2009 Star Mazda Update Kit Technical Brief

January 2009

To: Star Mazda Competitors
From: Star Race Cars, Tim Lewis
Cc:
Date: December 08, 2008
RE: 2009 Star Mazda Pro Car Update Kit

Introduction

The Star Formula Mazda Pro car was introduced for the 2004 racing season and has been used for five years widely. No racecar is ever really fully developed, and this one is no exception. While we at Star Race Cars are proud of the car we have been able to provide, we are equally proud to be able to provide an update kit for the 2009 season that will improve upon the present car while keeping racing parity between the two.

The changes that were made to the car were done to make the car easier to work on, easier to tune and better to race. The updates can be grouped as either functionality or performance changes.

Functionality items:

- Threaded adjusters on front and rear pushrods
- Threaded adjuster on front toe link
- Redesigned rear camber block
- Redesigned rear rocker post

Performance items:

- New aerodynamic package
- Ohlins TTX-36 Dampers
- Updated front and rear rocker package

This brief is not going to be an exhaustive analysis of each part of the update kit. It is meant to give the competitors an idea of the thinking behind the new designs and a look into how it has changed the engineering aspects of the Star Formula Mazda Pro Racecar.

Analysis

Pushrod Ride Height Adjusters

The threaded adjusters on the front and rear pushrods were introduced to provide easier and more accurate pit-lane adjustability of ride height. It should also reduce the time to make changes. To make things easier on the mechanics, we would recommend fabricating two ride height wrenches that have all open ends. This will allow a mechanic to adjust ride with only two wrenches as opposed to trying to handle four.

The new adjusters give the following adjustment sensitivities:

Pushrod Ride Height Adjustment Sensitivity With Threaded Adjusters		
	1 flat	1 turn (360 degree rotation)
Front	0.8mm / 0.032 inches	4.8 mm / 0.190 inches
Rear	1.0mm / 0.040 inches	6.0 mm / 0.240 inches

<u>Front Toe-Link Adjuster</u>

To adjust the front toe settings with the original toe links, the wheels need to be pulled off the car and the front toe-link is spun moving right and left-handed threads. This adjuster does essentially the same job as with just the toe link, but it does so without having to remove the wheels from the car. The adjuster itself is the same as has always been used on the rear of the car.

<u>Rear Camber Block</u>

The new rear camber block has been made with a shorter distance between the upper ball joint and mounting face. This has been done to allow for a greater range of camber adjustment without resorting to adverse wishbone jigging which introduces bump steer. The upper ball joint pocket has also been widened to allow for a greater range of vertical motion without the monoball housing on the wishbone to contact the inner portion of the camber block.

When used on the left hand side of the car on an oval, it may be advantageous to use an unslotted ½" camber shim to achieve the desired camber setting. It should also be noted that competitors may also choose to use the original camber block when trying to achieve positive camber settings on the left rear without an excessive number of camber shims. Range of motions issues will probably not be of concern under these conditions, but it is something that should be monitored.

<u>Rear Rocker Post</u>

There have been bearing wear issues front and rear on the car with the original rocker systems. The new rockers have larger bearings and, specifically on the rear of the car, these bearings are spaced with a greater center-to-center distance. This should significantly increase the life of the bearing, but it has meant the old rocker post is not tall enough to adequately support the new rocker.

<u>New Aerodynamic Package</u>

New wings are available front and rear. These wings are made of carbon fiber as opposed to the old aluminum fabricated wings. The quality control of the carbon composite wings is much tighter than possible with the fabricated aluminum wings. No one will have a reason to sort through inventory when purchasing wings to find 'a good one'. This substantial increase in part quality also makes technical inspection a more clear-cut process. Wings will not deform or warp with normal use.

The new wing designs were developed to allow competitors a greater range of effective downforce and an altogether more raceable package. The front wing has been raised off the ground a significant amount both in an effort to reduce both pitch sensitivity and following wake sensitivity. The elimination of front wing endplate feet also reduces pitch and roll sensitivity by reducing the tendency to 'seal' and 'un-seal' as the car transitions from braking to cornering to acceleration.

The overall downforce level of the 2004-2008 Pro Mazda aerodynamic package has not been exceeded by a large margin. This downforce level is viewed by the series and most competitors as appropriate for the overall performance characteristics of the car. In a comparison of the old and new wings set for maximum downforce, the new wing package has about 10% higher downforce and drag numbers than the previous configuration. When adjusted to minimum downforce settings the wings do not 'blank' each other like with the previous triple element rear and there is a considerable downforce and drag reduction. In addition to providing a wing package that has fewer unfavorable attributes, Star Racecars has attempted to provide a range of aerodynamic adjustment that is greater than most competitors will choose to use.

The testing that Star Racecars performed showed linear relationships between wing angles and downforce/drag levels. The wings were sized in an effort to make the front and rear adjustments correspond. A low front setting can be matched with a low rear setting; a middle front setting is balanced by a mid-range rear setting, etc. Star Racecars test drivers were most comfortable with aerodynamic balance in the range of 40-41.5% front bias depending on conditions.

Gurney flaps are going to be allowed on the rear lower element and front flaps. The standard front flap gurney as delivered from Star has a maximum height of ¾". It may be trimmed to any height. The rear lower gurney has a maximum height of ¾". It should be noted that during testing it showed a favorable interaction, presumably with the diffuser exit, that increased front downforce as well as rear. There is also the indication that it positively affected cooling behavior.

The rear upper flap is adjustable for tuning purposes. It is not legal to use a gurney flap on rear flap. At high angles of attack an air of flow separation bubble forms on the backside of the wing. The wing does not stall at maximum angle settings, but it does have a significant portion of the wing affected by this flow separation. Adding wing angle will always gain more aerodynamic grip, but past a certain threshold, that gain in downforce comes at a higher and higher drag penalty.

