

ALPHA Engine Generation Toyota TNGA 2.5L

version: 01-12-2017

This engine represents Toyota's new TNGA gasoline naturally aspirated engines presented at the 25th Aachen Colloquium Automobile and Engine Technology in 2016. The target presented for this engine is over 40% thermal efficiency and a high engine specific power of 60kW/L for vehicles with conventional transmission. The specific data selected for this engine is the 2.5L with 40% peak thermal efficiency, and peak power of approximately 150 kW.

Engine Physical Characteristics

Source: Eiji Murase, Rio Shimizu, "Innovative Gasoline Combustion Concepts for Toyota New Global Architecture". 25th Aachen Colloquium Automobile and Engine Technology 2016

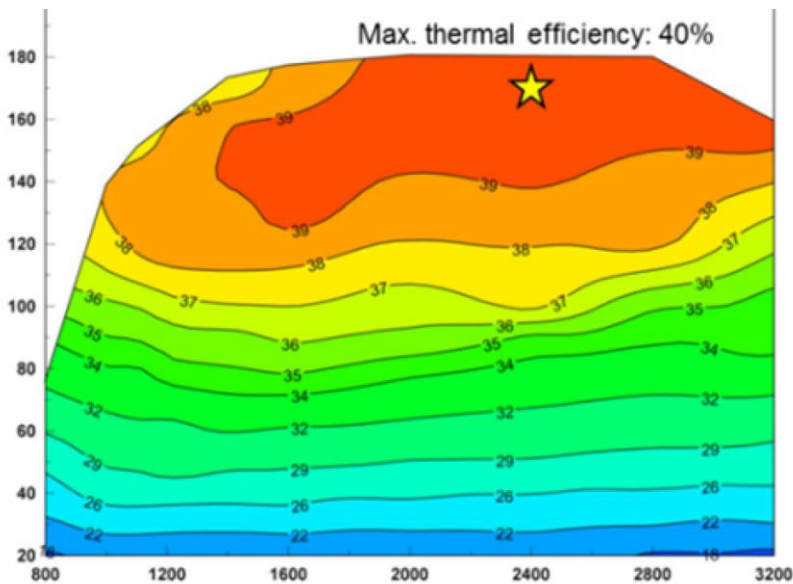
```
engine = [];  
engine.name = 'Toyota TNGA 2.5L';  
engine.combustion_type = enum_engine_combustion_type.spark_ignition;  
engine.displacement_L = 2.5;  
engine.num_cylinders = 4;  
engine.compression_ratio = 13;
```

Source: Estimated from similar inline 4 cylinder engines

```
engine.inertia_kgm2 = 0.095;
```

Load Map Image

Source: Eiji Murase, Rio Shimizu, "Innovative Gasoline Combustion Concepts for Toyota New Global Architecture". 25th Aachen Colloquium Automobile and Engine Technology 2016



This image was digitized by tracing the efficiency contours.

```
load('..\data\2016 Toyota 2.5L TNGA efficiency image.mat');  
  
image_data.name = 'Efficiency Map Image';  
image_data.speed_rpm = efficiency(:,1);  
image_data.torque_Nm = efficiency(:,2);  
image_data.thermal_efficiency_pct = efficiency(:,3);  
image_data.fuel_prop = class_REVS_fuel('MTE_GASOLINE'); % Need assumed fuel for Efficiency Input
```

Additional Fueling Points

The maximum torque data presented in the paper efficiency map is roughly 180 Nm, while the maximum torque output presented is approximately 250 Nm. Extrapolation of the image efficiency data resulted in high load fuel consumption that is likely too efficient. These additional points are added to provide more appropriate behavior.

```
estimated_data.name = 'Estimated Data';
estimated_data.speed_rpm = [ 2000, 2500, 3000, 2500, 3000, 4000, 5000, 5000, 5000, 5500, 7000,
    900, 800, 1500, ];
estimated_data.torque_Nm = [ 200, 195, 190, 225, 220, 240, 240, 150, 50, 190,
    200, 170, 140, 200, ];
estimated_data.eta_pct = [ 37, 39, 35, 39, 34, 35, 33, 35, 33, 33, 34,
    33, 35, 26, 35, 34, 33, 33, 33, 34, ];
estimated_data.fuel_prop = class_REVS_fuel('MTE_GASOLINE'); %Need assumed fuel for Efficiency Input
```

