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BMW M235i Racing Performance Book

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Statement of Non-liability.

This performance Handbook suggest realistic solutions to racecar handling problems. The suggested solutions point the way and by implementing the suggestions from the next pages you should get unstuck. It will be a result of your own conscious decisions, therefore we disclaim responsibility for your actions and for accident.

The goal of car tuning is to be able to drive quickly and safely on the racetrack. The next pages explains - re-summed in different chapters - how to improve lap times and safety by improving racecar handling.

Index:

I. Driver

Handling problems, car or driver?
Many handling problems can be attributed to driver errors, especially for new or inexperienced drivers. It can be difficult without data logging to determine if a handling problem is Set-up or driver related.
Below is a list of clues where to look first when handling problems occurs:

- If a problem is inconsistent, it is likely driver related
- If a problem occurs at every similar type of track section, it is likely Set-up related
- If a problem is either on left or right turns only, it is likely Set-up related
- If a problem is at one turn only and not at any other similar turn, it is likely driver related

II. Tire pressure

Effect of tire pressure:
The tire pressure in a tire has a big effect on tire traction. A specific tire on a given car with a given load will have only one correct tire pressure which should first be requested at the tire brand engineer for the specific used car. In practice it is a narrow range of pressure, within about 3 psi. If the pressure is outside of this range, the contact patch is deformed and not fully contacting the road surface.

Setting tire pressures:

- When the target pressure is p. ex. 28psi at hot conditions, then start with ~ 23psi and run a stint of min. 10 laps. Check the tire pressures all-around and adjust to the target value.
- Then take the adjusted tire set off the car and let cool down to ambient temperature for obtaining cold tire pressure values.

Note:

- Use always the tire temperature pressure sheet (pressure lookup table) and stick to the reference values of 20deg C.
- The attached tire pressure lookup table helps to determine cold pressures in each wheel when ambient temperatures are changing during the event.
- During every session should tire pressures and track surface / air temperature be monitored.
- When track gets ~10deg warmer, bleed ~0,72psi cold or ~1,16psi warm air pressure from the tire to avoid over pressures which results in less grip.
- Tire pressure gauges has to be re-calibrated from time to time to avoid wrong pressure settings. An on track tire service can always be asked for double checks at your tire pressure gauge or for some tire contact patch evaluations.

Trouble shooting:

- **Too much tire pressure**
  → Sliding at slightest provocation, wheel spin, responds to quickly
- **Tire pressure too low**
  → car feels unresponsive, rolls a lot, slow to take a set in corners
- Rear tire pressure ~2.9psi **higher than front** tire pressure gets over-steer
- Rear tire pressure ~2.9psi **lower than front** tire pressure gets under-steer

Note: Tire pressures to be Set-Up with the slower driver if using more than one driver per car

III. Tire temperature

All racing and high-performance street car tires are designed to operate within an optimum temperature range when driving near or at the limits of the racecar.

- **If the tire temperature is too low**, the coefficient of friction will be to low and maximum traction will not be achieved.
- **If the tire tread is too hot**, traction will again be lost and the tire will wear more quickly.

The optimum tire temperature range for the specific car should be requested at the tire brand engineer. The tire temperature should be measured by a tire pyrometer with a needle probe and checked as close as possible to the tire steel construction. Measuring the temperature with a needle probe will be much more accurate as the surface might cool down when entering into the pit lane at lower speeds.

Measuring temperatures:
The tire temperature range will be measured at the outside, middle and inside area of the tire patch.

Note: The difference between the spots should be ~10°C., per ex. outside 60°C., middle 70°C. and inside 80°C.

Trouble shooting:

- Too much tire temperature and wear at the center of the tire
  → too much tire pressure
- Mid temp. too height
  → set less tire pressure
- Mid temp. too low
  → set more tire pressure

Note: Tire wear check should be done with the tire brand engineer

Wear check with the tire depth indicator:

- Too much tire wear inside → check camber or toe-out settings
- Too much tire wear outside → check camber or toe-in settings

Tire graining:

- Could be a result of a “green track” (no rubber on tarmac, as beginning of the event)
- Tire compound not adapted to the track temperature

Tire cleaning on track:

Front: Apply excessive steering angle (Zig-Zagging) which cleans the tire surface.

Rear: Wheel spin or increase tire pressure to clean the tire in the middle.

IV. Brakes and straight line instability

Every corner will be followed by a straight line which will end up in a braking zone.
Straight line instability:

- Too much rear wheel toe-out, either static due to incorrect set-up or dynamic due to bump steer or deflection steer
- Way too much front toe-in or toe-out
- Uneven front castor or trail settings
- Loose or broken chassis, suspension or suspension link mounting points
- Dead shock absorber

Straight line instability under acceleration:

- Malfunction of limited slip differential
- Not enough rear toe-in
- Deflection steer from rear chassis, suspension member or mounting point
- Dead rear shock absorber
- Way too uneven corner weights

Straight line instability over bumps:

- Too much front toe-in or toe-out
- Uneven front castor or trail settings
- Dead or uneven shock forces or incorrectly adjusted packers / bump rubbers
- Way too uneven corner weights
- Front anti roll bar too stiff

Instability under hard braking, front end wanders:

- Too much front brake bias
- Too much front damper rebound setting

Instability under hard braking, car wants to spin:

- Too much rear brake bias
- Too much rear damper rebound setting
- Too much rear camber

V. Dampers

The primary purpose of the shock absorbers is to dampen oscillations or vibrations. The shock has to keep the spring from bouncing beyond one full cycle. The shock absorbers has two jobs. First, it must control oscillations of the unsprang mass. Second, the shock absorber must control the sprung mass of the car. The spring does most of the work in bump travel, while the shock controls the return motion with rebound travel.