Ohlins TTX-36 Dampers

The decision to change dampers was one that was as much by necessity as it was by a conscious decision to upgrade. The ST44 damper that has been the specified Pro Mazda damper for the past five years is being discontinued by Ohlins (as are several other dampers using similar components). We had the task of finding a suitable replacement. It should be noted that we did not confine our search for a new damper to Ohlins, only. We contacted several manufacturers about fulfilling our need for a new damper package. In the end, Ohlins was picked as the best option due to factors that include quality, servicing, price, reliability and overall performance. We feel that the new damper package is an improvement over the previous one in every way.

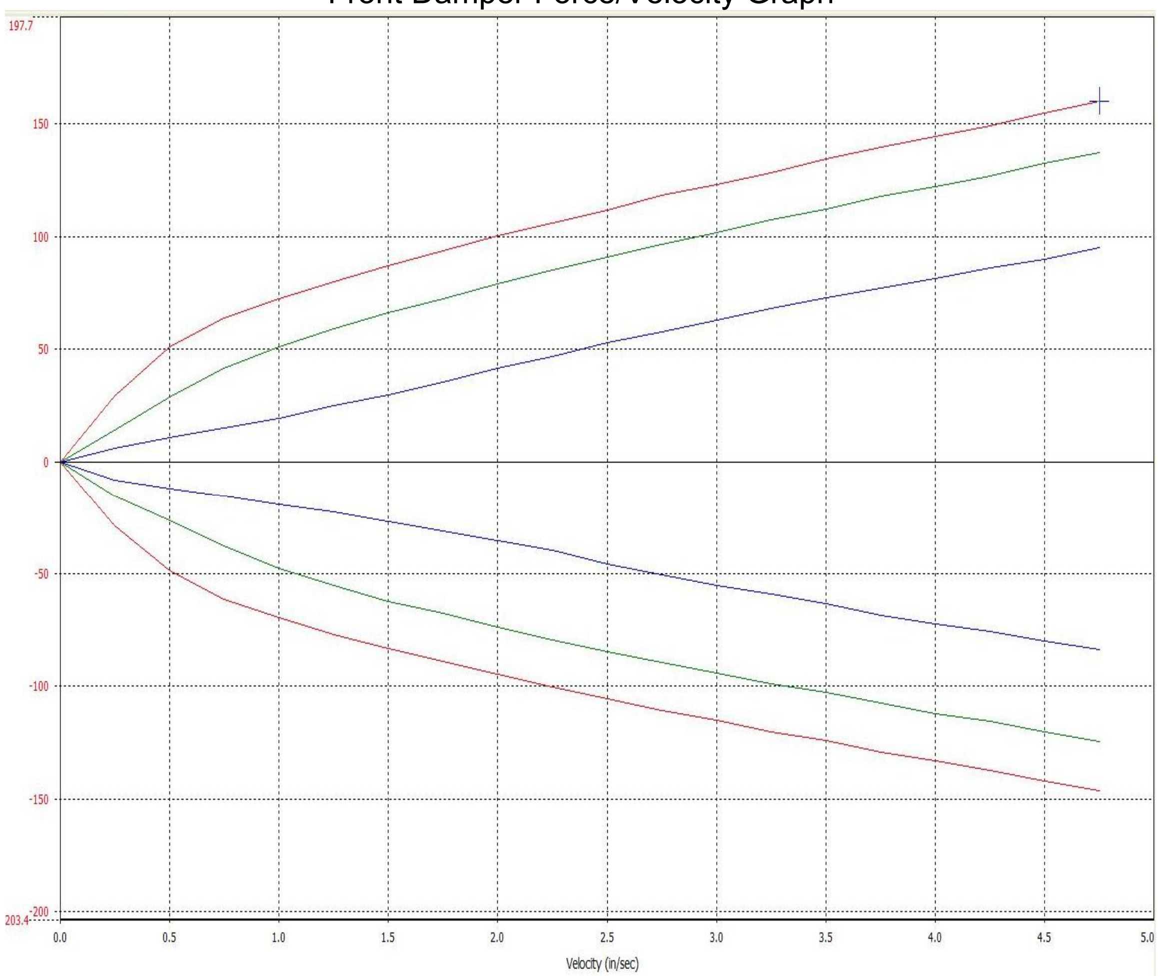
The new dampers are double adjustable with the external adjustments controlling what amounts to a piston bleed (through the outer tube). There is one compression and one rebound adjuster. The included damper curves show that the dampers have a relatively large range of adjustment, consistent adjustment step size and minimal cross-talk between adjusters. The extended length of these dampers (280mm front, 290mm rear) is very close to the ST44 damper and the two can be used with either rocker package. Having said that, the spec. valving has been specifically developed with the new rocker package (and the associated motion ratios) in mind.

The damper testing that Star Mazda conducted was done to provide the competitors with a reasonable damper setting with the adjusters at about a mid-range setting. With that in mind, the recommended baseline settings are Front Compression:-15, Front Rebound:-15, Rear Compression:-15, Rear Rebound:-15. Adjusters are always counted from fully closed, which is designated ‘0’. Each click reduces damping force, so they are considered negative.