An estimated idle point has also been included as extrapolation in that region appeared to be overly optimistic.

```
estimated_data2.name = 'Estimated Data';
estimated_data2.speed_rpm = 630;
estimated_data2.torque_Nm = 7;
estimated_data2.fuel_gps = 0.17;
```

Maximum Torque (WOT) Curve Data

Source: Eiji Murase, Rio Shimizu, "Innovative Gasoline Combustion Concepts for Toyota New Global Architecture". 25th Aachen Colloquium Automobile and Engine Technology 2016

22 25th Aachen Colloquium Automobile and Engine Technology 2016

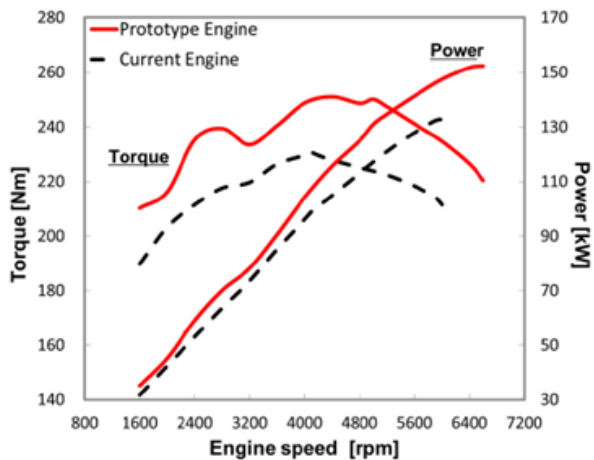


Fig. 34: Comparison of engine performance result between current model and TNGA prototype 2.5L conventional engine

```
load('..\data\2016 Toyota 2.5L TNGA WOT image.mat');

WOT_data{1}.speed_rpm = image_WOT(:,1);
WOT_data{1}.torque_Nm = image_WOT(:,2);

% Add Low speed point
WOT_data{2}.speed_rpm = 900;
WOT_data{2}.torque_Nm = 170;
```

Minimum Torque Curve Data

Source: None - With no available data the REVS_build_engine function will utilize a default minimum torque curve which is scaled by engine displacement.

Fuel Properties

Source: No Fuel Information - Assuming Generic Gasoline

```
engine.fuel = class_REVS_fuel('MTE_GASOLINE');  
disp(engine.fuel);
```

class_REVS_fuel with properties:

```
            id: 'MTE_GASOLINE'  
    description: 'Gasoline for MTE'  
    density_kgpL_15C: 0.7401  
    energy_density_MJpkg: 43.3088  
    carbon_weight_fraction: 0.8660  
    anti_knock_index: 93  
    alcohol_pct_vol: 0  
    gCO2pgal: 8887  
    energy_density_BTUplbm: 1.8619e+04  
    specific_gravity: 0.7408
```

Idle Speed

Source: Estimated based on idle speed observed during benchmarking of several recent gasoline engine vehicles, 600-700 RPM is typical. 700 RPM was selected to be conservative for this engine's idle fuel consumption.

