

Development of Engine Rock Dampers for the Manual Transmission 2003 Acura 3.2CL Type-S

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ABSTRACT

Engine mount development for the manual transmission 2003 3.2 CL Type-S included the use of engine rock dampers, a new technology for Honda. A damper mounted between the engine and subframe with isolation rubber to control engine-roll motion was developed as a countermeasure to improve shock hunt. Engine rock dampers are found to be an effective means of controlling engine roll stiffness for transient torque input. Shock hunt targets are achieved, sports coupe drivability is maintained, and marketable noise and vibration levels are preserved.

要 旨

アキュラ CL Type-S において、走り感を損なわず、加減速ショックハンティング性能を向上させる目的で、エンジンロックダンパーシステムを開発した。このシステムは、エンジン、サブフレーム間に防振処理をしたメカニカルダンパーを追加することにより、エンジンからの過渡大入力時のロール剛性をコントロールすることが出来るため、CLのスポーツコンセプトに求められるソリッド感を NVH 性能を犠牲にすることなく実現した。

1. Introduction

The goal of the mount development for this vehicle was to achieve a marketable throttle tip-in acceleration feeling without compromising the drivability expectations of the sporty coupe driver. Shock hunt describes the undesirable acceleration feeling upon throttle tip-in. These phenomena would be commonly described as jerkiness under acceleration. The initial jerk after applying the throttle is shock. The 'back and forth' feeling after the shock is hunting. Generally the primary engine mount technical concern for front-engine front-drive manual transmission vehicles is shock hunt.

The 3.2CL presented very difficult challenges from a shock hunt standpoint. The powertrain generates 232 lb-ft of torque, more than any other Honda with a manual transmission. Drivetrain layout, front drive with a transverse front engine, is fundamentally weak for shock hunt. Reducing shock hunt levels imparts the vehicle with a stable and secure feeling under acceleration.

This report will detail the development of engine rock dampers as part of an engine mount system that is compatible for shock hunt as well as noise and vibration.

2. Shock Hunt Mechanism

The shock hunt time history data below (Fig. 1) shows the longitudinal acceleration experienced upon abrupt and heavy throttle application. Average acceleration is the rate of the vehicle acceleration forward. Overshoot equals the difference between peak acceleration and average acceleration. Overshoot describes shock. Hunting is the sinusoid portion of the acceleration time history as it decays to steady state.

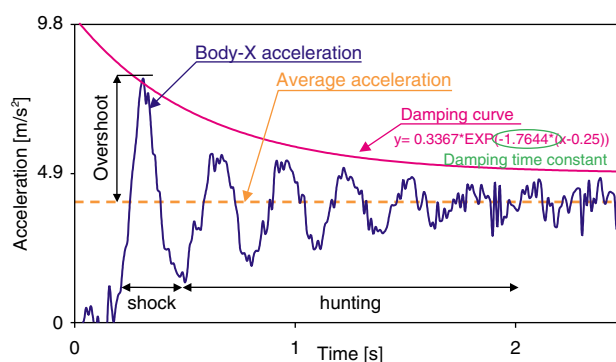


Fig. 1 Shock hunt acceleration time history

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The main cause of shock hunt is the powertrain 1st order torsional resonance. As the simplified model below illustrates (see Fig. 2), the primary springs for this system are the driveshaft, clutch spring, and engine mounts. Important masses include engine mass and flywheel inertia. The input for this system is transient engine torque. If the mounts have nonlinear characteristics, the engine roll resonance, and sometimes the suspensions unsprung resonance can also contribute to shock.⁽¹⁾

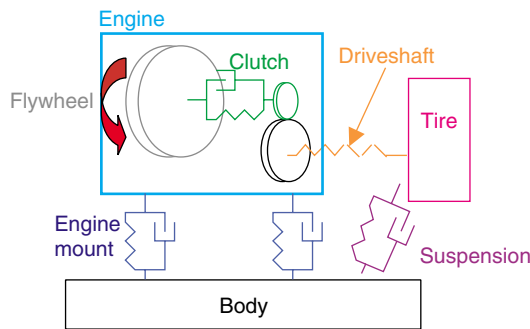


Fig. 2 Simple powertrain model for shock hunt

Generally the primary shock hunt concern is coupling of engine front to back motion and powertrain torsional resonance. The frequencies of engine roll and suspension resonances are higher than powertrain 1st order, but their effect can be seen in multiple peaks within the main shock peak. Figure 3 shows the typical frequency ranges of areas important for shock hunt.