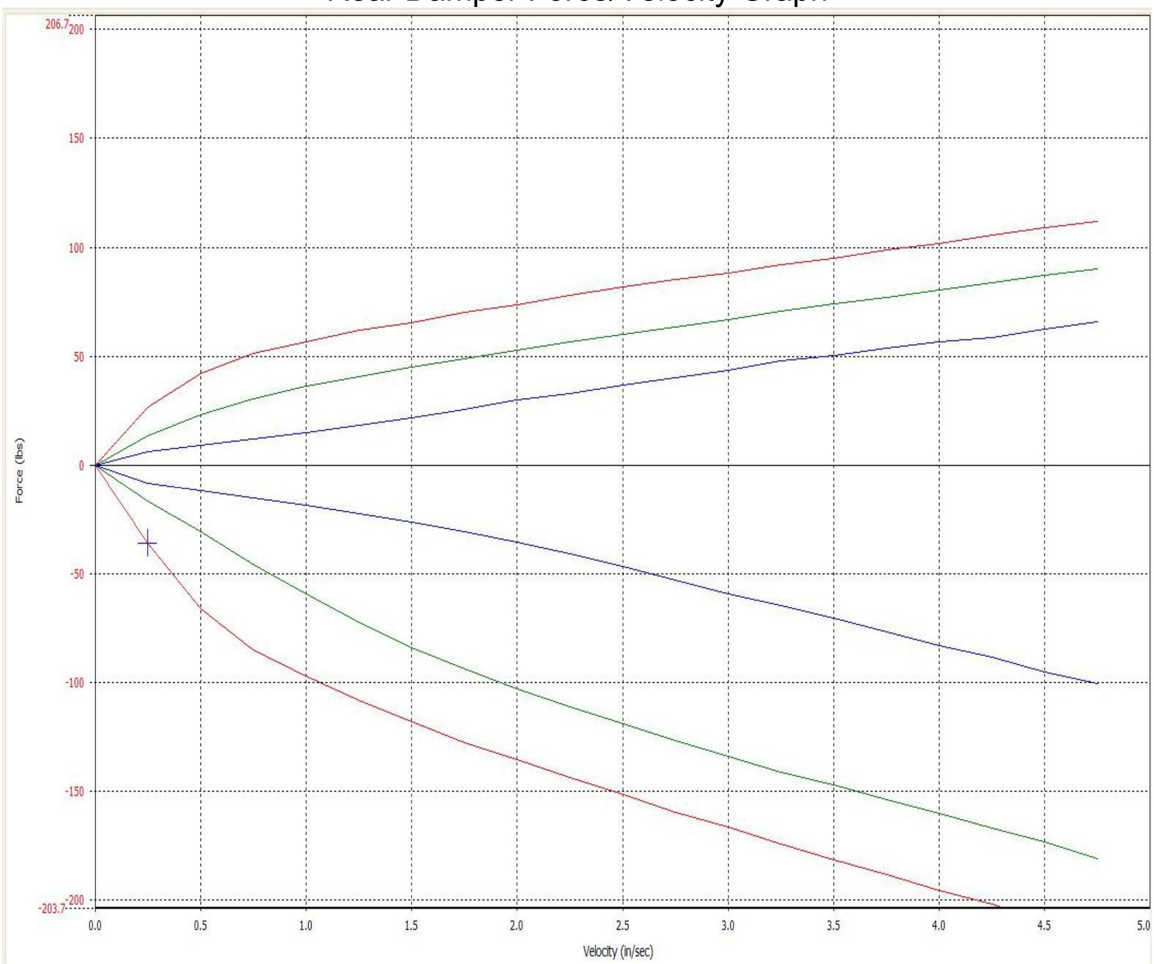
The spring hardware associated with the new dampers is the same as on the previous version. The springs themselves have also been left as is. The gas canister uses the same tool for pressuring and canister. The influence of gas pressure on damper performance is reportedly very small.

Below are damper dynamometer graphs of the front and rear damper. The red graph is with the damper adjusters set full stiff and the blue graph is with the damper adjusters set full soft. The green curve is a typical mid-range setting of Compression:-10 and Rebound:-10.

Front Damper Force/Velocity Graph



Rear Damper Force/Velocity Graph



<u>Pro Mazda Mk II Rocker Package</u>

This is the single biggest design change from the original Star Pro Mazda racecar in the update kit. While the other changes are evolutionary in nature, this takes a bigger step. The changes that were made were done after analyzing the geometry of the original design, talking to competitors and taking note of car setup trends through the entire field as the cars were put through technical inspection.

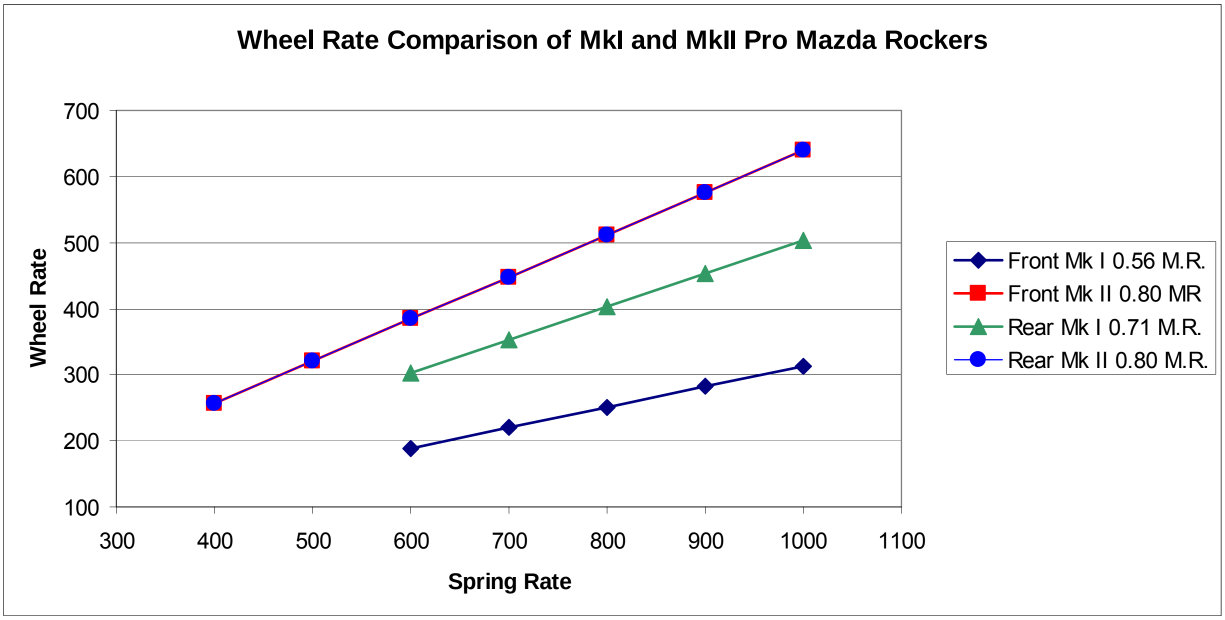
The decisions made with the new design were done so with an attempt to provide the competitors with the best possible performance gain with the least amount of investment. In the past five years, the competitors have, for the most part, fully explored the available tuning envelope of the original design. Specifically, after the introduction of radial tires the tuning envelope has not provided the easiest car to drive or engineer. Of the design criteria that played a role in the new design, there were some deemed most important. They were as follows:

- Design should allow for a reasonable balance when same spring rate is used on each end of the car
- Maintain the same spring catalog that the teams presently use.

