Spec Miata 4-Post Shaker Validation

Test Details

Sweep Profile: 100, 150, 200mm/sec constant peak velocity heave sine sweep
(200mm/sec profile used for metrics analysis)
.25-16Hz at .15Hz/sec

Track Data: VIR Recorded data on 9/26/2018
Run 10 Lap 2 24SM NB (second afternoon outing). No drafting

Lap Time: 2:19:00

Tires: Hoosier SM8

Driver: Joel Miller

Add'l Notes: The NB chassis (24SM) had a front body accelerometer issue that skewed some body response values. Body response results for the NB are comparable against itself, but not against the other chassis.

Vehicle Setup

Weights: Each car setup at 50% cross at minimum legal weight (or minimum achievable)

Driver Weights: Standard driver weight of 180lbs, increased to 220lbs and decreased to 160lbs

Ride Heights: Ride heights set up by distance from center of bottom shock bolt to the top of ` the ride height adjuster nut, where the bottom of the spring sits
Ride height based upon the heights tested at VIR on 9/26/18
Ride height for each vehicle was set as below, then adjusted equally for wedge

LF 10-3/16”	RF 10”
LR 6-1/16”	RR 5-7/8”

Project Goals

Throughout the development process, the goals of a new Spec Miata package were clearly defined:

- Improve handling and overall performance by increasing mechanical grip and providing a more stable and forgiving damper package
- Decrease reliance upon bump stops to decrease suspension component damage & wear, decrease edginess in handling and decrease sensitivity to vehicle setup heights
- Remove potential advantages found in decreased ride heights and greater utilization of the bump stops

- Deliver a dynamic package that was flexible rather than optimized to any one track, while leaving racers room to develop their own setup packages
- Provide the highest level of parity between NA, NB1 and NB2 platforms

As defined by these goals, the purpose was specifically not to create a package that favored any sort of track or driver, or to inherently attempt to decrease lap times. In addition, the package should not obsolete existing vehicle setups, but it also should not limit the teams' ability in any way to apply their knowledge and experience to improve upon their cars through on track testing, adjustment and development of setup combinations.

Development Process Overview

Initial vehicle testing took place at Carolina Motorsports Park to determine the baseline package based upon driver feedback. After vehicle testing, significant development testing was performed to prepare for the final track test at VIR on 9/26/18.

After the initial track test, 4-Post testing was utilized to benchmark and further develop the new damper package and develop the production bump stop package. Using a test profile created to simulate hitting a 50mm tall obstacle at 100mph, a bump stop package was created that would protect the vehicle from hitting the track and prevent suspension damage from over-travel while being minimally invasive to any standard on-track activities. The bump stop package was specifically designed to be compact to prevent contact except in extreme cases, and stiff to prevent reaping any performance benefits by lowering the car down to engage the stop regularly.

The cars were taken with the updated Penske Racing Shocks 'Production' spec packages to VIR on 9/26/18, where three similarly prepared cars (an NA, an NB1 and a NB2) were tested by three drivers (Mazda Motorsports drivers Tom Long and Joel Miller along with Spec Miata expert Tom Fowler). Cars were put through their paces on track and off track – from fast laps to going over curbs, through grass and anywhere the drivers could simulate and attempt both best case and worst case scenarios.

Initial outings in one car utilized a ¼" taller bump package in an attempt to generate driver feedback, then shortening the package further to prevent it. Joel Miller stated he was able to slightly contact the bump package 'if he tried to' under significant heave from elevation change in the bottom of Hog Pin (Turn 14), validating the shaker rig prepared package. Data showed approximately 1/16" of engagement into the bump stop. After validation, ¼" of spacer was removed to match the 'Production' spec package.

Driver feedback across the board was positive, stating the cars were more forgiving, easier to drive and 'actually felt like a race car.' Despite removal of the bump stops from the package, there was no mention of any loss in platform or performance. Turn in was described as 'crisp' and there was no mention of any losses of body control or agility. No negative feedback was recorded, and feedback was consistent from all three drivers across all three platforms.

Post-VIR Shaker Test Overview

Having validated the package on track, the cars were brought back to the shop for further validation and comparison testing. A 4-post track map was generated from recorded track data using the NB data acquisition car. For shaker rig testing, the NA and NB2 cars used the exact same set of shocks and springs as was used on track for data acquisition to minimize any potential error between vehicles.

Each car was set to the track-validated ride height adjuster locations, and then fine adjustments were made to generate an equal 50% cross weight in each car. The cars underwent a test matrix where multiple variables were changed in an attempt to determine if the damper package had created any advantages or disadvantages of any combinations. Each car was run at minimum allowable weight with three driver weights: 160, 180 and 220lbs. Tests were performed using Hoosier SM7, the new Hoosier SM8 prototype, Hoosier Rain and Toyo tires at recommended hot pressures along with 5psi over and 5psi under. The cars were also run at various ride heights including raised, pitched, lowered and lowered all the way down to the bump stops.

The cars were run through 100mm/sec, 150mm/sec and 200mm/sec constant peak velocity sine sweeps in heave along with VIR track simulations. Metrics analysis was performed primarily using the 200mm/sec constant peak velocity sweeps and validated with the other frequencies.

The primary objective of these tests was to ensure each chassis reacted similarly and generated similar performance with each combination of variables. The 4-post shaker rig inputs energy to the vehicle through precisely controlled, high speed hydraulic rams located beneath each tire of the vehicle and records data from each run in a number of ways – including contact patch load (the force the tire exerts upon the ground), body acceleration and hub acceleration, all at each corner. The vehicle is assumed to be symmetric in setup and is looked at as a front system and a rear system.

