AMS throttle/torque mapping and turbo model briefish semi complete explanations by Niels (July 2021)

Contents

Engine Throttle / Torque mapping explained, to some extend.

RF1, GSC, GTR2 part throttle behavior

RF1 and GSC (and probably all ISI based games until RF2) use very simple logic to find the engine torque between 0% and 100% throttle.

You enter two torque curves, one for 0% throttle and one for 100% throttle. If your axis sensitivities are 50%, linear, your 0% torque is -50Nm and your 100% torque is +50Nm, then 50% throttle gives you 0Nm. Torque output is nothing more than simple linear interpolation between the 100% and 0% throttle curves based on your pedal position. For each RPM you get:

Torque = EngineBrakingCurve + (ThrottlePos * (EnginePowerCurve – EngineBrakingCurve))

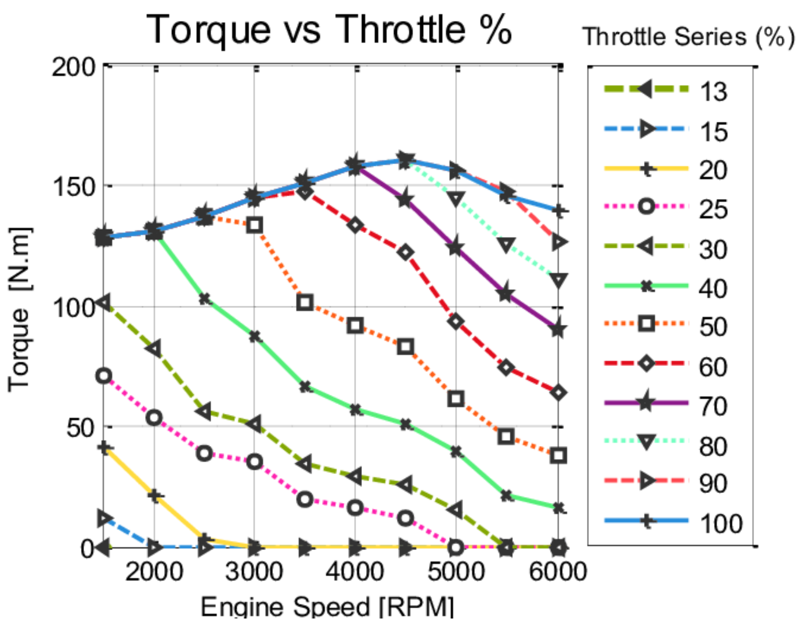
At 75% throttle with -50Nm engine braking and 200Nm full throttle torque:

137.5 = -50 + (0.75 * (200 - -50))

Why Bad?

My explanation for how it works in real life is this. At low RPM, you don't need a fully open throttle valve because you only need so much air to run at 3000 RPM compared to 9000RPM. So at 1/3rd throttle, you're basically allowing enough air into the engine for 3000 RPM to behave as if you're full throttle.

The RF1 method of linear interpolation does not allow the down sloping 'part throttle torque curves' that you probably see in real life as seen here:



In real life, throttle position sets the RPM at which the torque curve no longer has its max output. 4500RPM for 80% throttle 2000RPM for 40% throttle etc.
RF1 would basically give you just vertically offset versions of the 100% throttle curve, looks WAY different, and probably quite wrong.

Why Bad 2

This in my opinion has been a huge issue, probably not just in ISI based sims! In AC and ACC as well you tend to need a LOT of throttle at low RPM to get decent torque output. Yet if you get wheelspin, the torque curve is always shaped like the full throttle one, so torque grows usually until fairly high RPM. Wheelspin will get worse unless you let go off the throttle pedal.

If in real life, part throttle torque curves are sharply down sloping lines, you get two benefits.

1) Corner exit might start at 40% throttle, as this gives you a lot of torque at low RPM already, unlike the old model where you might start at 80% throttle.
2) Wheelspin is naturally controlled because if you get spin at 40% throttle, your torque curve is sloping down sharply, so even at constant throttle position, your torque will drop as revs and wheelspin grow. You limit your wheelspin this way
3) Meaning you can gradually apply 40% to 100% throttle, without wheelspin causing sudden rev increase
4) Unlike the old model where you start with 80% throttle, and then be very aware of wheelspin because you need to reduce throttle very soon once that happens to stop torque, and wheelspin, from growing.

However, since we've used the bad method since 1999, you have to re-learn proper throttle pedal use. Feeding it in rather than starting at 80%. Because if you start at 80%, you probably have 100% torque until pretty high revs.