- Tuning range should allow a wide range of adjustment for teams while at the same time not encouraging a heavily oversteering or understeering spring balance
- Design spring/damper motion around the compression distance before coil bind available for 36mm springs (these springs have a relatively small amount of travel when compared to longer, larger diameter springs)
- Motion ratios need to be compatible with dampers to provide effective damping
- Would like to provide a greater range of adjustability for anti-roll bars front and rear
- Rocker bearings front and rear need higher capacities to increase service life and reduce pitting
- Rocker motion ratios (both damper and anti-roll bars) need to progress in a way to keep the car balanced in a wide range of applications from street racing to ovals
- Rockers need to be designed to reduce the workload of the competitors in event of damage/replacing
- Update package should introduce as few new parts as possible

Motion ratios have changed in the front and the rear. Star Racecars has measured the original front and rear motion ratios at 0.56 and 0.71, respectively. These values may vary from team to team as they are dependent on wishbone jig lengths, but these numbers should be viewed as representative. The MkII rockers have nominal motion ratios of 0.80 front and 0.80 rear.

Wheel Rates Spring Rate	Front Mk I 0.56 M.R.	Front Mk II 0.80 MR	Rear Mk I 0.71 M.R.	Rear Mk II 0.80 M.R.
400		256		256
500		320		320
600	188	384	302	384
700	220	448	353	448
800	251	512	403	512
900	282	576	454	576
1000	314	640	504	640



Choosing the damper motion ratios of the rockers was not an easy task. A numerical analysis of the car suggested that it was under-sprung when limited to the legal spring selection, especially on the front end of the car. The rear of the car had a reasonable, if low, motion ratio, but because of the rocker geometry, it had the unfortunate attribute of falling off as the suspension compressed. Many competitors commented that this contributed to a roll-oversteer condition that was very difficult to address. The front rocker was the first end of the car to be addressed. The ratio was made as high as possible while attempting to limit the possibility of coil bind of the spring. There is marginally more than two inches of wheel travel available on the front end of the car before coil bind.

The rear design was meant to compliment the front by allowing a similar spring to be used on both ends of the car at the same time. This will be dependent upon a range of factors, but the goal was that if a competitor was in doubt on the setup, they could put the same spring all the way around on the car and not be too far off the mark.

There are many different ways of looking at suspension stiffness. Among them is an analysis of a suspension's ride natural frequency. It's a very simple way of looking at the spring stiffness of a car while taking car weight into account. Looking at the ratio of front to rear spring frequency is a way to judge the balance of a given setup. If the front is softer than the rear (in terms of natural frequency); then the ratio will be less than one. If the rear is softer than the front; the ratio will be greater than one. Having a frequency ratio of one does not mean that the car will have neutral handling characteristic, as no roll couple values are being assigned. We are only evaluating vertical stiffness. One thing that it does mean is if the aero loading is in the same proportion as the sprung mass, then with a ratio of one, the car will settle evenly as speed (i.e. aero-loading) increases. If the ratio is less than one, then it will settle 'nose first'. If the ratio is greater than one, then it will settle 'tail first'.

Ride Frequency (cycles/sec) Spring Rate	Front Mk I 0.56 M.R.	Front Mk II 0.80 MR	Rear Mk I 0.71 M.R.	Rear Mk II 0.80 M.R.
400		2.91		2.46
500		3.17		2.69
600	2.56	3.39	2.63	2.90
700	2.73	3.58	2.80	3.07
800	2.88	3.74	2.95	3.23
900	3.02	3.89	3.09	3.37
1000	3.14	4.02	3.21	3.50

Ride Frequency Ratio of Mk I Pro Mazda Rocker Package

Rear Spring Rate	Front Spring Rate 600	700	800	900	1000
600	0.97	1.04	1.10	1.15	1.19
700	0.91	0.98	1.03	1.08	1.12
800	0.87	0.93	0.98	1.02	1.06
900	0.83	0.88	0.93	0.98	1.02
1000	0.80	0.85	0.90	0.94	0.98

F/R λ ratio	Front	400	500	600	700	800	900	1000
Rear	λ	2.91	3.17	3.39	3.58	3.74	3.89	4.02
400	2.46	1.18	1.29	1.38	1.46	1.52	1.58	1.63
500	2.69	1.08	1.18	1.26	1.33	1.39	1.45	1.49
600	2.9	1.00	1.09	1.17	1.23	1.29	1.34	1.39
700	3.07	0.95	1.03	1.10	1.17	1.22	1.27	1.31
800	3.23	0.90	0.98	1.05	1.11	1.16	1.20	1.24
900	3.37	0.86	0.94	1.01	1.06	1.11	1.15	1.19
1000	3.5	0.83	0.91	0.97	1.02	1.07	1.11	1.15

The first thing that is apparent from these tables is that the new rocker package produces a significantly stiffer car vertically, both front and rear. The second is that the front stiffness has been shifted further up than the rear.

