TVS2 Technology: Improving Supercharger Efficiency and Capability

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Abstract: The market drivers of higher power density and improved fuel economy have led to an increased demand of efficiency and capability from the boosting system. Eaton has developed its next generation supercharger that is tailored to the needs of combining a supercharger and turbocharger in series. Eaton's TVS2 supercharger technology focuses on improved thermal efficiency, reduced mass, wider airflow range, and high-pressure stage capability in a series boosting configuration. The project requirements have driven improvements in 9 technology areas to create an attractive system solution. These technologies have been demonstrated through a 400cc displacement supercharger but have been designed to apply to a range of sizes

Key Words: Supercharger, Performance, Efficiency, Turbo-Super, Compound Boost, NVH, Packaging, Mass Reduction

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1 Introduction

Advanced boosting systems for the passenger car market will become more prevalent to satisfy the typically diverging needs of increased vehicle performance and improved fuel consumption simultaneously. To address these needs, Eaton has developed the next generation positive displacement supercharger. TVS2 technology provides significant capability and efficiency improvements. TVS2 technologies specifically cater to the needs of a boosting system that combines a supercharger and turbocharger. As an additional benefit, many of the enhancements can also be applied to a single supercharger application.

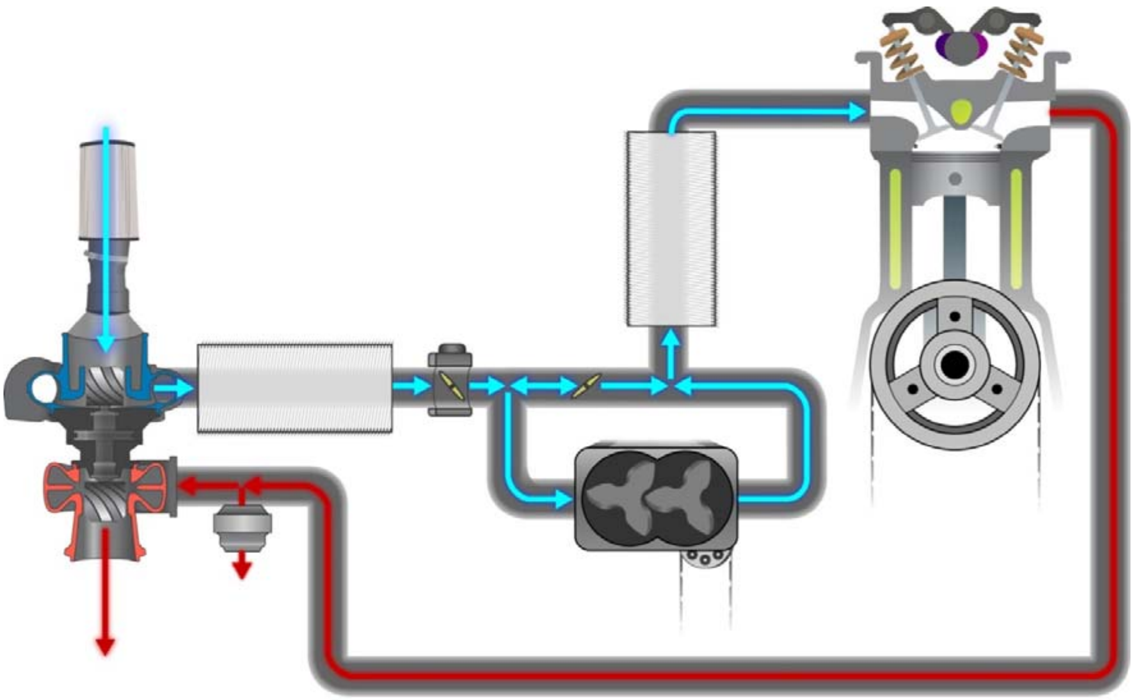

Figure 1: Turbo-Super system layout

The TVS2 project goals focused on creating a state of the art supercharger targeting the performance metrics critical to the combined boosting system. Efficiency being the top priority, many of the improvements either directly reduce the power required to drive the supercharger or allow other aspects of the system to be optimized. The first area of focus was the thermal efficiency, as it directly impacts the supercharger drive power. The efficiency improvement areas were targeted to the regions where the supercharger is most utilized.

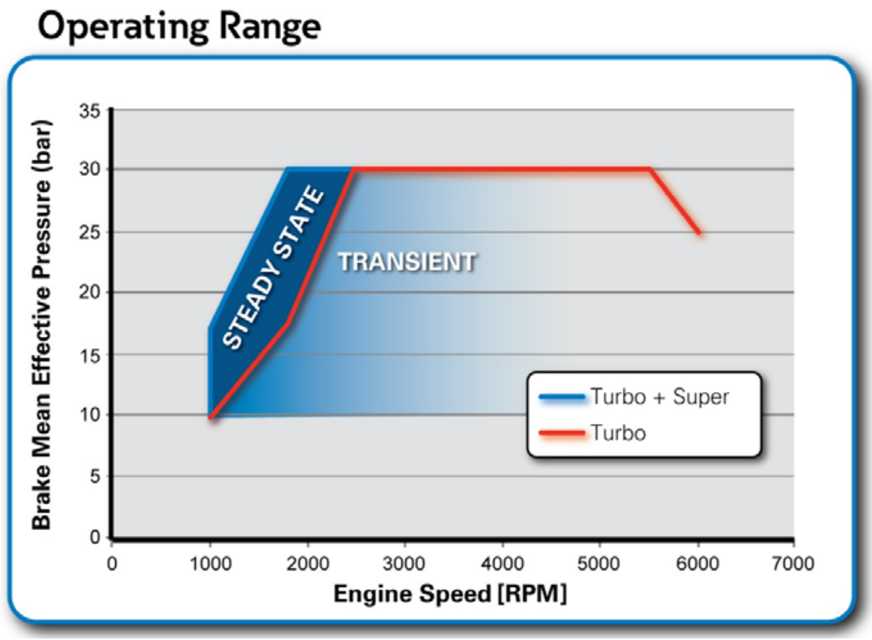

Figure 2: Supercharger operation region on engine BMEP map

The TVS2 thermal efficiency improvements are focused at the steady state operating region while the increase in capability expands the transient operating region to higher engine speeds, as shown in Figure 2 above. A larger transient region has the potential to offer more flexibility in turbocharger selection and will allow greater focus on system level efficiency.

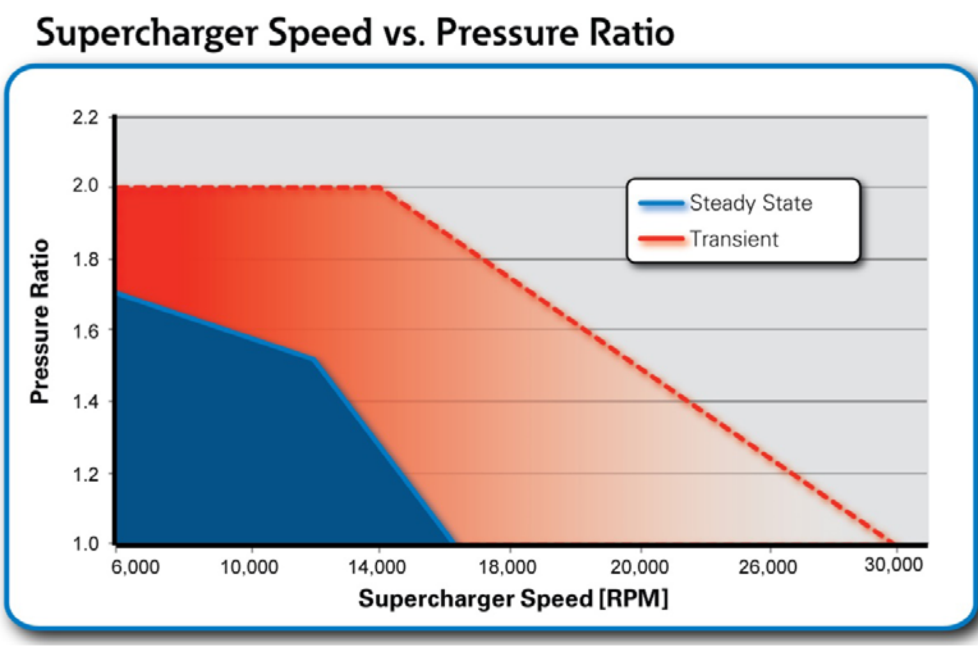

Figure 3: Supercharger Speed vs. Pressure Ratio

Figure 3 above shows an example of steady state and transient pressure ratio curves for a supercharger. The supercharger speed vs. pressure ratio graph will be similar for either a Super-Turbo system or a Turbo-Super configuration. However, in a Turbo-Super configuration, where the supercharger is utilized as the high pressure stage, the supercharger must withstand peak intake manifold pressures. Additionally, when the engine throttle is located upstream, the supercharger must resist the maximum intake manifold vacuum conditions. The Turbo-Super configuration has expanded the operating pressure range requirements for the supercharger compared to a Super-Turbo configuration. The expanded pressure operating range also increases the pressure differential across the supercharger. With an atmospheric inlet pressure to the supercharger, a 2.0 pressure ratio would only require a ΔP of 100 kPa. When utilized as the high pressure stage device, with 200 kPa intake pressure, a 2.0 pressure ratio requires a 200 kPa ΔP and 400 kPa outlet pressure.

