2.43	0.16	7.05
1600.00	50.00	2.63	4.58	1.95	74.14
1600.00	25.00	3.37	4.29	0.92	27.30
1400.00	100.00	1.89	2.66	0.77	40.74
1400.00	75.00	2.21	2.21	0.00	0.00
1400.00	50.00	2.84	3.84	1.00	35.21
1400.00	25.00	2.65	4.47	1.82	68.68
1200.00	100.00	2.13	1.86	-0.27	-12.68
1200.00	75.00	1.87	2.26	0.39	20.86
1200.00	50.00	2.57	2.88	0.31	12.06
1200.00	25.00	2.57	3.88	1.31	50.97
	TOTAL	57.09	75.38	18.29	32.04

In all cases there was an increase in peak value data after catalyst injection. The overall increase for all peak value data was 32 percent. This increase in energy is apparently due to increase fuel and exhaust flow through the engine valves.

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Conclusions:

1. AEI test cell instrumentation indicated a modest increase in engine horsepower at maximum speed and torque after catalyst injection.

2. The total overall engine vibration energy was reduced by 7% after catalyst injection.

3. The third order engine vibration energy was reduced by 17% after catalyst injection.

4. The high frequency acceleration peak energy increased by 32% after catalyst injection indicating an increase in energy in the engine cylinder.

5. The catalyst injection clearly reduced the vibration energy present in the engine.