If you are trying to compare a setup from the original rocker package to the Mk II rocker package, you may have trouble finding a suitable match. There is only partial overlap on the spring rates. A good approach would be to get as close as you can in overall stiffness and make the ride frequency ratio the target that you match from old to new. For instance, if you were running a 1000 lbs/in front spring and a 900 lbs/in rear spring on the Mk I rockers, then a good match would be a 500 lbs/in front spring with an 700 lbs/in rear spring on the Mk II rockers. Although the new combination is slightly different, it has the same vertical stiffness characteristics as the old setup and should be a reasonably good comparison in terms of handling balance.

The front and rear rocker also have some rising rate built into the rocker for the damper. On the front of the car, the progression is 8% and on the rear it is 11%. One of the common complaints about the handling characteristics of the car was a corner exit understeer. Along with the other changes, the rear progressive rate was made to counteract this particular handling issue.

The anti-roll bar pickups for the front and rear rockers now offer two motion ratio options. Star Racecars measured the original front anti-roll bar (FARB) motion ratio 0.71. The nominal MkII front 'fast' motion ratio is 1.0 and the nominal MkII front 'slow' motion ratio is 0.60. The 'fast' motion ratio makes the effective road rate approximately twice as stiff as the original. Using the 'slow' front ARB rocker pickup makes the front ARB have an effective stiffness of about 70% of the original.

On the MkII rear the 'fast' hole was designed to be very close to the original motion ratio. The original pickup motion ratio was measured at 0.43. The 'fast' hole has a nominal motion ratio of 0.37. The rear anti-roll bar (RARB) with this pickup has about 75% of the effectiveness as the original rocker. The 'slow' hole reduces the motion ratio to 0.11. This reduces the effective spring rate of the RARB to only about 7% of the original rocker.

One of the comments that was very common from competitors was that there was too large of a step between the rear anti-roll bar at its minimum setting and disconnecting the RARB altogether. The calculated minimum spring rate for the original RARB was about 122 lbs/in. The new rocker has a minimum spring rate on the 'fast' hole of 106 lbs/in. In the 'slow' hole, this rate drops to 10 lbs/in.

It should be noted that the motion ratio for the RARB is taken with the bar attachment point in the flush position on the top of the vertical bar of the ARB. When adjusting the RARB settings, you are changing the stiffness of the 'U' bar and increasing the rocker motion ratio at the same time. Because of these compound changes, the accuracy of the adjustments is critical for good repeatability.

All of the above ARB motion ratios have a certain amount of progression to them. The Front ARB motion ratios have a rising rate of about 12%. The rear has a greater rising rate of around 20% on the fast hole and about 25% on the slow hole. The rising rate percentages on the FARB pickups were very close to the design targets. The rising rate percentages on the RARB pickups were higher than design targets, but a product of compromise between rocker geometry, damper motion ratio, packaging and the nominal RARB motion ratio. When you take into account that the forces on the RARB in general, and the slow hole in particular are rather small, the effective change in roll couple at the contact patch due to ARB motion ratio rising rate becomes a very small component of the overall handling picture. This is why this design compromise was made.

Appendix A is a series of damper and anti-roll bar motion ratio graphs that we measured off of an actual car, as opposed to just using the numbers from the design program. It should be noted that the numbers did come out slightly different than what the design software shows, but close enough that minor differences in alignment, jigging tolerances and measurement error can account for difference. The data points have a linear best fit line drawn through them and the slope number from that line equation is the motion ratio.

In terms of serviceability, we have made a number of changes to make the new rocker package easier to work on. First, every pickup hole is pre-drilled with 4-40 threaded holes to mount captive nuts. This is a small point, but in a situation where they need to be replaced at the track, it will reduce turn-around time significantly. As mentioned earlier, the bearing sizes have also been increased significantly to increase service life and reduce pitting. Another subtle point is that when changing ARB drop link holes, they have been positioned so they don't require a change in drop link length.

Recommendations

The balance characteristic that was most prevalent in the previous version of the car was oversteer. Nearly every change that has been made to the car has been done to reduce this tendency.

The static rake numbers that competitors relayed to me during interviews were very small, if any. The Star Pro Mazda car is a flat-bottomed car with a diffuser. While we don't have wind tunnel data to back this up, we suspect that adding 10, 20, or 30mm of rake to the car will make for a substantial gain in downforce. Previously, the balance of the car would not allow these types of rake angles. The changes that have been made to the car should allow competitors to experiment with increasing the static rake of the car to realize these gains. The increased chassis stiffness in the front and rear will limit the dynamic pitch characteristics. Along with raising the front wing, changes in anti-roll bar stiffness and having better overall damper control, I'm hoping that it is not difficult to have a car with stable corner entry characteristics. I've generally found that when the corner entry is stable that it is much easier to find a consistent car balance. Once the balance is consistent and there is only a single problem to fix you're well on your way to a fast racecar.

Appendix B is the recommended starting setup for the Sebring open test. This is a setup that has been ran on an updated car, but obviously, not at Sebring. It is the best that we have to provide and is exactly where we would start if we had a car to run at this test. Having said this, it is just a starting setup. These are not 'magic' racecar settings and we hope that everyone finds improvements to be made in them over the course of the test. While running this setup, the test car had mostly understeer. We would specifically be cautious with ride height. We don't have a good feel for the necessary ride height at Sebring, but we do know that it's a bumpy place that could require a higher ride height than what is called out. However, if you're not bottoming in at least a couple areas of this track, you're probably not low enough. Finding that happy medium should be an early testing goal.