Enabling engines to achieve peak torque at low engine speeds requires the supercharger to provide sufficient airflow at low supercharger speeds. The airflow is a combination of supercharger speed (drive ratio), displacement, and volumetric efficiency. To reduce the power needed to drive the supercharger, Eaton has focused on improving the supercharger volumetric efficiency at low speeds. The operating point that Eaton uses to quantify this metric is 4000 rpm and pressure ratio of 1.4. Improving the low speed volumetric efficiency reduces supercharger drive power in two ways; enabling a lower drive ratio for the same airflow rate and increasing the thermal efficiency.

When adding a second boosting device to an engine, the extra mass and complexity must be minimized to all extents possible. Mass reduction and packaging envelope are key metrics that were important from the beginning of development. All efforts to eliminate mass are evident in the execution of the TVS2 development.

Key metrics of the TVS2 project are listed below. This project utilized the TVS R410 supercharger as a baseline. The development project consisted of the rotating group and housing. The cover and pulley were excluded as they will be different for every application.

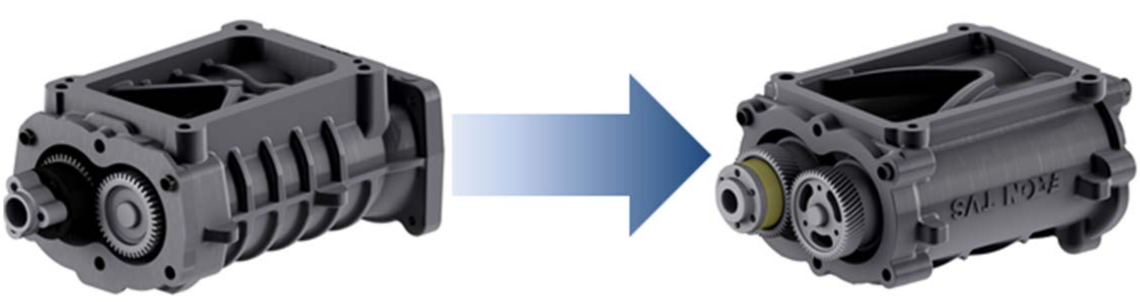

Figure 4: TVS R410 (left) vs. TVS2 V400 (right)

TVS2 Project goals

Goal	TVS R410	TVS2 Target	OEM Benefit
Max. Outlet pressure	2.5 Bar	4.0 Bar	Enables high pressure stage supercharger (Turbo-Super)
Low Speed Flow	51% VE	68% VE	Reduction in supercharger drive power for the same airflow rate
ΔP (Outlet-Inlet)	150 kPa	200 kPa	Enables increased boost pressure for high pressure stage
Max Transient speed	24,000 rpm	30,000 rpm	Wider supercharger airflow range increases turbocharger sizing flexibility
Mass Reduction	Baseline	-25%	Reduced engine mass and improved packaging
Inertia Reduction	Baseline	-5%	Simpler engine calibration on clutched applications
NVH Reduction	Baseline	-3 dB outlet pulsations	Reduced NVH treatment required

2 Thermodynamics and Efficiency

The key project goals targeting improved low speed volumetric and thermal efficiency of the supercharger can be linked together. Improving both volumetric and thermal efficiency also reduces the overall drive power for a given flow rate.

At low speeds, volumetric efficiency (VE) can be a direct measure of the performance for a volumetric flow device. This efficiency is expressed at standard atmospheric conditions and is calculated by Eq. 1 below:

$$\eta_{volumetric} = \frac{\dot{V}_{real}}{\dot{V}_{ideal}} \qquad \text{Eq. 1}$$

VE provides insight to how well the

Figure 5 below is a VE curve for the base TVS R410 unit, the benchmark to the TVS2 design. The shape of the curve shows how the VE drops in the low speed range of the supercharger. The target for the original TVS product was to develop a game changing device that encompassed a broad operating range. This was done by increasing the speed capability of the device through porting and rotor designs. However, the design changes did have an impact on VE at lower speed ranges, an issue the TVS2 supercharger addresses.

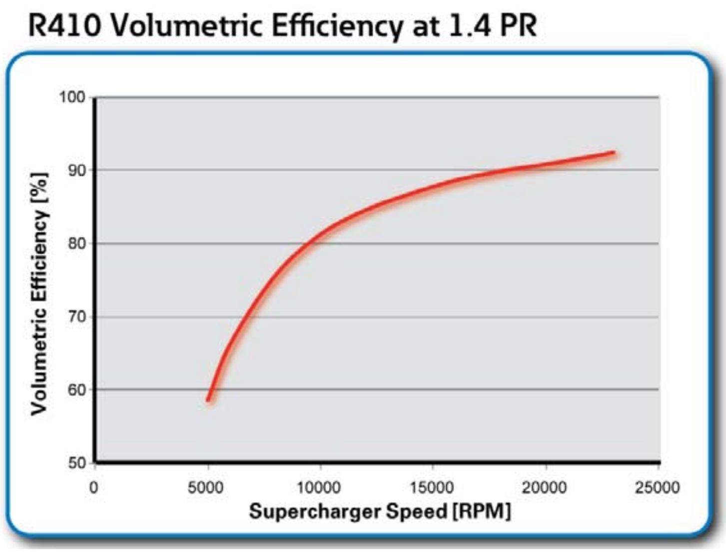

Figure 5: Volumetric Efficiency of the R410 at a 1.4 Pressure Ratio

The VE curve can be reflected in a thermal efficiency map as evidenced in the R410 thermal efficiency map in Figure 6 below. While the VE curve does provide insight to the performance of the device, it does not capture the complete picture.

The main focus for improved overall efficiency in the TVS2 supercharger is within the steady state condition, where drive power is critical. Emphasis was be placed on improved VE and higher peak thermal efficiencies in this area. The thermal efficiency, represented by $\eta isentropic=\frac{h_{2s}-h_1}{h_2-h_1}$ Eq. 2 below, indicates how effectively the supercharger moves and compresses the air.

$$\eta_{isentropic} = \frac{h_{2s}-h_1}{h_2-h_1} \quad \text{Eq. 2}$$

The current state-of-the-art TVS R410 thermal efficiency map indicates peak thermal efficiency at the high speed ranges.