Damper settings:

- Low speed adjustments when car is rolling (corners)
- Height speed adjustments for bumps and Kerbs

Note: Bump gains traction and helps in braking

Too much bump

- harsh reaction to road surface irregularities
- Car slides rather than sticking
- Car doesn't put power down well
- Car responds too quickly, slides at slightest provocation

Note: Rebound helps the unloaded axle

Too much rebound

- wheels do not return quickly to road surface after displacement
- Inside wheel in a corner may be pulled off the road by the damper
- Car doesn't put power down well at exit of corners when road surface isn't extremely smooth
- Instability under hard braking, car wants to spin.

VI. Springs

A spring, defined in terms of physics, stores energy. When a constant force is applied to a spring, it will store the energy of that force and return to its original shape when the force is no longer applied.

- Too much dive of the front while braking → harder spring needed
- Entry turn front more rolling than the rear → harder spring front needed
- Entry turn rear more rolling than the front → harder spring rear needed
- Rear no traction at all → softer spring rear needed

Bump rubbers / packers:
Note: Check ride height at height speed if bump rubbers or packers are not on block (With tie-rap at the damper-rod).

VII. Coner over-steer

Entry-corner oversteer:

- Front anti-roll-bar stiffer
- Rear ride height lower
- Front ride height higher
  (also if the car touches at the end of the main straight)
- Rear damper stiffer in re-bound
- Rear more Aero load
  (when issue happens in height speed corners > 4th gear)

Mid-corner oversteer:

- Rear more camber
- Front anti-roll-bar stiffer
- Rear more Aero load
- Rear softer springs

Exit-corner oversteer:

- Driver accelerate too early or too much
- Rear anti-roll-bar softer
- Rear damper softer in bump
- Front damper stiffer in re-bound
- Rear ride height lower
- Front ride height higher
- Rear more Aero load (when issue happens in height speed corners > 4th gear)

VIII. Corners under-steer

Entry-corner understeer:

- Driver trail-brakes too much (staying on brakes while turning in)
- Driver carries too much speed into the corner-entry
- Front anti-roll-bar softer
- Front ride height lower
- Rear ride height higher
- Front damper softer in bump
- Rear damper softer in re-bound
- Front more Aero load (when issue is at height speed corners > 4th gear)
- Rear less Aero load (when issue is at height speed corners > 4th gear)
- When the problem of the under-steer occurs when the tire temperature is too cold:
- try more tire pressure to get them quicker at target temperature

Mid-corner understeer:

- Front more camber
- Rear less camber
  (check lap-times for double check if driver feels car better)
- Front anti-roll-bar softer
- Front spring softer

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Exit-corner understeer:

- Driver accelerate too early (with still too much steering angle)
- Front ride height lower
- Rear ride height higher
- Front damper stiffer in re-bound
- Rear damper stiffer in bump
- Front anti-roll-bar softer

IX. Wet conditions

- Go to rain tires
- Rise front and rear up – Center of gravity rise (increase load transfer)
  - Adjust camber to initial Set-up
  - Adjust toe to initial Set-up
- Damper softer (Bump & rebound)
- More Aero where it is possible

X. Suspensions adjustments scans

Every test-kilometer should be used to better understand the car, therefore prepare well your tests and generate always a run-plan where you write down what you want to test / to learn about the different suspension adjustments.

A Set-up scan can be achieved on the following adjustments at the front and at the rear:

- Wheel-Toe
- Wheel-Camber
- Tire pressure
- Car-Ride-height
- Anti-roll-bar

How to do:
Start always with your base-line Set-up and run 7 laps on a new tire set

- Do a 1st change to a "positive" value and run 7 laps on a new tire set
- Do a 2nd change to a "negative" value and run 7 laps on a new tire set
- Go back to base-line Set-up and run 7 laps on a new tire set to evaluate any track improvement or downgrade comparing to the first base-line run

With this method you as an engineer and the driver will learn where to adjust to improve what kind of handling problem.

XI. Differential

Cars needs differentials between the driven wheels because the outside wheel in any cornering situation must travel on an arc of greater radius than the inside wheel so will have to turn more times.

The standard differentials allows to the wheels to have different speeds. When the wheel speed is very different, the car losses performance because all the torque is going to the unloaded wheel with more speed.
We need to minimize this difference between the wheels speed to improve the traction and the braking.
If the two driving wheels are locked together, the unloaded inside wheel will be forced to rotate at the same speed as the outside one (get less torque to reduce the speed), therefore we use a limited slip differential to adapt the difference of radiuses.

The idea behind the limited slip differential is to allow one wheel gets more torque than the other and to try to have the same wheel speeds.
Note:

- The outer wheel has always more load, so the outer wheel should have always more torque
- The diff. always load more torque in the outer wheel and less in the inner wheel
- More locking in the diff. means more torque difference between the outer and the inner wheel
- The angle of the ramps and the faces of the discs in contact give us the locking percentage
    - Less angle of the ramps, produces more locking torque
    - More faces of the discs in contact, produces more locking torque
- In a high locking diff. we can put much more torque in the outer wheel – that is the wheel with more grip and very little torque in the inner wheel – that is the wheel with less grip.
    - If we have little locking, we will have wheel spin and high difference wheel speed between both sides
    - If we have much locking, we will have the same speed in both sides and will be a problem in cornering

As the differential locking torque is improving the car handling on track, you should check the differential pre-load value at new condition and before every session.
When the pre-load changes too much during the season, this will get less differential locking torque, which could provoke inner wheel spins and result in entry-corner oversteer.