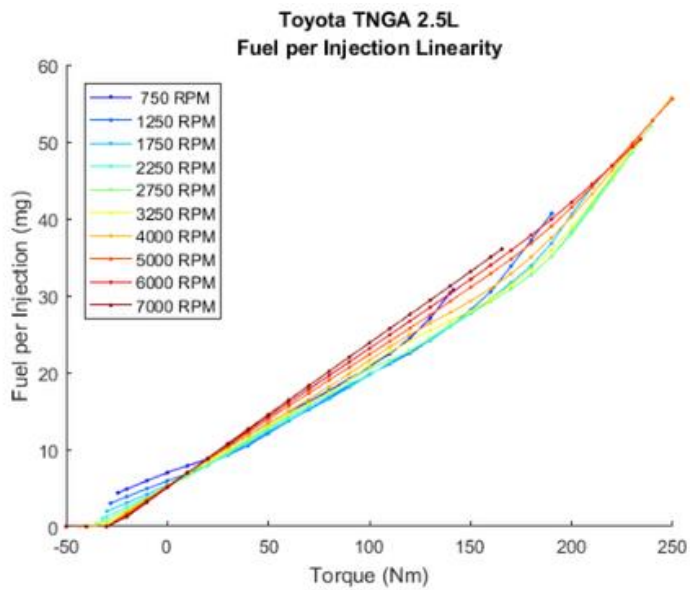
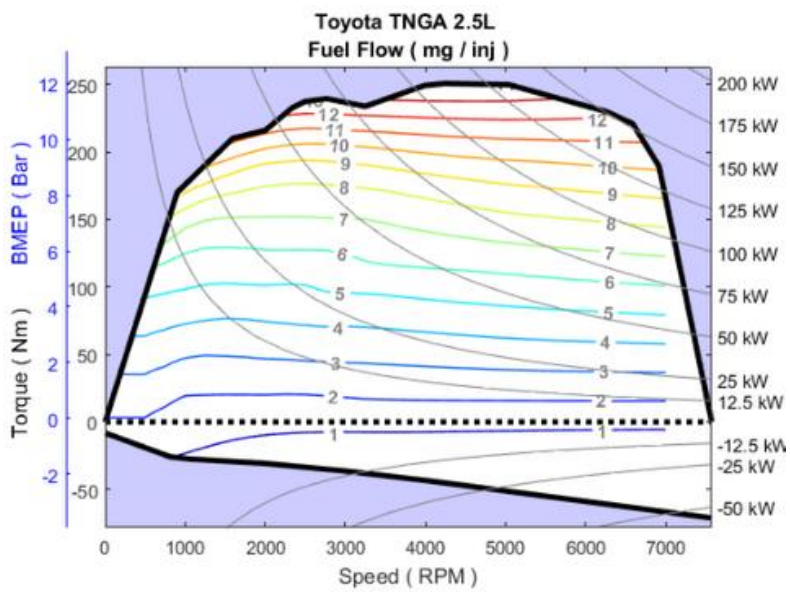
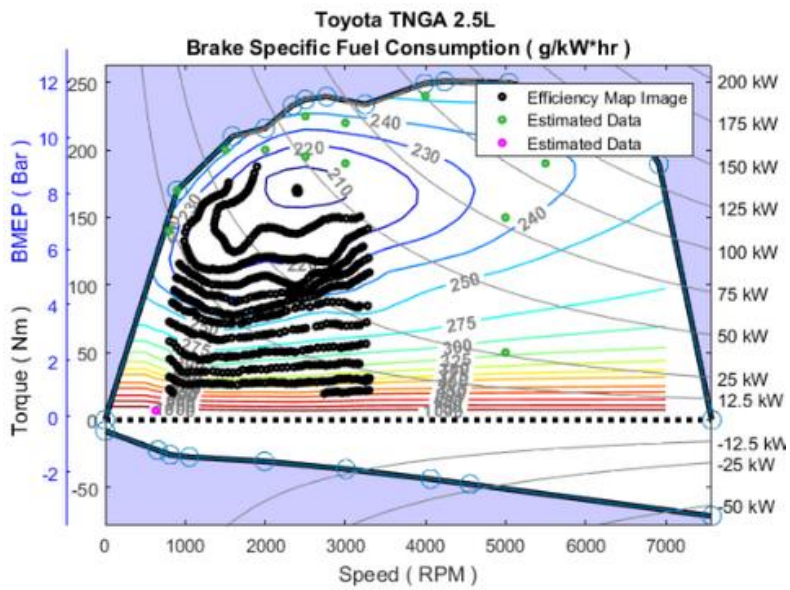
```
engine.idle_speed_radps = 700 * convert.rpm2radps ;
```

Build Fuel Map

Generate complete REVS engine description using REVS_build_engine.