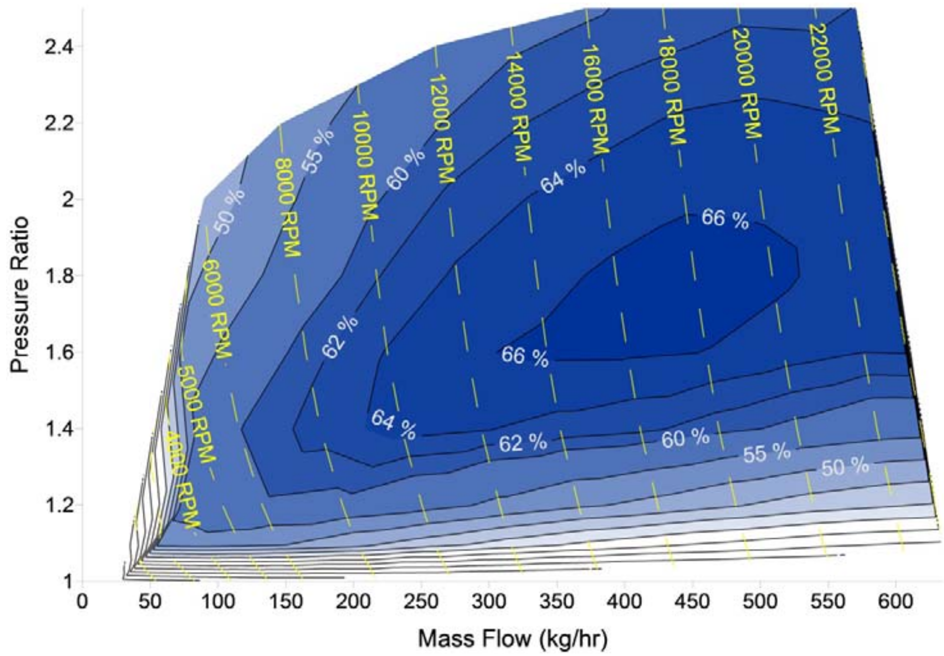

Figure 6: R410 Thermal Efficiency Map

The goal for TVS2 was to shift the peak efficiency island, centered in the 16,000-18,000 rpm speed range in the R410, as far to the low speed area as possible while maintaining or improving efficiencies at the higher speed ranges.

Comparing the two graphs of VE, Figure 5, and thermal efficiency, Figure 6, illustrates the trend and relationship between VE and the thermal efficiency. Simply put, poor VE leads to poor thermal efficiency. Optimizing operating clearances or reducing leakage is key to improving low speed efficiencies, however rotor design and aerodynamics also play an important role in the influence of thermal efficiency.

2.1 Aerodynamics: Rotor Profile

The TVS and TVS2 should be

The first form of compression is done

The second form of compression is

The third form of compression is

Table 1: Relationship between Rotor

Rotor	Twist		
3	60	Low	Leve
3	80		

3	100		
3	120		
4	100		
4	120		
4	140		
4	160		
4	180	High	

The various stages of air flow and compression within the control volume are illustrated in Figure 7 below.

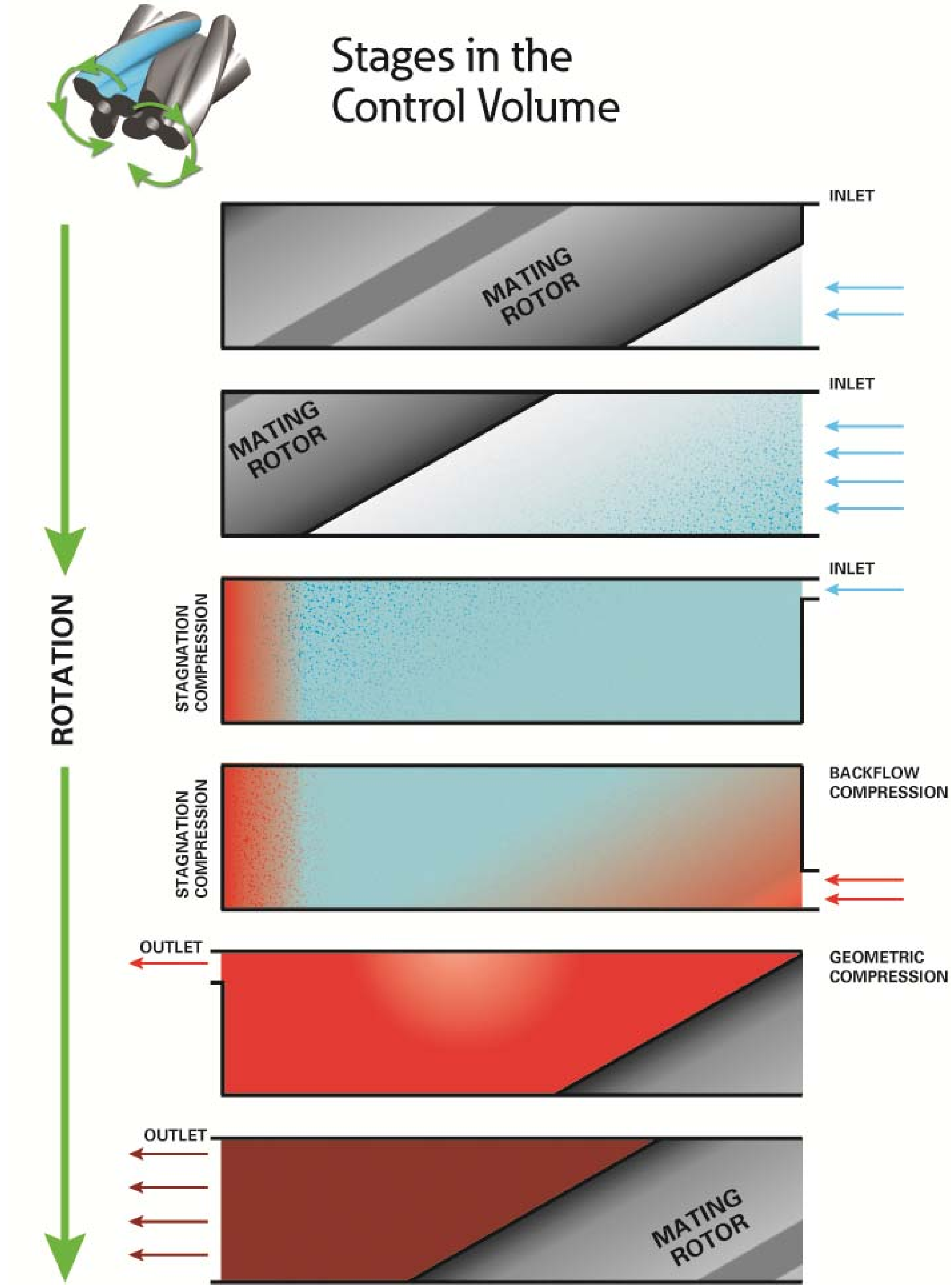

Figure 7: Stages in the control volume

The goals for TVS2 focus on the low

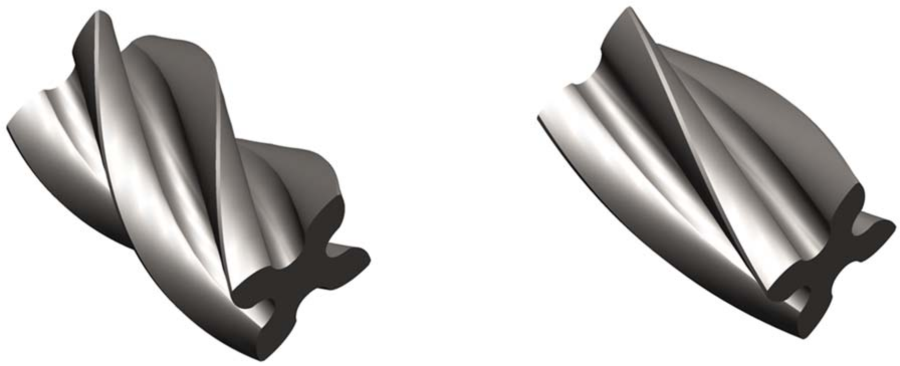

Figure 8: Low lead Extrusion (left) and high lead extrusion (right)

Figure 9 below was compiled from extensive supercharger testing with various rotor designs and illustrates the relationship between lead and peak thermal efficiency as a function of speed. V1 through V7 characterize axial air velocities, where the peak thermal efficiency occurs at V3. For TVS2, a lead was selected which gave the largest operating range and the peak thermal efficiency at the lowest speed.