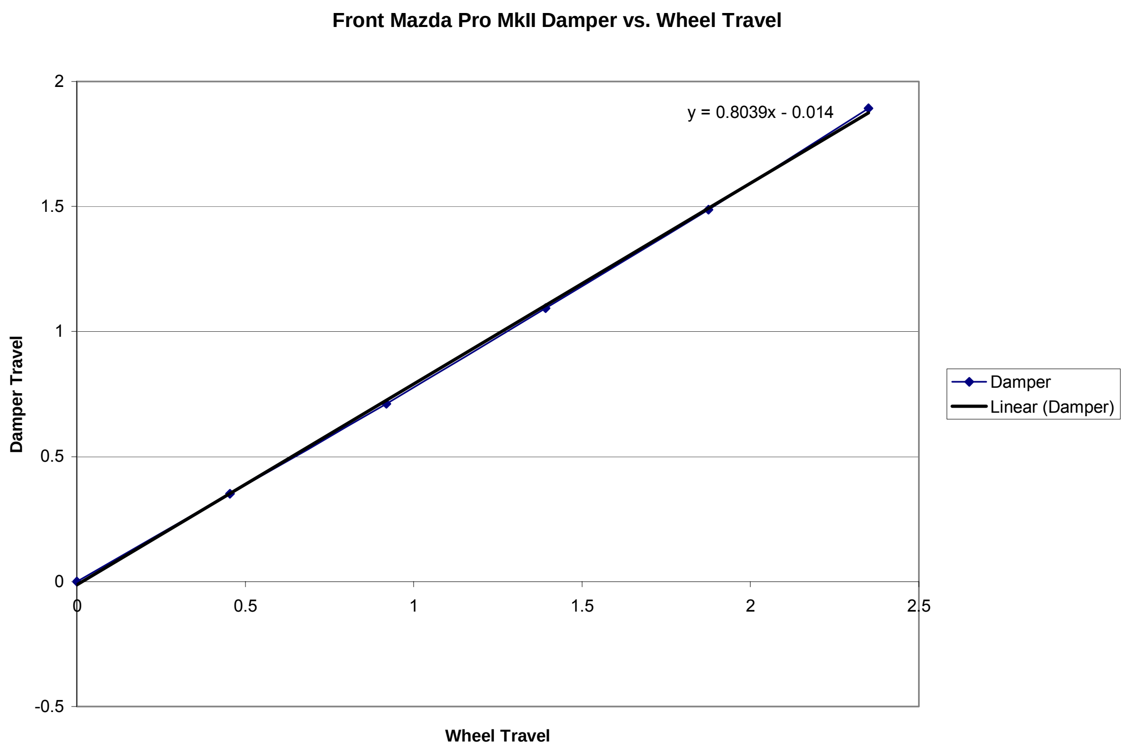
Conclusion

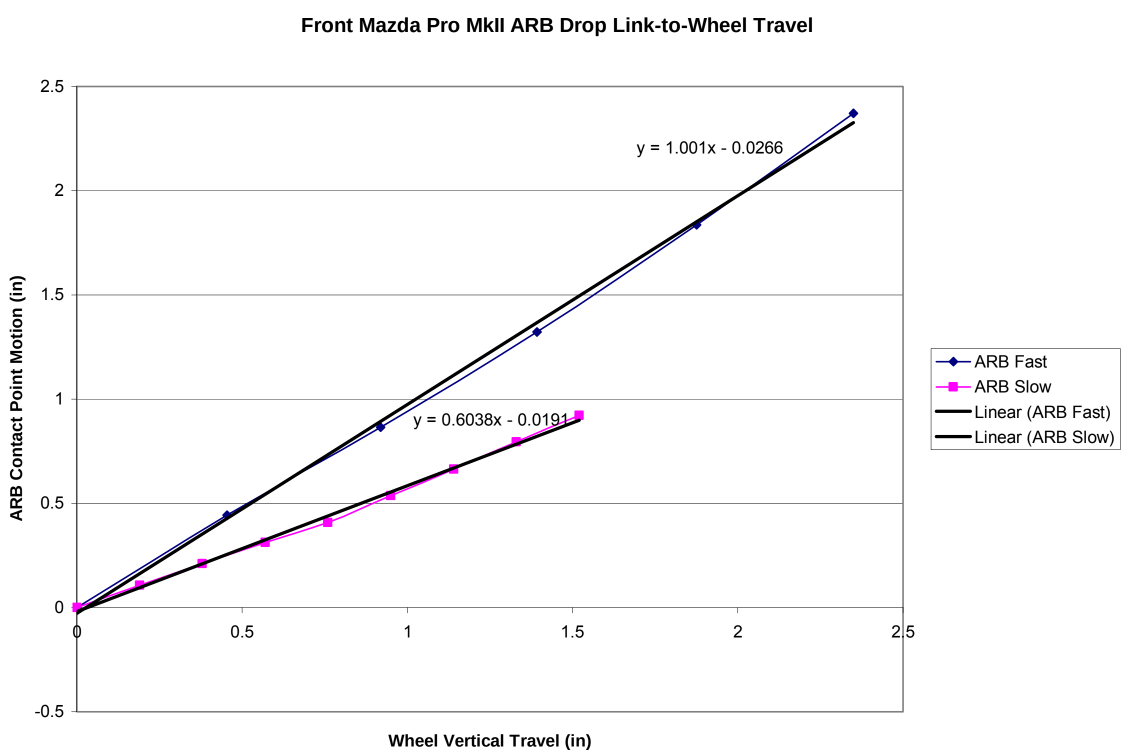
There were many opinions taken from competitors when contemplating the design changes for the update kit. Many of the ideas came from competitor interviews or through noting the evolution of setups through the last several seasons. It isn't possible to control all the variables at play or produce a few bits that will make this the best of all possible racecars. That was never the goal. What we've tried to do is provide meaningful improvements that will improve the racing and the car without costing the car owners an excessive amount of money.

We have taken a genuine concern about the health of the series, the strength of the racing and the success of all competitors. We have tried to introduce changes that will make the car nicer to drive with a better and more consistent aerodynamic and mechanical balance. We've tried to source and design high-quality parts that are a good value to teams, and we've tried to make changes that will assist teams in zipping up the tent a little bit earlier in the evening.