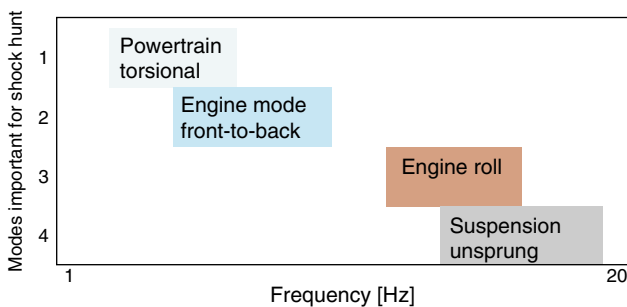


Fig. 3 Shock hunt primary and secondary modes

For the 3.2CL engine roll stiffness is very important. Since engine torque is high, drive reaction force at the mounts are much larger than a typical car. Therefore, it is very important to control roll stiffness with engine mounts.

3. Typical Shock Hunt Countermeasures

Typical shock hunt countermeasures can be broadly grouped into three categories: software, powertrain, and chassis. Software countermeasures include ignition retard and throttle response control. Relying on software to meet shock hunt targets would result in a vehicle that

feels sluggish. Other countermeasures offered a better compromise for 3.2CL Type-S sporty image.

On the powertrain side, the 3.2 CL applied a dual mass flywheel. This imparted the vehicle with a very flat clutch-spring characteristic, which is a good direction for shock hunt. The negative of the dual mass flywheel is lighter engine-side mass as compared to a conventional flywheel. Increasing the mass of a conventional flywheel reduces shock hunt level, but can result in a vehicle that feels slow to respond.

Finally, chassis countermeasures, including engine mount stiffness, damping, and stopper characteristic tuning are available to control shock hunt. Mount characteristics are especially important if the engine roll mode is contributing to shock. Increasing engine mount stiffness reduces powertrain peak acceleration and also helps keep the movement within the linear segment of the mount's stiffness characteristic (see Fig. 4). However, increased mount stiffness also reduces isolation between the engine and body, resulting in higher noise and vibration levels. Mount damping can also be used to diffuse shock hunt, but effectiveness is limited. Increasing damping is basically limited to changing material, typically up to 10% due to other engine constraints.

Stopper characteristic tuning is important if the mount is contacting its stopper in the shock hunt driving mode, targeting smooth and linear engagement.

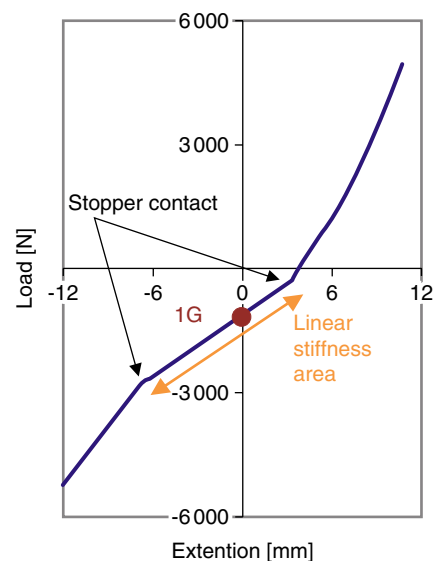


Fig. 4 Engine mount and stopper characteristic

Every countermeasure has tradeoffs. A new chassis countermeasure to improve shock hunt was required. To maintain sports car image a limited, reliance on ignition retard and minimizing flywheel inertia were important for this vehicle. Therefore, the 3.2CL applied a new chassis countermeasure to meet shock hunt targets.

4. New Shock Hunt Countermeasure

Engine rock dampers offer the opportunity to dramatically increase stiffness and damping in a dynamic

event while maintaining relatively low stiffness under conditions where engine movement and velocity are small. Of the typical shock hunt countermeasures, only increasing powertrain roll stiffness would maintain the vehicles sporty character and have enough impact to meet shock hunt target. However, in order to maintain noise and vibration performance, the engine mount system could not be stiffened sufficiently by conventional means to meet the shock hunt target. Therefore, engine rock dampers were considered as a new countermeasure. The engine rock damper is a dashpot/absorber mounted between the engine and subframe (see Fig. 5).