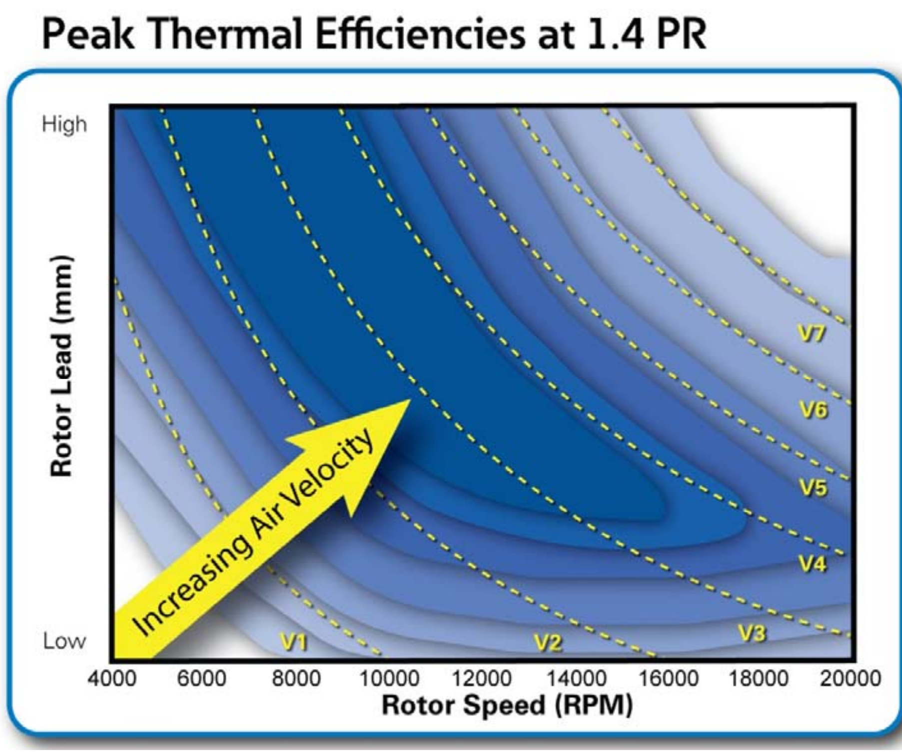

Figure 9: Peak Thermal Efficiency at 1.4PR

The lead for TVS2 was selected to

With the lead selected, the final design of the rotor was determined based on additional requirements of a compound boost application. With the turbocharger being utilized for the engine's highest intake pressure needs, the targeted PR for the supercharger is <1.8 with a max range up to 2.5 PR. In conjunction with the requirements for improved low speed efficiency, a three lobe design was selected for its lower leakage area. Three lobe designs also have lower internal leakage between the lobes due to reductions in the traversed leakage area as highlighted in Figure 10 below.

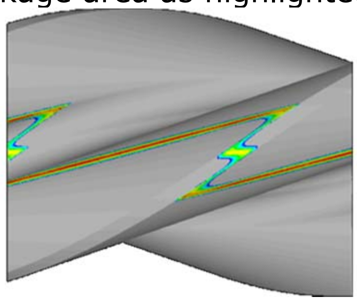

Figure 10: Mesh leakage area

In addition to reducing the length of the mesh area within the TVS2 rotors, the mesh clearances were optimized, providing a more consistent clearance throughout the rotation of the profile. By adjusting the involute profile parameters, the clearance between the rotors was optimized to converge to a consistent value. A comparison between the TVS2 and TVS R410 clearances is shown in Figure 11 below.

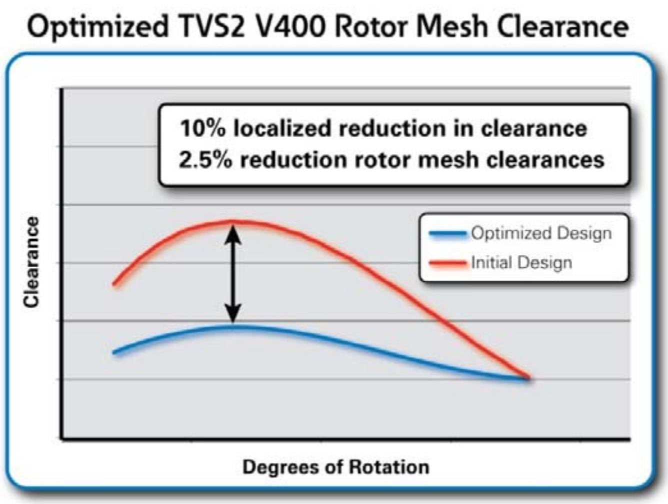

Figure 11: Rotor mesh clearance

The final area of sealing improvement

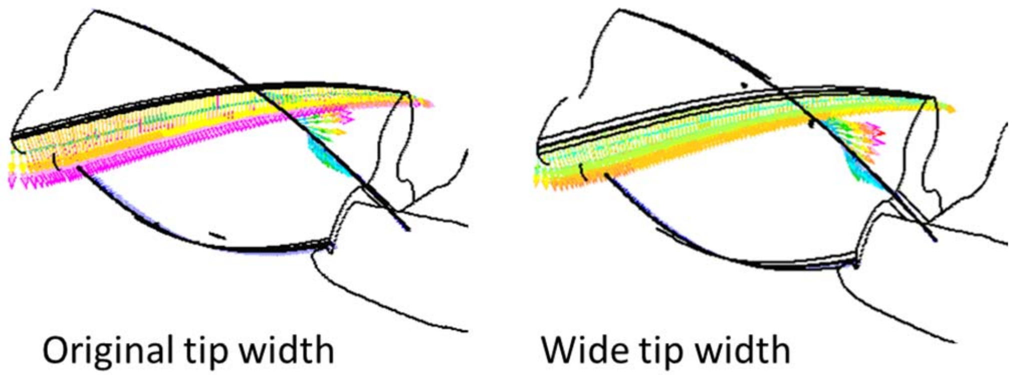

Figure 12: Tip width study – CFD

After tuning each design parameter for optimal low speed flow performance, the TVS2 supercharger was able to far surpass the VE of the TVS R410. Figure 13 below shows this improvement at a pressure ratio of 1.4.

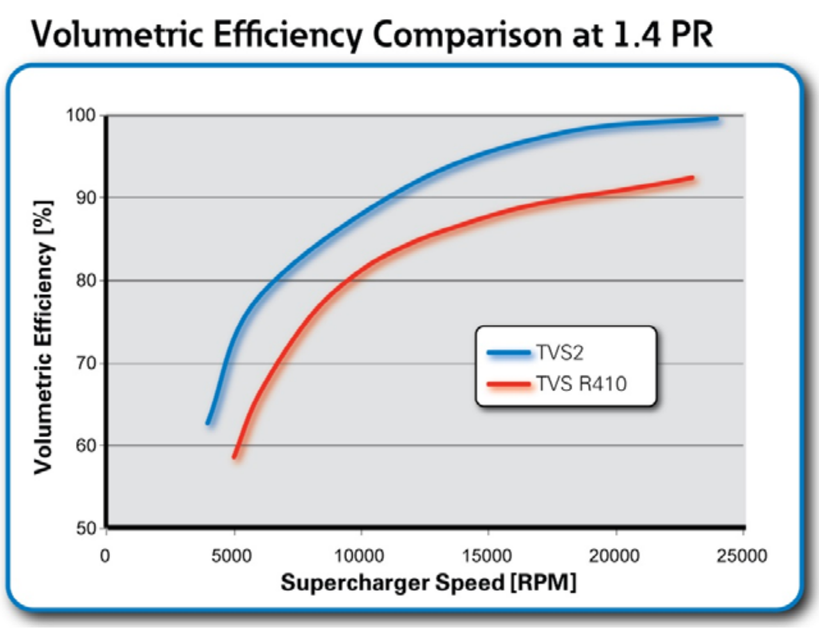

Figure 13: TVS2 Volumetric Efficiency Improvements compared to TVS R410 throughout the operating speed range

2.2 Aerodynamics: Porting

Reducing drive power at steady state or

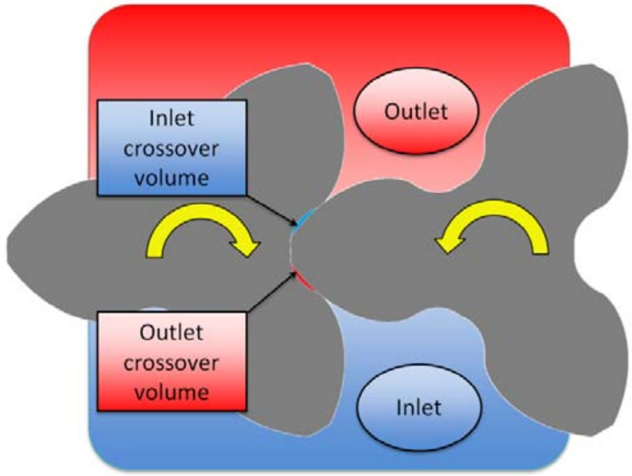

Figure 14: Crossover volumes - rotor mesh

One of the critical port areas investigated for TVS2 was the bearing plate outlet port. This port defines the end of the outlet cycle. Due to the nature of the involute rotor design, there is potential to trap small volumes of air and compress them to very high pressures, resulting in excessive drive power. The red area in Figure 15 below shows this high pressure region.