AMS Virtual throttle solution

In AMS we made it possible to enter a different throttle percentage into the simple linear interpolation routine than your actual throttle position. At low RPM and small throttle, you can tell the game to use say 90% throttle instead of the 30% throttle you are actually applying.

You can create 21x21 tables where normalized RPM and throttle are going in 5% increments, and you can set your desired throttle output for each of this RPM and input throttle combinations.

Double linear interpolation is used to find the desired throttle position for every possible throttle input step and RPM.

In the engine.ini:

VThrottleGear=(a,b,c,d)

A = gear (0 = R, 1 = N, 2 = 1, 3 = 2 etc) Use 2 if you want the same map to be used for all gears (not sure if this is necessary but that at least works..)

B = input throttle, 0 to 100 , stepsize 5

C = Engine normalized RPM, 0 = 0, 100 = max RPM in Engine.ini torque curve, stepsize 5

D = Throttle output, 0 to 1

Example,

- Your engine.ini curve: RPMTorque=(3300,-30,180)
- This line: VThrottleGear=(2,20,30,0.6)
- Means: In 1st gear, at 20% input throttle and 30% of 11000RPM (3300), actually output 60% throttle

Old method engine torque: -30 + (0.2 * (180 - -30)) = 12Nm

New method engine torque: -30 + (0.6 * (180 - -30)) = 96Nm

For each 5% input throttle and 5% normalized RPM you need 21 lines, like this for 1st gear, 10% throttle input and then normalized RPM from 0 to 100 in steps of 5. You see output throttle dropping from nearly 80% to 0% as RPM goes from 0 to 100.

```
VThrottleGear=(2,10,0,0.77395)
VThrottleGear=(2,10,5,0.729855172413793)
VThrottleGear=(2,10,10,0.685760344827586)
VThrottleGear=(2,10,15,0.641665517241379)
VThrottleGear=(2,10,20,0.597570689655172)
VThrottleGear=(2,10,25,0.553475862068966)
VThrottleGear=(2,10,30,0.509381034482759)
VThrottleGear=(2,10,35,0.465286206896552)
VThrottleGear=(2,10,40,0.421191379310345)
VThrottleGear=(2,10,45,0.377096551724138)
VThrottleGear=(2,10,50,0.333001724137931)
VThrottleGear=(2,10,55,0.288906896551724)
VThrottleGear=(2,10,60,0.244812068965517)
VThrottleGear=(2,10,65,0.20071724137931)
VThrottleGear=(2,10,70,0.156622413793103)
VThrottleGear=(2,10,75,0.112527586206896)
VThrottleGear=(2,10,80,6.84327586206895E-02)
VThrottleGear=(2,10,85,2.43379310344828E-02)
VThrottleGear=(2,10,90,0)
VThrottleGear=(2,10,95,0)
VThrottleGear=(2,10,100,0)
```

You can adjust engine braking by giving some throttle output even when the input is zero. Here throttle output starts at 2% at zero RPM and grows to 4.14% at max RPM. You can do this per gear, so it is a nice way to reduce engine braking / handbrake effect in lower gears. It also allows you to use fair amounts of engine braking to bring the revs down when shifting (gear is in Neutral) without this causing handbrake effects in low gears.

```
VThrottleGear=(2,0,0,0.02)
VThrottleGear=(2,0,5,2.10689655172414E-02)
VThrottleGear=(2,0,10,2.21379310344828E-02)
VThrottleGear=(2,0,15,2.32068965517241E-02)
VThrottleGear=(2,0,20,2.42758620689655E-02)
VThrottleGear=(2,0,25,2.53448275862069E-02)
VThrottleGear=(2,0,30,2.64137931034483E-02)
VThrottleGear=(2,0,35,2.74827586206897E-02)
VThrottleGear=(2,0,40,0.028551724137931)
VThrottleGear=(2,0,45,2.96206896551724E-02)
VThrottleGear=(2,0,50,3.06896551724138E-02)
VThrottleGear=(2,0,55,3.17586206896552E-02)
VThrottleGear=(2,0,60,3.28275862068966E-02)
VThrottleGear=(2,0,65,3.38965517241379E-02)
VThrottleGear=(2,0,70,3.49655172413793E-02)
VThrottleGear=(2,0,75,3.60344827586207E-02)
VThrottleGear=(2,0,80,3.71034482758621E-02)
VThrottleGear=(2,0,85,3.81724137931034E-02)
VThrottleGear=(2,0,90,3.92413793103448E-02)
VThrottleGear=(2,0,95,4.03103448275862E-02)
VThrottleGear=(2,0,100,4.13793103448276E-02)
```