Output grid for fuel map must be specified when source data is not approximately gridded.

```
out_speed = [0, 500:250:3500,4000:500:7000] * convert.rpm2radps;  
out_torque = -50:10:260;  
  
engine = REVS_build_engine(engine, {image_data, estimated_data, estimated_data2}, 'WOT',WOT_data ,  
'out_speed',out_speed,'out_torque',out_torque,'no_point_labels');
```



0.00000000, 0.070263677, 0.093556150, 0.10903669, 0.11702824, 0.11834755, 0.11435333, 0.10662222, 0.096520388, 0.084981318,
0.072520561, 0.059397733, 0.045769465, 0.031716722, 0.0058785434, 0.00000000, 0.00000000, 0.00000000, 0.00000000,
0.00000000, ;
0.00000000, 0.089576920, 0.12155484, 0.14534409, 0.16170633, 0.17226892, 0.17923581, 0.18464475, 0.18988284, 0.19564919, 0.20213120,
0.20925817, 0.21684825, 0.22457896, 0.24061153, 0.25255511, 0.26151638, 0.26962425, 0.27743645, 0.28428040, 0.28925482, ;
0.00000000, 0.10874555, 0.14892552, 0.18042351, 0.20498245, 0.22551876, 0.24466436, 0.26418716, 0.28518550, 0.30816771, 0.33334781,
0.36067901, 0.38960805, 0.41911094, 0.47445608, 0.52153109, 0.56500386, 0.60795041, 0.65103900, 0.69365770, 0.73502302, ;
0.00000000, 0.12757533, 0.17499135, 0.21298214, 0.24636351, 0.27921130, 0.31271021, 0.34720475, 0.38373428, 0.42302831, 0.46621822,
0.51385989, 0.56451983, 0.61526586, 0.70554719, 0.78685839, 0.86565632, 0.94445527, 1.0235107, 1.1023260, 1.1804370, ;
0.00000000, 0.14511931, 0.19736995, 0.24159209, 0.28717666, 0.33608530, 0.38600660, 0.43585618, 0.48651153, 0.54046107, 0.60099842,
0.66908960, 0.74190517, 0.81038537, 0.93134471, 1.0477259, 1.1631930, 1.2788574, 1.3944821, 1.5099329, 1.6252486, ;
0.00000000, 0.16310738, 0.21874349, 0.26815563, 0.33322742, 0.39804500, 0.46454211, 0.53227805, 0.59339865, 0.66155541, 0.74217176,
0.82779080, 0.91906435, 0.99699404, 1.1503839, 1.3040615, 1.4576498, 1.6109420, 1.7635530, 1.9160855, 2.0691757, ;
0.00000000, 0.18671410, 0.25786458, 0.31041014, 0.38621862, 0.45915327, 0.54368393, 0.63194316, 0.70842632, 0.79393991, 0.88873420,
0.99515139, 1.0715597, 1.1699166, 1.3643988, 1.5562479, 1.7492410, 1.9404732, 2.1303009, 2.3203944, 2.5119386, ;
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1.1409492, 1.2395052, 1.3503492, 1.5753896, 1.8046687, 2.0382151, 2.2671235, 2.4943344, 2.7225343, 2.9532921, ;
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1.2925515, 1.4144732, 1.5356427, 1.7844278, 2.0506028, 2.3244417, 2.5905001, 2.8553943, 3.1223040, 3.3930469, ;
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1.4452479, 1.5827733, 1.7140103, 1.9925261, 2.2962249, 2.6063659, 2.9104311, 3.2134627, 3.5196722, 3.8310800, ;
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1.5893436, 1.7301354, 1.8799937, 2.2027037, 2.5437558, 2.8870086, 3.2274484, 3.5688088, 3.9148080, 4.2673401, ;
0.00000000, 0.30322461, 0.44130439, 0.57243747, 0.69741329, 0.82422146, 0.96577886, 1.1202483, 1.2806142, 1.4447439, 1.5996748,