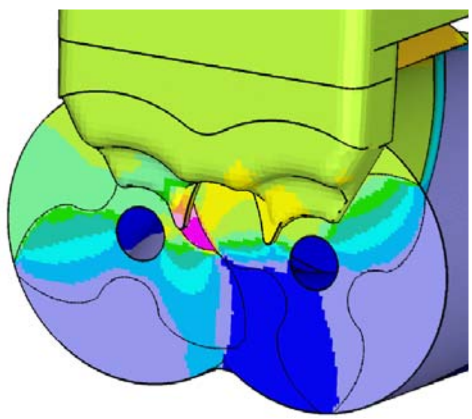

Figure 15: CFD on initial bearing plate port

For TVS2, a specific design guide was developed to outline the port based on the specific rotor profile and event timing. Due to the rotor involute geometry, there are a few degrees of rotation where the inlet and outlet crossover as referenced in Figure 14 above. The communication of the crossover point in the port can be adjusted based on application requirements. Less crossover helps low speed VE whereas more cross over helps high speed drive power. For TVS2, a compromise between low speed and high speed operation was selected. Figure 16 below shows the basic outline for the port geometry.

However, the rotor geometry only sets

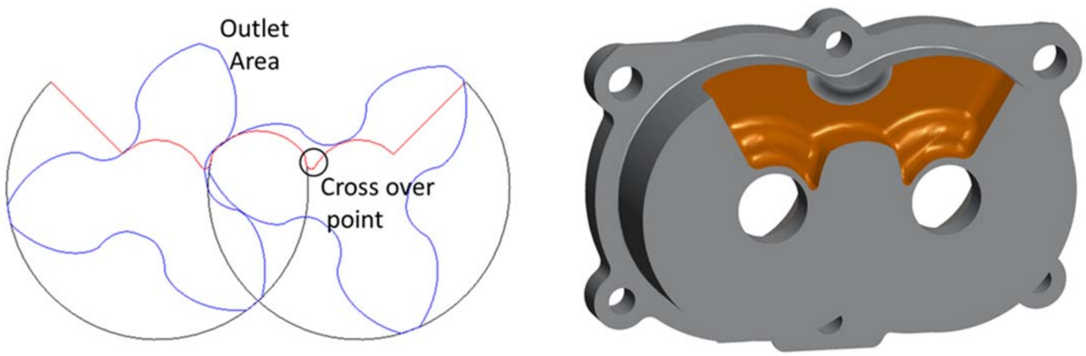

Figure 16: Bearing plate outlet port outline and actual geometry

The results revealed that the depth of the port at the minimum point of the crossover section is critical. The depth of the port was then optimized based on the CFD results. This resulted in a 30 kPa reduction in the upper speed range and helped improve thermal efficiency and reduce drive power by 1 to 2 %. Figure 17 below shows the large reduction in pressure build-up within the trapped volume region.

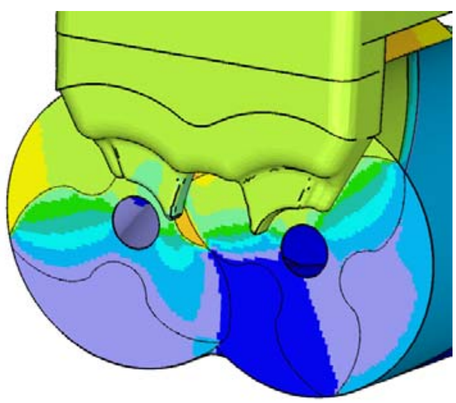

Figure 17: Final verification of bearing plate port – CFD

2.3 Performance Results

Figure 13 above showed the improvement in the VE at a pressure ratio of 1.4, however, a thermal efficiency comparison truly demonstrates the improvements. The full thermal efficiency map and improvement map (displaying % improvement vs. the TVS R410), shown in Figure 18 and Figure 19 below, demonstrate the sum of the impact of all the performance improvements targeting the steady state area of a compound boost system.

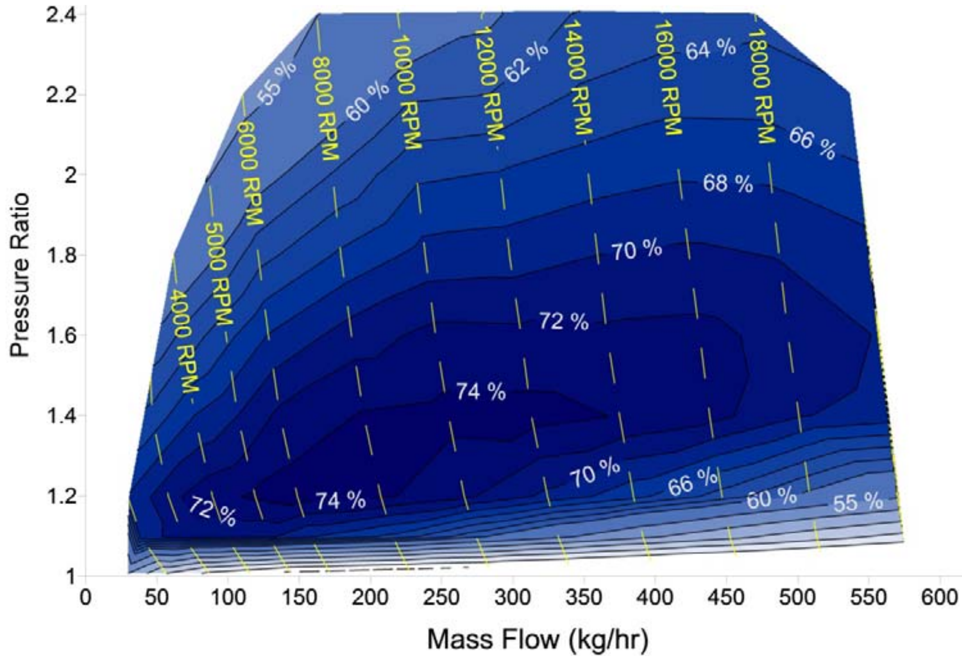

Figure 18: TVS2 V400 Thermal Efficiency Map

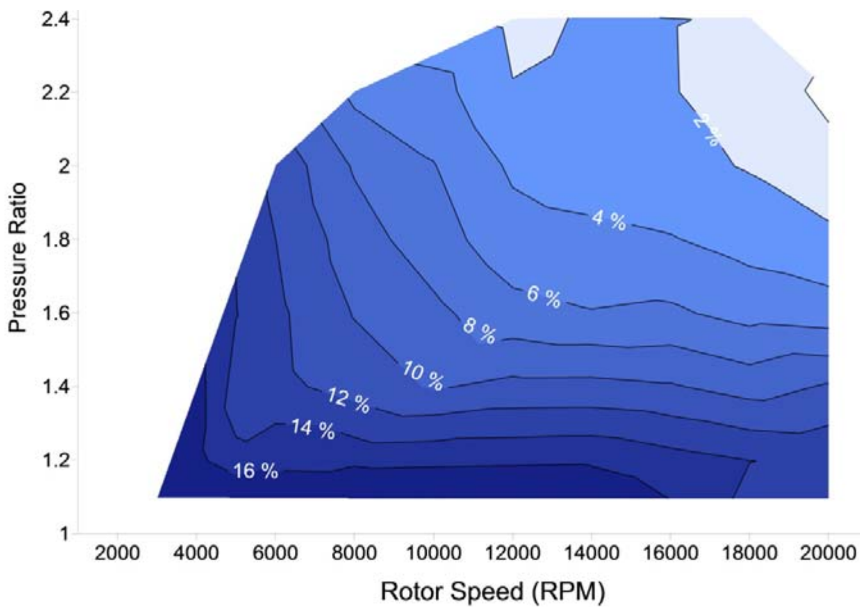

Figure 19: Efficiency Improvement Map (TVS2 vs. TVS R410)