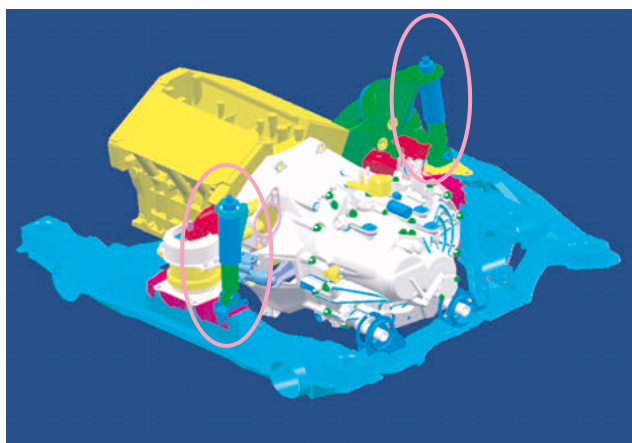


Fig. 5 3.2CL engine mount layout

The engine rock damper (Fig. 6) consists of a soft upper bushing which sandwiches a bracket attached to the engine. Engine movement compresses the upper bushing and displaces the damper piston. The lower bushing is very stiff and experiences little deflection. This construction is very advantageous for 3.2 CL application. At shock hunt driving mode, the damper experiences large displacement at approximately 3 Hz where damping force is high. Under steady-state conditions, the damper is not moving and the relatively soft upper bushing offers isolation.

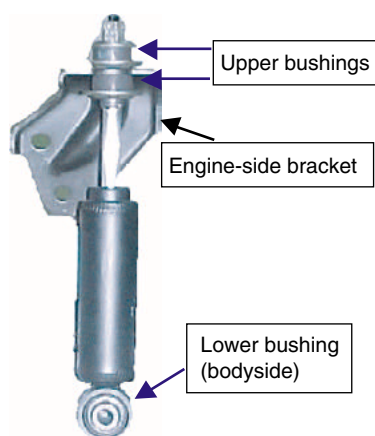


Fig. 6 Engine rock damper

In a dynamic event with large gross engine displacement, engine rock dampers provide additional stiffness to the engine mount system. Fig. 7 shows the load borne by the rock damper peaks 0.03 seconds before that of the engine mount. The rock damper distributes the shock to the body over a longer period than conventional engine mounts. This smooths the peak acceleration experienced by the body.

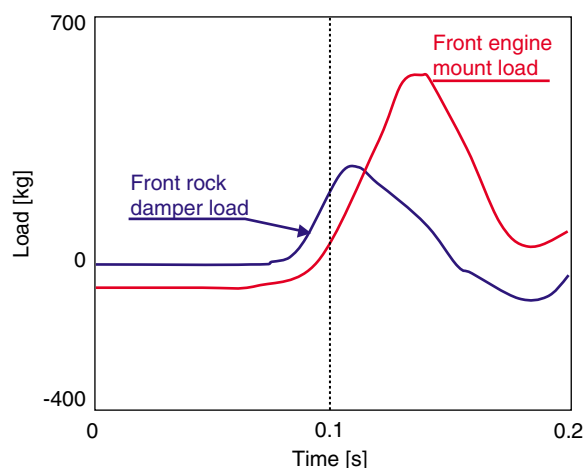


Fig. 7 Rock damper and engine mount loads in shock

The damping characteristic, not including the upper bushing has the shape seen in Fig. 8. Positive damping force is bump, or compression. The plot illustrates the peak damping force value for each velocity. At lower piston velocities, and for those in the shock hunt driving mode, bump and rebound have similar stiffness characteristics. Over 200 mm/s stiffness in bump remains flat, while stiffness in rebound continues to increase. However, this is outside of the shock hunt driving mode.



Fig. 8 Rock damper damping force

Rock dampers offer a large increase in stiffness and damping of the engine mount system in engine dynamic events, like shock hunt. When the rock damper piston is not moving, static friction effectively makes the damper rigid. The upper bushing affords isolation between the engine and the body.

5. Shock Hunt Result

Using engine rock dampers, engine dynamic roll stiffness and damping were increased to meet shock hunt targets. Peak body acceleration was reduced by 25%. Target of 3 [m/s²] overshoot for shock and -1.6 hunting time constant was achieved (see Fig. 9 and 10). Adding rock dampers increased peak dynamic roll stiffness of the engine mount system 45% in shock. In hunting, dynamic roll stiffness is increased approximately 30%.

Below on the shock judgment chart (Fig. 9), the vertical axis is overshoot, the height of the first peak over average acceleration. The vertical axis on the hunting chart (Fig. 10) is the time constant of an exponential curve fit to the hunting peaks (see Fig. 1).

Rock dampers increase powertrain transient natural frequency by 5%, from 3.25 to 3.42Hz. Steady-state movement does not change. Peak overshoot movement is reduced 45%. See Fig. 11. Rock dampers are velocity devices and have little static stiffness. Final engine position under acceleration does not change, but transient movement is reduced. Stiffness of the rock damper in shock is very high due to high engine velocity.