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2.0737924, 2.2709185, 2.4684735, 2.8787618, 3.2974056, 3.7274499, 4.1716149, 4.6269406, 5.0915506, 5.5663880, ;
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2.2052531, 2.4551063, 2.6834917, 3.1087636, 3.5475270, 4.0088223, 4.4887867, 4.9807272, 5.4830354, 5.9971883, ;
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2.9388867, 3.2030304, 3.4866953, 4.1232657, 4.7988154, 5.4773639, 6.1318201, 6.7917700, 7.4703306, 8.1674579, ;
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3.3022949, 3.6209532, 3.9556195, 4.6707694, 5.4073925, 6.1304486, 6.8357527, 7.5682598, 8.3082527, 9.0546553, ;
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3.5386299, 3.8874582, 4.2501445, 5.0019550, 5.7613036, 6.5031495, 7.2232331, 7.9854180, 8.7448876, 9.5032857, ;
0.00000000, 0.81649266, 1.1823327, 1.5210420, 1.8341932, 2.1215291, 2.3669915, 2.6104058, 2.8695228, 3.1580271, 3.4831301,
3.8342364, 4.2046940, 4.5863305, 5.3666020, 6.1481335, 6.9116096, 7.6581082, 8.4274774, 9.1949365, 9.9569857, ;
0.00000000, 0.85764195, 1.2495166, 1.6173972, 1.9613020, 2.2795635, 2.5711689, 2.8497377, 3.1347116, 3.4471575, 3.7966880,
4.1750614, 4.5629770, 4.9561995, 5.7589074, 6.5641919, 7.3522473, 8.1218655, 8.8918199, 9.6583927, 10.419141, ;
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0.00000000, 0.93586967, 1.3762436, 1.7980371, 2.2012800, 2.5869959, 2.9580097, 3.3192818, 3.6795217, 4.0524168, 4.4593373,
4.8841579, 5.3100173, 5.7364242, 6.6003070, 7.4578467, 8.3011229, 9.0967727, 9.8648207, 10.617660, 11.358538, ;
0.00000000, 0.97351649, 1.4376195, 1.8866306, 2.3210127, 2.7421086, 3.1525042, 3.5564054, 3.9601462, 4.3717166, 4.7965012,
5.2336234, 5.6785346, 6.1270917, 7.0324026, 7.9178808, 8.7899621, 9.5940173, 10.363072, 11.107679, 11.832824, ;
0.00000000, 1.0107308, 1.4986634, 1.9753464, 2.4415677, 2.8987125, 3.3488302, 3.7946451, 4.2393248, 4.6857560, 5.1357295,
5.5910817, 6.0521891, 6.5173433, 7.4564740, 8.3765948, 9.2676747, 10.091100, 10.864435, 11.600962, 12.308675, ;
0.00000000, 1.0478085, 1.5596581, 2.0642406, 2.5626205, 3.0561077, 3.5459299, 4.0328239, 4.5167838, 4.9973999, 5.4749690,
5.9513238, 6.4287915, 6.9084453, 7.8784013, 8.8333520, 9.7430728, 10.587339, 11.366769, 12.095440, 12.785145,];

% Fuel Properties

engine.fuel = class_REVS_fuel('MTE_GASOLINE');

% Idle Speed

```
engine.idle_speed_radps = class_REVS_dynamic_lookup;
engine.idle_speed_radps.axis_1.signal = 'veh_spd_mps';
engine.idle_speed_radps.axis_1.breakpoints = [ 0.00000000, 10.000000,    ];
engine.idle_speed_radps.table = [ 73.303829,    ; 73.303829,    ];

% Pedal Calibration
engine.pedal_map_type = enum_engine_pedal_map_type.max_engine_power;

% Calibration Adjustment Factors
```

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