Compared to the TVS R410 map, the peak

2.4 Airborne NVH

Positive displacement superchargers

2.4.1 Backflow Port Mechanics

TVS2 is a three lobed rotor design that

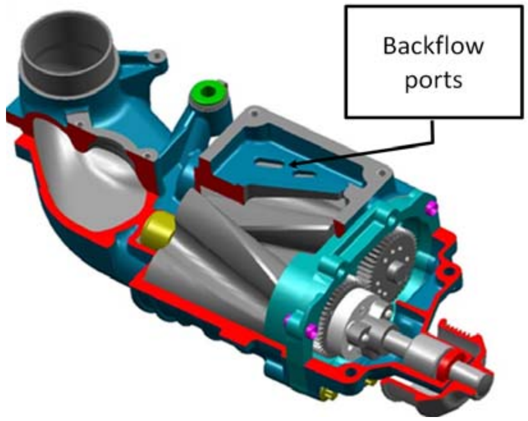

Figure 20: 5th Generation M45 Supercharger with radial backflow ports

However, the radially placed ports did

The concept for the port was to maintain the momentum of the working fluid and capitalize on potential pressure wave compression. Basically, the air of the supercharger is introduced at the inlet end of the supercharger and the inlet of the control volumes in the rotor. The concept is to introduce the backflow air into the control volume at the inlet end. This allows the high pressure backflow air to follow any wave that was setup in the control volume at the point the inlet closed, referenced in Figure 7 above.

To do this, the backflow port was

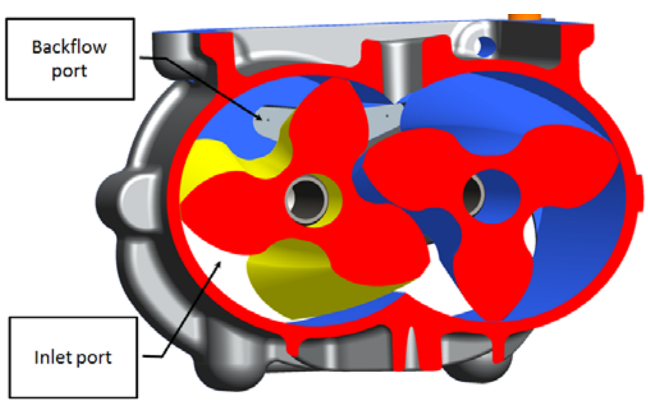

Figure 21: TVS2 Backflow port

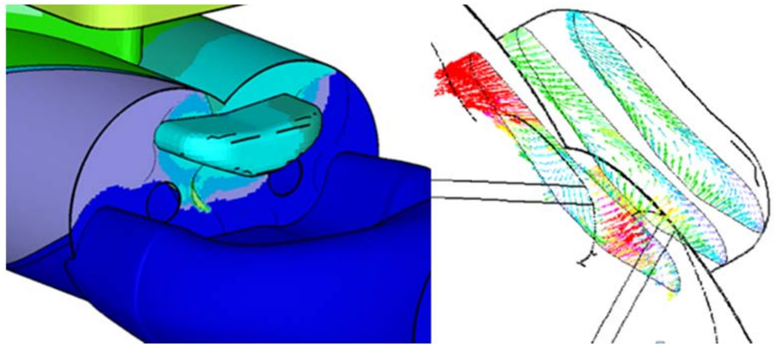

Figure 22: Backflow port CFD

CFD was also conducted to help design
The following section will discuss the

This port can also be tuned for

2.4.2 Backflow Port Application

A drastic attenuation of dynamic pressure level is achieved by placing the backflow port at the inlet. While dynamic air pulsations were successfully predicted using CFD, traditional performance testing was utilized to further optimize the backflow port NVH performance. Figure 23 below shows the dynamic pressure changes due to the backflow port measured in the TVS2 unit. Up to 10 dB dynamic pressure reductions were observed in the supercharger outlet over a wide range of operating speeds.

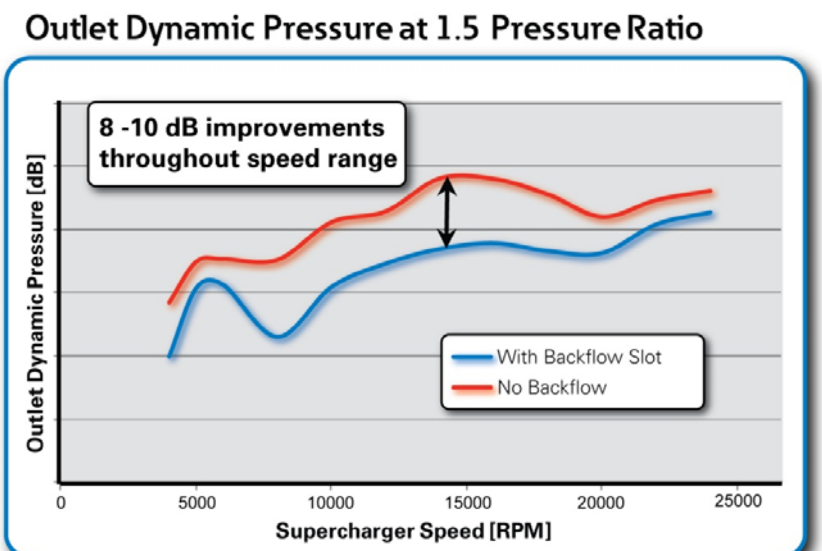

Figure 23: Outlet dynamic pressure reduction due to backflow port

2.4.3 Microperforated Panel (MPP)

When the low pressure inlet air encounters the high pressure air in the backflow port, turbulent mixing occurs. Although the backflow port promotes smooth low to high pressure transition, it can also be the area where high levels of air pulsation are generated. Microperforated Panel (MPP) technology was chosen to further reduce the pulsation because it can be used under severe operating conditions of superchargers. A MPP is a thin, acoustic panel with small holes whose size and quantity (porosity) can be tuned for damping specific frequencies. The TVS2 MPP, shown in Figure 24 below, was designed to have the maximum attenuation at 1kHz using the analytic equation derived under no flow condition.

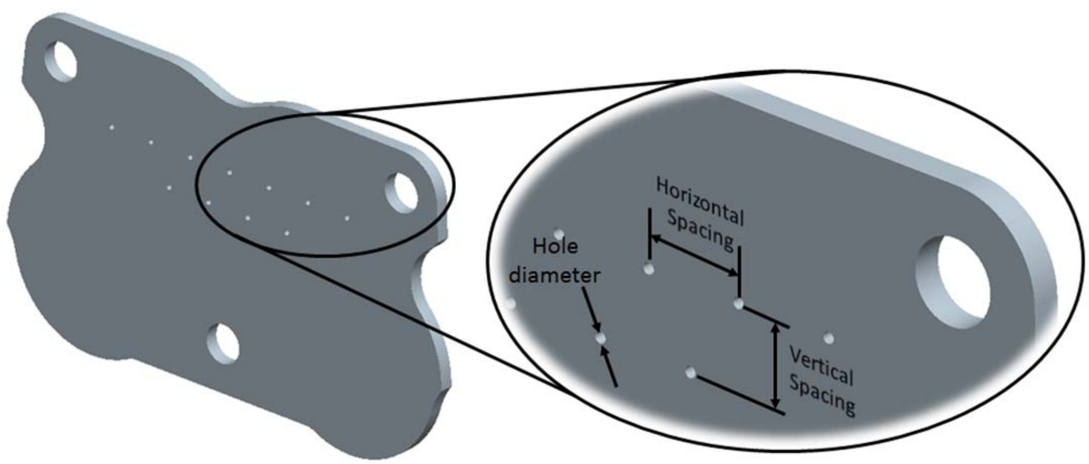

Figure 24: Example Microperforated Panel (MPP) design used for the TVS2 supercharger highlighting key geometric considerations