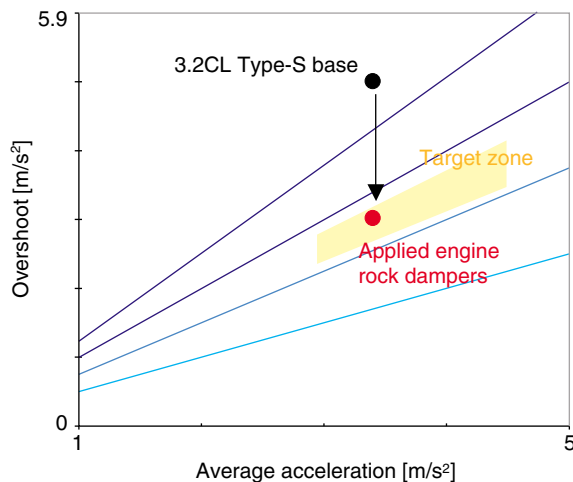


Fig. 9 Shock judgment chart - 2nd gear WOT

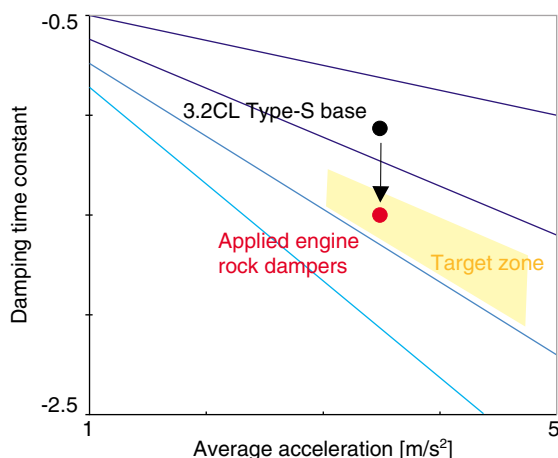


Fig. 10 Hunting judgment chart - 2nd gear WOT

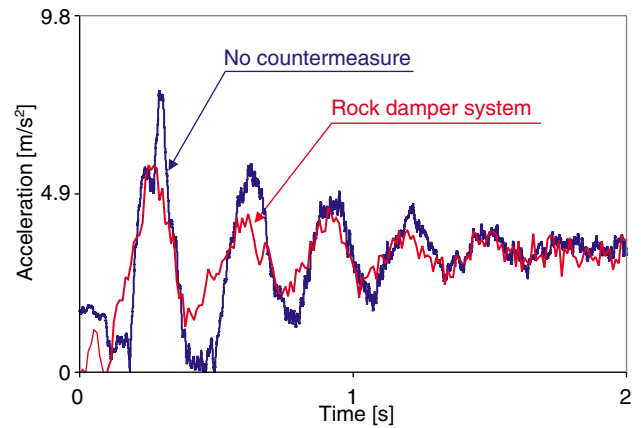


Fig. 11 No countermeasure vs. rock damper system shock hunt time history

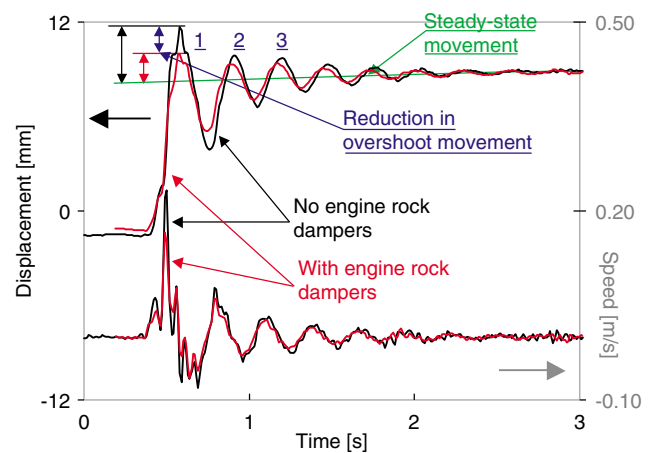


Fig. 12 Rock damper displacement and velocity - 2nd gear WOT

Rock dampers add roll stiffness and damping to engine mount system in dynamic events. Applying engine rock dampers reduces engine overshoot movement. Fig. 12 shows the effect of rock dampers on the first three cycles of engine overshoot movement. Fig. 13 expresses the reduction in movement for the first three cycles as a percent increase in stiffness. The percent increase in stiffness for each point is plotted against roll frequency. Roll frequency for each cycle is analyzed from measured data using the inverse of time from peak-to-valley divided by two.