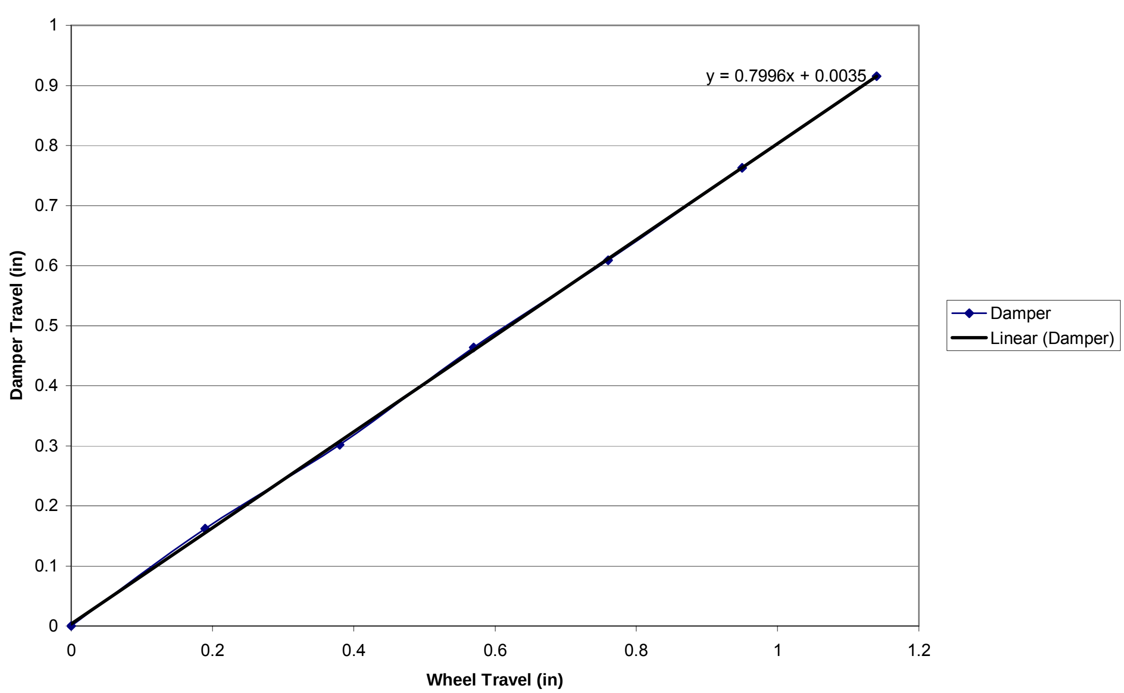
Appendix A

Motion Ratio Graphs

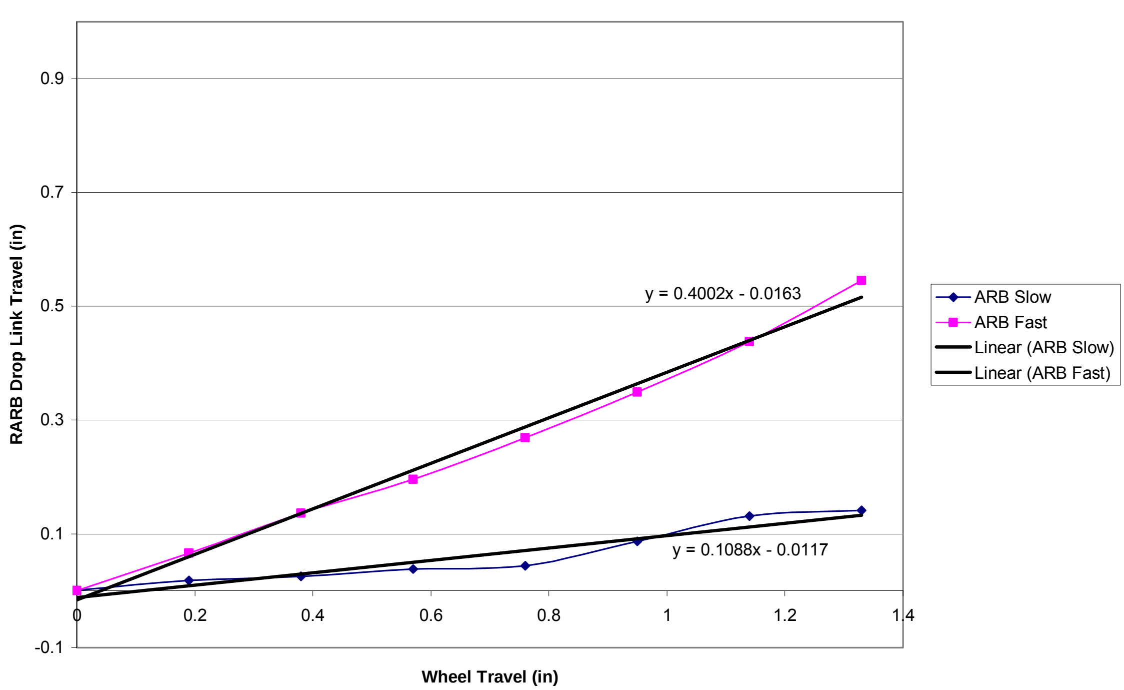




Rear Mazda Pro MkII Damper vs. Wheel Travel



Rear Mazda Pro ARB Drop Link vs. Wheel Travel



Appendix B

Recommended Starting Setup

PRO MAZDA RACECAR CHASSIS BUILD SHEET

		TRACK	Sebring	TRACK LENGTH	3.70 Miles
DATE	27-Jan-09	CHASSIS	Star Pro Mazda	Sheet Version	1
EVENT	Open Test	CHASSIS #		SESSION:	Session 1
DRIVER		ENGINE#		SETUP FUEL: 10	SESSION FUEL: 10

FRONT AERO

Front Wing Main Angle	std.				Part #
Front Wing Flap Angle	23.0	Footplate		FWEP Gurney	n/a
Front Wing Flap Gurney	3/4	Forward	0	FWEP Footplate	n/a
Front Wing Middle Gurney	0	Trailing	0	Footplate Skid	n/a