Transfer impedance of the MPP is expressed as $Ztr = \frac{\Delta p}{\rho c v} = \frac{32\eta t}{\sigma\rho c d^2}\left(\left(1+\frac{\beta^2}{32}\right)^{1/2} + \frac{\sqrt{2}}{8}\beta\frac{d}{t}\right) + j\frac{\omega t}{\sigma c}\left(1+\left(3^2+\frac{\beta^2}{32}\right)^{-1/2} + 0.85\frac{d}{t}\right)$ Eq. 3 below [2]:

$$Z_{tr} = \frac{\Delta p}{\rho c v} = \frac{32\eta t}{\sigma\rho c d^2}\left(\left(1+\frac{\beta^2}{32}\right)^{1/2} + \frac{\sqrt{2}}{8}\beta\frac{d}{t}\right) + j\frac{\omega t}{\sigma c}\left(1+\left(3^2+\frac{\beta^2}{32}\right)^{-1/2} + 0.85\frac{d}{t}\right) \qquad \text{Eq. 3}$$

where p is the acoustic pressure, ρ is the mass density of the air, c is the speed of sound, v is the particle velocity, η is the viscosity, t is the panel thickness, σ is the panel porosity, d is the pore diameter, ω is the angular $\omega\,\rho\,4\eta$ Eq. 4 [2]:

$$\beta = d\sqrt{\omega\rho/4\eta} \qquad \text{Eq. 4}$$

Figure 25 below shows the influence of MPP technology to the dynamic pressure, as measured on the supercharger. For this unit, the MPP was designed to reduce pulsation borne NVH at 1 kHz, equivalent to 10,000 rpm. Reductions of up to 4 dB dynamic pressure were observed at this targeted speed. Additional reductions in the larger speed range of 10,000–18,000 rpm were also observed. These reductions are in addition to the large improvements made by the backflow port alone and can help target specific problem areas on various vehicle applications.

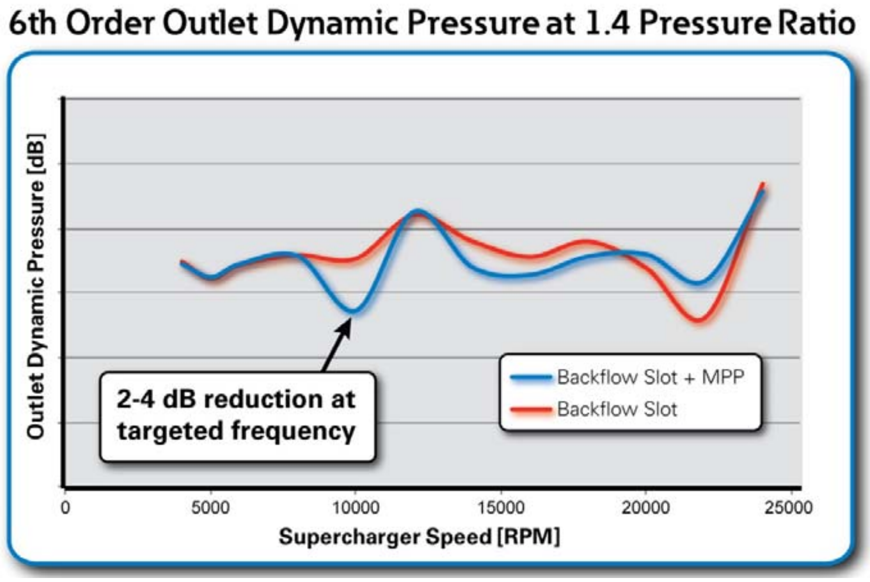

Figure 25: Influence of MPP to dynamic pressure

3 Mechanical Design

Once the aerodynamic design of the supercharger was defined, the mechanical components and sub-systems of the TVS2 supercharger were re-designed to meet the specifications required for Turbo-Super combined boost systems and provide improved packaging on increasingly restricted space engine applications.

3.1 Mass Reduction, Packaging and Inertia

To aid in reducing boosting system mass and size, Eaton focused on the optimization of several key areas within the TVS2 supercharger design. TVS2 rotating group and housing system mass is reduced by 26% vs. the TVS R410 supercharger and overall envelope dimensions were reduced in each direction. The length from coupling to inlet mounting face is reduced by 19% (43.3 mm) while overall housing width and height are reduced by 9% and 4% (11.9 and 3.3 mm) respectively. Figure 26 below shows a comparison of these packaging dimensions. Additionally, rotating inertia was reduced by 5.6% vs. the R410, an improvement that will benefit clutched applications by easing calibration efforts. These improvements came largely from design emphasis on three key components: timing gears, coupling and housing.

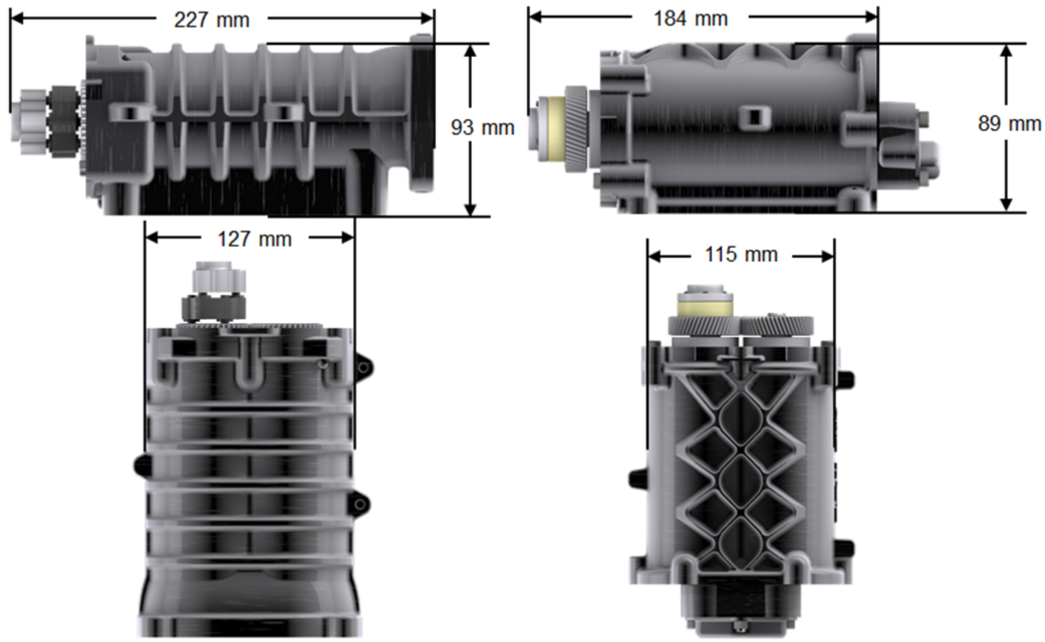

Figure 26: Envelope dimension comparison between TVS R410 (left) and TVS2 (right)

3.1.1 Timing Gear

Optimization of the timing gears on the TVS2 yielded large reductions in both mass and rotating inertia. Mass was reduced by 38% and inertia by 23% as compared to the R410 gears which have the same center distance, pitch diameter and face width as the TVS2 gears. A visual comparison of the gear designs is shown in Figure 27 below. Material was removed primarily from the web and rim sections of the gears without compromising the strength or stiffness that is needed for Turbo-Super system operating conditions.

Figure 27: TVS2 (right) vs. TVS R410 (left) timing gear

3.1.2 Coupling

Traditional couplers, like that on the TVS R410, consist of a steel hub with three press fitted steel pins, an input timing gear also with three press fitted pins, and a nylon puck between them. This arrangement has been proven over time, but it consumes valuable space along the shaft axis. The TVS2 coupling, shown in Figure 28 below, is a simple PEEK overmolded steel hub, that inserts directly into the web of the input timing gear. Overall, 18 mm of axial length are conserved with the new coupling design.

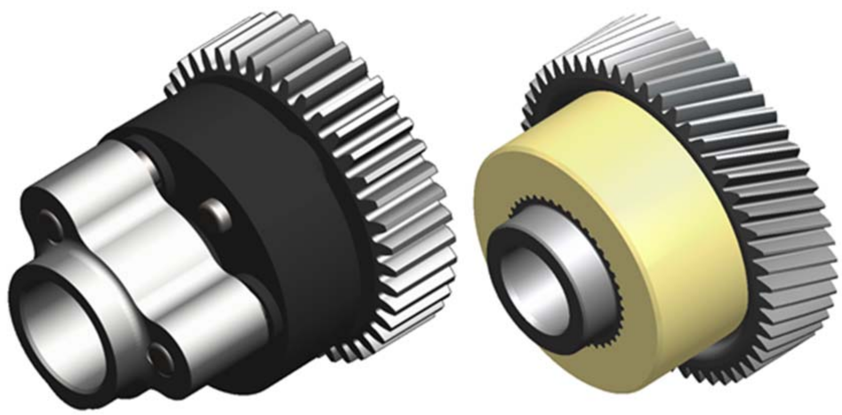

Figure 28: TVS2 coupling (right) reduces axially length by 18 mm vs. the TVS R410 coupling (left)

3.1.3 Housing

In anticipation of production manufacturing, the TVS2 supercharger housing was designed with High Pressure Die Casting (HPDC) intent. To minimize the risk of shrinkage porosity and cold shuts, common HPDC defects, casting wall thicknesses were minimized and made as uniform as possible [3]. Select material was added in areas of the housing that required additional structural stiffness. The resulting TVS2 housing, shown in Figure 29 below, reduces mass by 46% versus the TVS R410 housing.