Constant peak velocity (degrading displacement magnitude) sine profile sweeps in heave (equal vertical motion input at all 4 corners) are used to provide an equal energy input across the frequency range anticipated to be seen by the vehicle across all conditions – allowing the results to be a good representation of an 'all-around' setup of the various conditions anticipated to be regularly seen by the vehicle and is not specifically catered to one specific track.

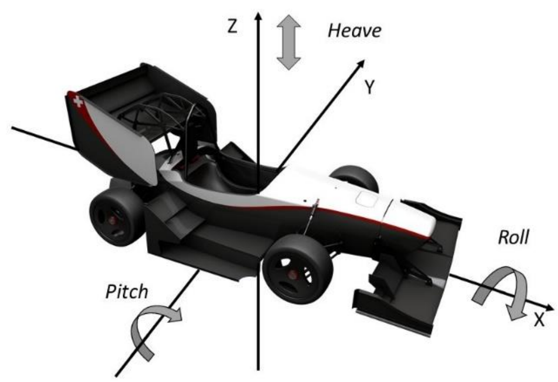

Figure 1: Heave, Pitch, Roll Diagram (Academic Motorsports Club Zurich, 2018)

Metrics analysis was performed upon the sine sweep data to study peak and average contact load variation and body response. Contact load variation is the difference between the maximum and minimum loads seen as a result of energy input into the tire. Decreased contact load variation is representative of more mechanical grip in the tire. Body response is a comparison of the accelerations input on the tire relative to the acceleration seen by the body of the car, and is representative of how the sprung mass of the vehicle responds to energy inputs such as bumps and curbs. Lower body response metrics are indicative of the vehicle being less impacted by inputs at the tire, which results in better handling characteristics. The metrics we focus on analyze at these values as the peaks and averages of the front and the rear of the car along with pitch, how the front and rear behave relative to one another and heave, the behavior of the entire car moving up and down.

Across our entire matrix of vehicles and setup changes, we observed less than 5% of variation in contact load variation and under 4% variation in body response across all platforms and changes, with one universal exception: decreasing ride height and contacting the bump stops. Decreasing ride height as far as physically possible and fully engaging the bump stops resulted in a significant increase in contact load variation and heave body response.

	Contact Load Variation					
Notes	Fax_CP_Pk	Rax_CP_Pk	Hve_CP_Pk	Fax_CP_ave	Rax_CP_ave	Hve_CP_ave
NB Baseline	1.703	1.684	1.650	0.669	0.598	0.632
NB2 Baseline	1.699	1.676	1.655	0.662	0.590	0.624
NA Baseline	1.736	1.637	1.670	0.697	0.615	0.653

Figure 2: Chassis comparison with baseline setups

Terms: Fax is Front Axle, Rax is Rear Axle, Hve is Heave. CP is Contact Patch. Pk is Peak, ave is average.

The numbers used for metrics analysis are the result of applying a transfer function to the data to create a characteristic curve in the frequency domain. The result is a value that is representative of the ratio of the system output to the system input. These numbers are comparative and are used to gauge magnitude.

When analyzing the baseline setups, it can be seen that the three were all very closely matched, with the NA showing slightly more tire load variation across the board. The variance is within 2% difference, which could be attributed to car preparation. The NA responds differently due to having a lower sprung mass (the chassis is lighter) resulting in a different response. The lower weight of the NA results in lower tire utilization, meaning slightly higher contact patch variation would help improve parity between chassis.

	Contact Load Variation						*Body Response*			
Notes	Fax_CP_Pk	Rax_CP_Pk	Hve_CP_Pk	Fax_CP_ave	Rax_CP_ave	Hve_CP_ave	Hve_Bdy_Pk	Pitch_Bdy_Pk	Fax_Bdy_Pk	Rax_Bdy_Pk
NB2 Baseline	1.699	1.676	1.655	0.662	0.590	0.624	1.520	0.528	1.075	1.572
NB2 on Stops	2.660	2.678	2.666	0.897	0.868	0.882	2.359	0.566	1.028	2.055

Figure 3: Comparison of Fully Engaged vs Disengaged bump stops

With the car lowered down significantly to engage the bump stops, a very significant result is seen. Almost unanimously across the board, engaging the stops is a significant disadvantage – with the sole exception being the additional stiffness very slightly improved front body response. The significant increase in contact load variation across the board shows that engaging the bump stops on this package will result in a *significant* loss of mechanical grip. There is also a significant increase in Heave body response due to increased heave travel. This may seem counterintuitive because of the increased stiffness, but the increase in stiffness is so significant that the bump stop is loaded so aggressively in compression that it causes the system to bounce significantly in rebound.

While not as extreme as in the new package, aspects of the same trends were seen when testing the previous package due to the regular engagement of the old bump stop package. Remedying this situation results in a more compliant and predictable race car.

Conclusion

We can confidently state that the production Penske Racing Shocks damper package delivers nearly equal performance across all three vehicle platforms across various driver weights with all available tire options. In pure heave, the package is less sensitive than before to setup adjustments such as ride height and pitch, assuming bump stop engagement is avoided. It is suggested that customers start near the ride heights as tested and experiment individually, being careful to avoid engaging bump stops by decreasing ride height, especially at significantly bumpier tracks and tracks with higher vertical loads due to factors such as high banking and abrupt elevation changes.

Bibliography

Academic Motorsports Club Zurich (2018). *Roll Pitch yaw Diagram*. [image] Available at: https://blogs.mathworks.com/racing-lounge/files/2018/02/Roll_Pitch_Heave.jpg [Accessed 6 Nov. 2018].