In shock, engine mount dynamic roll stiffness is increased 45% by adding engine rock dampers (Fig. 13). Damping force drops off as engine movement slows down and damper displacement is reduced. At steady state, when the rock damper is no longer moving, static friction locks the damper and the upper bushings alone contribute to mount system stiffness.

To achieve shock hunt target, the 3.2CL requires a rock damper rate of 1500N at 120 mm/s (see Fig. 14).

Although roll stiffness is significantly higher in a dynamic event; any increase in static stiffness in steady-state conditions comes only from the upper bushing. Shock hunt body acceleration levels experienced by the driver achieve targets.

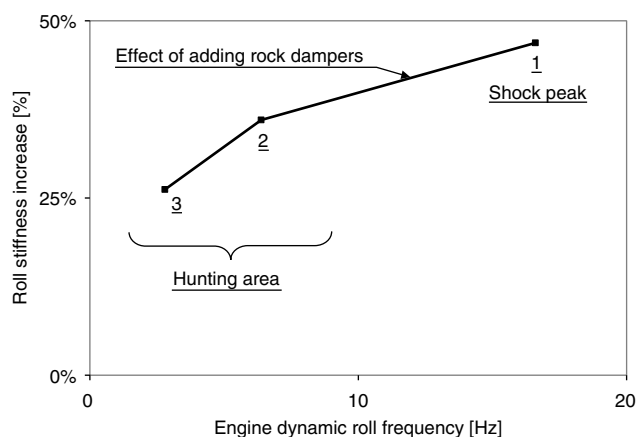


Fig. 13 Dynamic stiffness increase to engine mount system by adding rock dampers

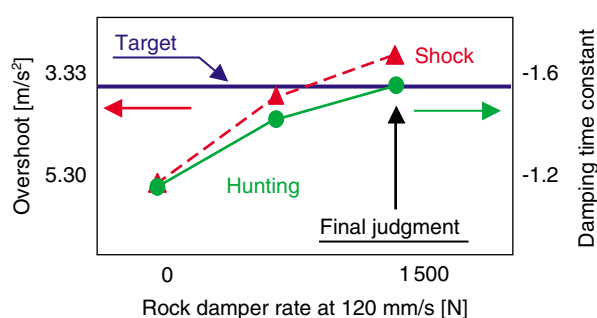


Fig. 14 Rock damper rate effect

6. Engine Rock Damper Tradeoffs

6.1. Idle Vibration

Idle vibration in the seat and steering wheel is heavily influenced by the engine roll mode in vehicles with V6 engines. Rock dampers reduce isolation between engine and body by 4dB. The 3.2CL required additional countermeasures for idle noise and vibration. Sporty car idle targets were achieved with the following countermeasures: bumper beam dynamic damper, idle engine speed increase to 790rpm, and tuning of steering dynamic damper. See Fig. 15.

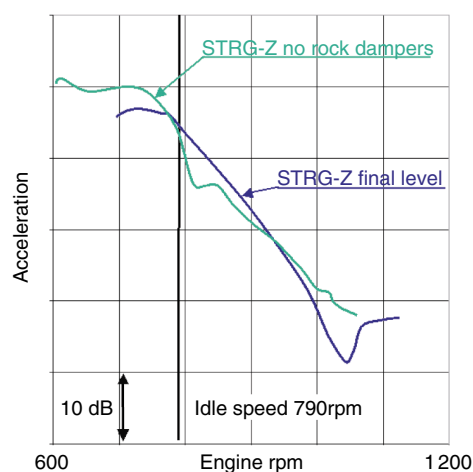


Fig. 15 3rd order steering vibration

6.2. Engine Noise

Engine noise during acceleration increased throughout the engine speed range but no bad feeling peaks were created. The increase in noise was judged acceptable for a sporty car.

7. Conclusion

Rock dampers are very effective countermeasure for shock hunt. Rock dampers are able to provide a significant increase in engine roll stiffness in a dynamic event while remaining relatively soft at steady state. Shock hunt acceleration levels experienced by the driver are reduced to meet targets. Acura 3.2CL Type-S shock hunt feeling improved to an acceptable level by applying engine rock dampers without compromising drivability expectations of the sporty car driver. Marketable noise and vibration levels are preserved.

Reference

- (1) Inoue, M.: "Analysis on Acceleration / Deceleration Shock and Vibration in FF Vehicle", Proceedings Journal of Society of Automotive Engineers of Japan 921087 (1992)

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