SPRINGS		CAMBERS		AVG.	RIDE HEIGHT		TOE				CASTER		
900	900	-3.50	-3.50	27.0	27.0	27.0	in	2mm	2mm	in	8.0	8.0	
700	700	-2.90	-2.90		37.0		in	1mm	1mm	in	8.0	8.0	on arm
				RAKE	10.0	TILT 0.0					Cold psi	Hot psi	

Cold psi		Hot psi	
17.0	17.0	21.0	21.0
17.0	17.0	20.0	20.0

SETUP WEIGHTS — Anti-Roll Bars

CORNER WEIGHTS		LF WEIGHT	% CROSS		Bar / Blades		Connected?	Adj.		Tire Codes	
297	297	0	50.00%	Front	19mm	STD.	CONNECTED	3		430	430
395	395	42.92%	1384	Rear	0.625	0.625	CONNECTED	0.75	From Top	430	430
		% FR. WEIGHT	TOTAL								

GEOMETRY

			Left	Right		Left	Right		
Front Rocker Main	STD.	Front Lower Fore	23.437	23.437	Rear Lower Fore	22.875	22.875	Steering pinion	9 teeth
Front ARB Rocker	STIFF	Front Lower Aft	26.625	26.625	Rear Lower Aft	22.375	22.375	Front Roll Center	STD.
Rear Rocker Main	STD.	Front Upper Fore	18.875	18.875	Rear Upper Fore	15.968	15.968	Rear Roll Center	UPPER
Rear ARB Rocker	SOFT	Front Upper Aft	24.781	24.781	Rear Upper Aft	n/a	n/a		

DAMPERS

Damper Specifications		Press	Comp. Valve	Reb. Valve	Bump Rubber	Packer	Gap-On Pad	Compression LS	Compression HS	Rebound LS	Rebound HS	Compression LS	Compression HS	Rebound LS	Rebound HS
Fr. ID	Ohlins TTX36-SPEC	75	X	X	0.000	######	2.000	-15		-15		-15		-15	
Rear ID	Ohlins TTX36-SPEC	75	X	X	0.000	######	2.000	-15		-15		-15		-15	

Extended Length		Pad Length		Static Droop		Est. Preload		Maximum Travel		Air Gap-Extended	
11.02	11.02	10.820	10.820	0.200	0.200			2.047	2.047		
11.42	11.42	11.120	11.120	0.300	0.300			2.047	2.047		

BRAKES

Brake Bias at 500 psi		Master Cyl.	Rotors	Calipers	Pads	Fluid
53%	Front	0.75	PFC	PFC	05	Motul 600
	Rear	0.812	PFC	PFC	05	

REAR AERO

				Cooling Blanking		
Upper Rear Wing Angle	STD.	Lower Rear Wing Angle	STD.	Left Side	0	inches closed
Upper Rear Wing Flap Angle	32.0	Lower Rear Wing Gurney	3/4	Right Side	0	inches closed

Gear Stack			Max RPM	8600
Final	9	31	Speed	RPM Drop
6th	19	21	152.3	996
5th	20	25	134.7	1035
4th	19	27	118.4	1267
3rd	15	25	101.0	1433
2nd	15	30	84.2	1483
1st	12	29	69.6	

Differential Settings		
Drive Ramp	n/a	DEG.
Coast Ramp	n/a	DEG.
Clutch Faces Active	0	faces
Preload Spring	none	
Assembled Preload	0	ft*lbs

Notes:	Amb.	Track

Appendix C

Star Pro Mazda Suspension Points

	X	Y	Z
Front:	fore-aft	width	height
Lower A-Arm forward on tub	1.377	5.656	6.259
Lower ball joint	7.851	27.055	6.254
Lower A-Arm rearward on tub	28.113	9.981	6.572
Upper A-Arm forward on tub	2.541	7.408	12.734
Upper ball joint	8.915	25.169	13.273
Upper A-Arm rearward on tub	28.127	9.964	12.514
Steering tie-rod on hub	5.502	20.632	13.393
Steering tie rod on rack	-0.745	3.425	12.283
Stationary damper mount on chassis	23.184	3.007	21.552
Moving damper pickup on rocker	12.609	2.621	22.132
Anti-roll bar axis	-1.057	4.933	12.26
Anti-roll bar mid-point	-1.057	0	12.26
Anti-roll bar blade	-1.057	4.933	20
Anti-roll bar pickup on rocker (fast)	11.314	2.181	22.425
Anti-roll bar pickup on rocker (slow)	11.414	3.691	21.739
Rocker pivot axis point 1	12.764	5.55	20.208
Rocker pivot axis point 2	12.759	6.319	21.544
pushrod attachment on rocker	10.35	5.647	21.051
pushrod attachment on lower A-Arm	7.948	25.275	7.185
Reference ride Height: 10mm			
Rear:			
Lower A-Arm forward on tub	11.35	6.209	5.734
Lower ball joint	-0.649	26.106	4.15
Lower A-Arm rearward on tub	-3.357	3.794	5.254
Upper A-Arm forward on tub	7.566	6.904	14.883
Upper ball joint	-0.795	20.564	13.504
Upper A-Arm rearward on tub	-7.676	2.448	16.368
Steering tie-rod on hub	-6.521	19.704	14.18
Steering tie rod on rack	-7.676	4.384	13.758
Moving damper pickup on rocker	-7.28	2.348	16.368
Stationary damper mount on chassis	3.851	1.62	17.704
Anti-roll bar axis	10.913	3.5	11
Anti-roll bar mid-point	10.913	0	11
Anti-roll bar blade	10.913	2.86	19.726
Anti-roll bar pickup on rocker (fast)	4.295	3.027	17.17
Anti-roll bar pickup on rocker (slow)	4.215	4.027	17.62
Rocker pivot axis point 1	3.233	4.358	16.557
Rocker pivot axis point 2	3.201	4.572	17.071
pushrod attachment on rocker	4.76	5.05	16.273
pushrod attachment on lower A-Arm	0.262	23.917	6.352
Reference Ride Height: 25mm			