Or reduce full throttle output in lower gears for example if you want to account for losses, or do modern ECU mapping where engine output is possibly restricted in low gears or reverse gear. Here full input throttle in 1st gear gives 90% output throttle:

```
VThrottleGear=(2,100,0,0.9)
VThrottleGear=(2,100,5,0.9)
VThrottleGear=(2,100,10,0.9)
VThrottleGear=(2,100,15,0.9)
VThrottleGear=(2,100,20,0.9)
VThrottleGear=(2,100,25,0.9)
VThrottleGear=(2,100,30,0.9)
VThrottleGear=(2,100,35,0.9)
VThrottleGear=(2,100,40,0.9)
VThrottleGear=(2,100,45,0.9)
VThrottleGear=(2,100,50,0.9)
VThrottleGear=(2,100,55,0.9)
VThrottleGear=(2,100,60,0.9)
VThrottleGear=(2,100,65,0.9)
VThrottleGear=(2,100,70,0.9)
VThrottleGear=(2,100,75,0.9)
VThrottleGear=(2,100,80,0.9)
VThrottleGear=(2,100,85,0.9)
VThrottleGear=(2,100,90,0.9)
VThrottleGear=(2,100,95,0.9)
VThrottleGear=(2,100,100,0.9)
```

To use this smartly you have to create some spreadsheet logic to generate logically downsloping lines that you can alter.

Originally I made lines for 0, 20, 40, 60 80 and 100% throttle, and also for 20% rev increments. Then I used double linear interpolation to expand this the 5% steps required. Then I only have to manage 6 simple curves and interpolation gives me the 400 lines required for each gear.

Remember that the output of 0.9 isn't 90% torque, it is 90% throttle going into the old linear interpolation model from RF1, so if you have engine braking, then 90% throttle will be less than 90% of max torque!

Once you've put this into a spreadsheet or similar aid, it isn't as much work as it sounds anymore.

AMS Engine Turbo explained, to some extent.

Limitations

RF1, GTR2 and GSC had no turbo modelling. You could shape the torque curve as if the turbo was on boost, but that means instant response all the time, which is incredibly wrong.

The AMS model is pretty simple and poorly tested because we didn't have experienced programmers and I had never actually made some sort of model. The idea was, if there is nothing there now, anything will be better. The simplest way to achieve a feeling of lag, easily adjustable, and a way to decide at what revs and throttle the turbo starts to spool and how fast.

Workings

Exhaust Flow

Exhaust flow is calculated by the throttle position multiplied by normalized revs. The last RPM in your torque curve (say 8500RPM) becomes 1.0. This means flow is throttle (0..1) * RPM (0..1) so the exhaust flow can't be more than 1.0. The turbo is not self feeding, to make it behave more predictable. So even at boost, exhaust flow is still 0..1.

You can use either the pedal position or the recalculated throttle discussed in the torque/throttle maps. This is recommended as it reflects better the flow coming out of the engine, and allows for better low throttle response of the turbo, assuming your throttle/torque maps are 'sensible'.

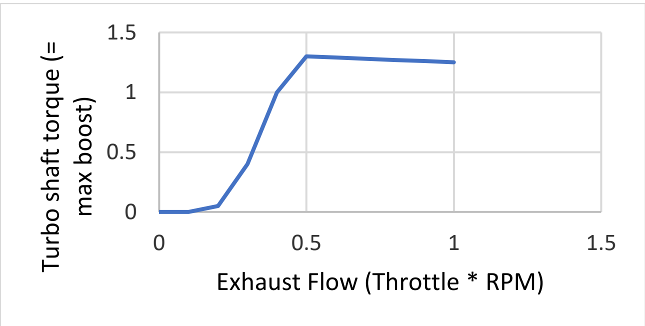
Pedal Pos 20%, Throttle/Torque map new pedal pos 60%:

TurboUseVirtualThrottle=1 gives an exhaust flow of 0.6 * normalized RPM

TurboUseVirtualThrottle=0 gives an exhaust flow of 0.2 * normalized RPM

Flow creates torque on a turbo shaft

Exhaust flow goes into a lookup table with exhaust flow on the x axis and 'turbo shaft torque' on the y axis. The turbo shaft torque will spin up the turbo. The values in the curve will also be your maximum boost as will be explained later. This is a 1.3 bar boost turbo:

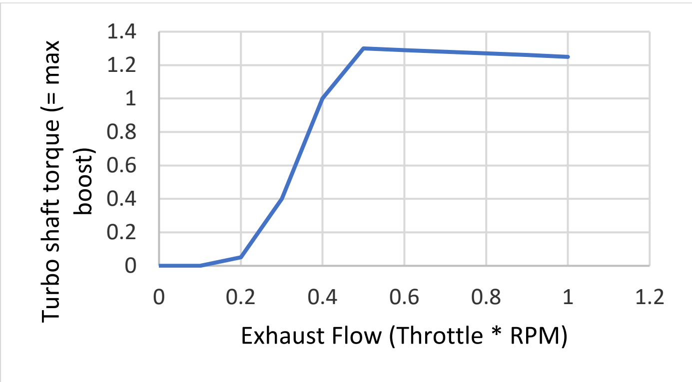


At FULL throttle, (1.0) the X axis becomes your normalized RPM, i.e. 0 to 8500 becomes 0..1. When the throttle output is 0.5, then your X axis, even with RPM at 8500, only goes to 0.5, just about the point where 1.3bar of boost is reached. For full throttle, the torque on the turbo shaft is 1.0 at 0.4 RPM, which would be 0.4 * 8500 = 3400.

There are 11 points in the curve

ExhaustTurboShaftTorque=0
ExhaustTurboShaftTorque=0
ExhaustTurboShaftTorque=0.05
ExhaustTurboShaftTorque=0.4
ExhaustTurboShaftTorque=1.0
ExhaustTurboShaftTorque=1.3
ExhaustTurboShaftTorque=1.29
ExhaustTurboShaftTorque=1.28
ExhaustTurboShaftTorque=1.27
ExhaustTurboShaftTorque=1.26
ExhaustTurboShaftTorque=1.25

You can use ExhaustFlowStep=0.1 to make these 11 points cover 0..1 exhaust flow. Use ExhaustFlowStep 0.08 to condense the curve to only reach 0.8 of exhaust flow, possibly giving you finer curve resolution in the 'used rev range' as your engine won't often spin at the fastest speed in the torque curve.



BUG alert! The turbo will go crazy after it reaches the end, so you can't safely use a ExhaustFlowStep smaller than the ratio of the cars rev limit versus the max RPM in the curve. I.e. if your rev limit is 7500 and the final torque curve point is at 8500, your ExhaustFlowStep becomes 0.1 * (7500/8500) = 0.088. Any less and the boost at high RPM and Throttle might behave erratic.

Remember the curve maximum will also be your max boost at that combination of throttle and RPM. In the above curve you get 1.3 boost at 0.4 exhaust flow, which can be 0.4 RPM (3400) and 1.0 throttle, or 1.0 RPM (8500) and 0.4 throttle.

Remember also, we don't HAVE boost yet, we just decided the torque that will spin up the turbo depending on your throttle and revs.

Torque spins up the turbo shaft

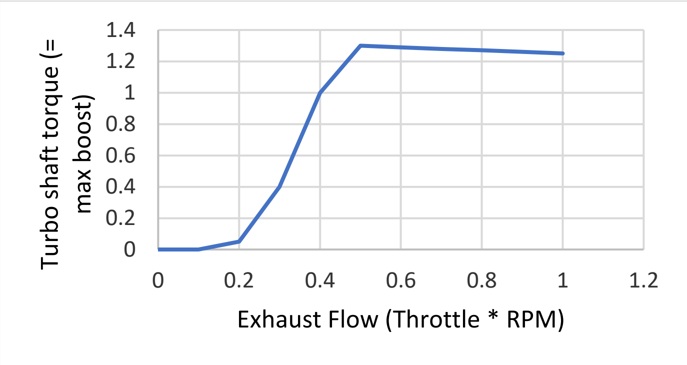
Torque, after looking it up in the table above, starts to accelerate the turbo shaft.

Acceleration = Torque / Inertia

This is where the TurboInertia=0.5 line comes into play. Since everything is normalized, we're not dealing with any physical real world inertia value. Based on your RPM and throttle, a certain maximum torque will be available, and it will spin the turbo up quicker if your TurboInertia is smaller. You could create an engine dyno with Motec and a weird car that has its tires dangling in the air (undertray -0.5 meters), or just go by ear and hear how long it takes for the turbo sounds to reach a high pitch with various curve shapes and.

Turbo Speed causes friction

Now that the turbo is spinning up, we used a very simple system to stop it getting out of control Turbo friction torque is equal to the speed. It is a little odd but works like this.



The max torque is 1.3. As the turbo spins up, at 0 speed there is 0 friction. At 0.5 speed there is 0.5 friction. At 1.3 speed, there is 1.3 friction. At that point you have 1.3 torque driving the turbo and 1.3 friction. Zero total torque, so no more turbo acceleration.

This way, the turbo curve also becomes the speed limit for the turbo. If your big 80s F1 turbo goes to 5.0 torque, friction will be 5.0 at a speed of 5.

Speed = boost

As mentioned briefly, and confusingly earlier, speed = boost. I hope you see now that we've created a non explosive turbo that has a maximum speed equal to the turbo torque curve, we can use the speed as "boost". A boost of 0 has atmospheric pressure going into the engine. A boost of 1 has 1Bar above atmospheric.

Boost = Torque

Boost multiplies the engine torque. In the curve above we reach 1.3 bar at 0.5 RPM i.e. 4250RPM and full throttle. If your engine has RPMTorque=(4250,-50,150) then the 150Nm torque becomes 150 + (1.3 * 150) = 345Nm

Again, since this is SPEED of the turbo, the response isn't instant! Turbo speed builds up depending on the turbo inertia. The instant you hit full throttle at 4250RPM, and if the turbo speed is 0 you have 150Nm torque. But then the turbo spins up as it has 1.3 torque applied to the inertia, and speed, thus boost, grows over time.

BUG alert (another one!) .TurboEfficiency was meant to reduce the linear engine torque scaling. Above, a turbo speed of 1.0 meant a doubling of engine torque. The plan was when using TurboEfficiency=0.8 to make a 1.0 turbo speed cause a 0.8 increase of torque. Sadly this seems very broken so you better use 1.0 for TurboEfficiency as I have no idea what weirdness is happening here.

Predicting torque curves

Since the turbo curve effectively is your max boost curve as well, you can plot your theoretical max 'on boost' torque curve as you can simply 'de normalize' the curve so it goes to 8500 and have the turbo torque value be a multiplier for your existing torque curve where

TotalTorque = Engine.ini Torque + (TurboTorqueCurveValue * Engine.ini Torque)

Bearing in mind you will never QUITE reach this as the turbo will lag behind. In first gear with a fast rising RPM, your effective torque curve will be different. As you go from 4000 to 8000RPM, perhaps the boost has not even come in fully. In 6th gear where the time spent to go from 4000 to 8000 RPM is much greater, the turbo probably is spooled up at 5000RPM.

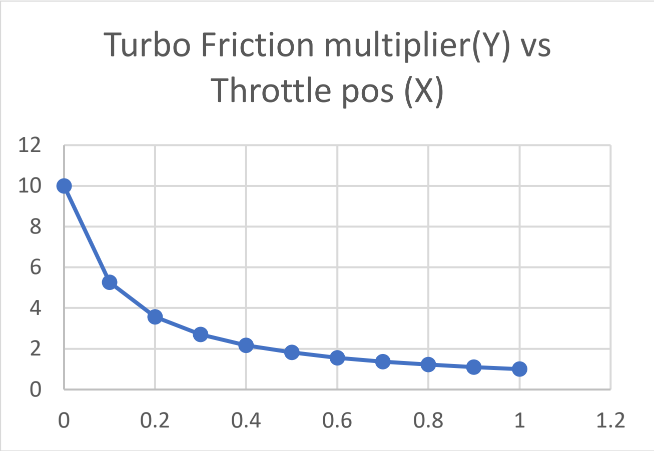
Adjustable boost

ScalableBoostLimiter=1 //if car HAS adjustable boost in garage and in car adjustments
ScalableTurboBoostLimitRange=(0,0.1,13) //range from 0 bar with 13 steps of 0.1 bar
ScalableTurboBoostLimitSetting=5 //default setting

BlowOff Valve

Not a lot of testing was done on this!

Pressure in the intake can increase rapidly if you close the throttle. The turbo friction will increase by this amount:



BlowoffValveInstalled=1
BlowoffValvePressureBase=0.25
BlowoffValvePressureBoostLimit=1

The BlowOff Valve shouldn't open below the boost pressure that we run. I doubt things behave when you try to model this. The current boost limit is either hard set or adjustable. Say it is 2.5 Bar. Then with a PressureBase of 0.25 and a PressureBoostLimit of 1, the blowoff valve will open at 0.25 + (1.0 * 2.5) = 2.75 bar

So instead of the pressure rising to possibly 10* boost (25bar) at 0% throttle, the blowoff valve limits it to 2.75bar. Without the valve, turbo speed will drop rapidly.

Other bits:

WasteGateInstalled = 1   I have not used 0. Probably not tested. I don't remember what this might do if set to 0

TurboBoostLimitation=0 I have never set it to 1, I don't know what it does as I always use adjustable boost to limit it..