Figure 29: TVS2 housing (right), optimized for HPDC fabrication, as compared to the TVS R410 housing (left)

3.2 Improved Capabilities

Current TVS superchargers are unable to operate as the high pressure stage in combined boost engine applications due to limitations in maximum outlet pressure and ΔP capabilities. The TVS2 unit is designed to improve these capabilities so that engine designers have the flexibility to utilize the supercharger as the high pressure device of the boosting system.

Existing gearcase seal technology has limited the ability of Eaton superchargers to operate at high absolute pressures. Current sealing solutions enable pressure ratios of 2.5 with ambient inlet conditions. Thus, a 150 kPa ΔP is the maximum that can be achieved. For the TVS2 supercharger, a new sealing solution was developed to increase ΔP capabilities, allowing elevated inlet pressure conditions like those that are required in Turbo-Super boosting systems. Figure 30 below shows a the TVS2 supercharger, highlighting the high pressure seals.

Figure 30: Supercharger seals (highlighted on the rotorshafts) improve maximum pressure differential to 200 kPa in the TVS2 supercharger

With the improved ΔP sealing capabilities, the TVS2 supercharger is capable of reaching uniform 400 kPa absolute pressure within the air cavity and ΔP up to 200 kPa at any combination of inlet and outlet pressures. This allows a turbocharger compressor to inject high pressure air across a wide range of operating conditions, improving system flexibility. The pressure ratio and outlet pressure capabilities of the TVS2 supercharger are highlighted and compared to the current production TVS R410 supercharger in Figure 31 below. The pressure ratio limit at ambient inlet pressures remains at 2.5 due to maximum temperature limitations of 180°C.

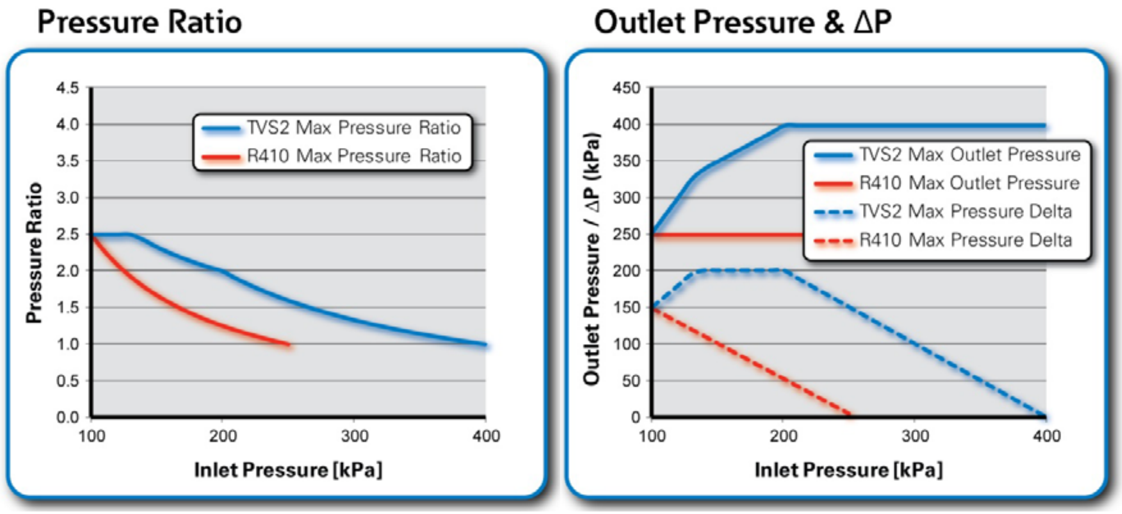

Figure 31: TVS2 maximum pressure ratio, outlet pressure and pressure differential capabilities vs. inlet pressure yield a dramatic improvement against the existing TVS R410 supercharger

To further improve system flexibility and specifically, allow for a greater range of turbo sizing options, the TVS2 supercharger is designed to achieve peak speeds of 30,000 rpm during transient acceleration events. This is made possible through the use of an all ball bearing arrangement to support the rotors, rather than the use of needle roller bearings on the rear side of the rotorshafts on current TVS superchargers. Using a supercharger with such high speed capability allows the device to operate higher into the engine speed range and can allow engine designers to select larger, more efficient turbochargers without the concern of turbo lag. Additionally, the increased speed range can prevent having to select the next larger displacement supercharger to achieve peak airflow requirements.

3.3 Mechanical NVH

Overall radiated noise is less than or equal to the incumbent TVS R410 supercharger at low boost despite the 26% decrease in overall mass which is primarily taken out of the structural housing components that provide the most acoustic damping. This was partially achieved through the backflow port and MPP technology, but also through the use of improved mechanical components such as helical timing gears and ball bearings in place of needle roller bearings to support the inlet end of the rotorshafts.

3.3.1 Helical Timing Gears

Helical timing gears are known to provide improved NVH performance and they have been used in Eaton superchargers in the past, but with limited success due to the difficulties experienced in the production level assembly process. The TVS2 supercharger was designed with helical gears in mind from the start and improvements in production processes enabled the engineering team to freely implement them.

For the TVS2 supercharger, 53 tooth helical gears were selected so that the acoustic orders would never overlap the air pulsation frequencies. On the TVS R410 supercharger, a 41 tooth straight cut spur gear is used. Comparing 53^{rd} and 41^{st} order frequencies from the TVS2 and R410 respectively shows an impressive reduction in overall gear whine throughout the speed range, as shown in Figure 32 below.

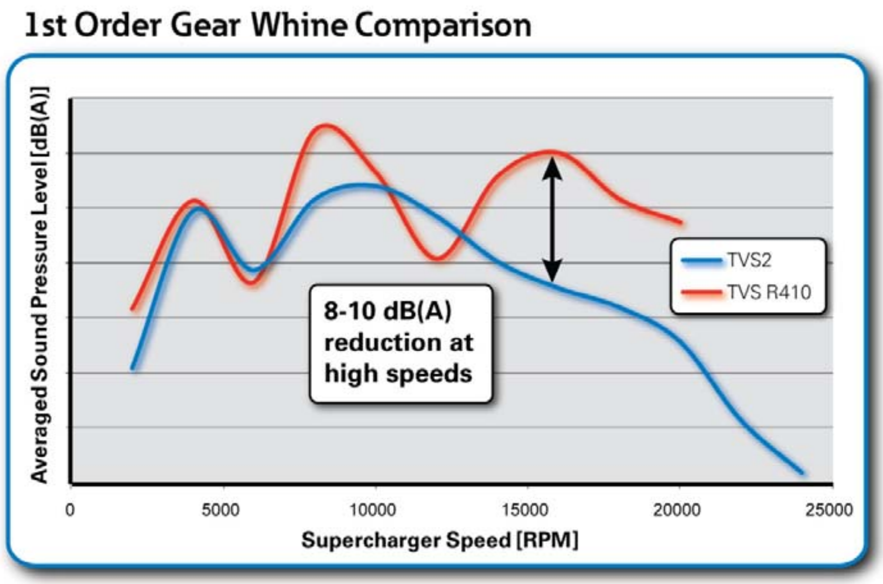

Figure 32: Gear whine reduction on the TVS2 supercharger as compared to the R410

This reduction in gear whine was primarily achieved through a higher contact ratio and lower peak-to-peak transmission error, parameters that favor helical gear designs. The overall contact ratio of the TVS2 gears was increased by 58% over the R410 and peak-to-peak transmission error was drastically reduced throughout the operating torque range up to the maximum design torque of 35 Nm, as shown in Figure 33 below.

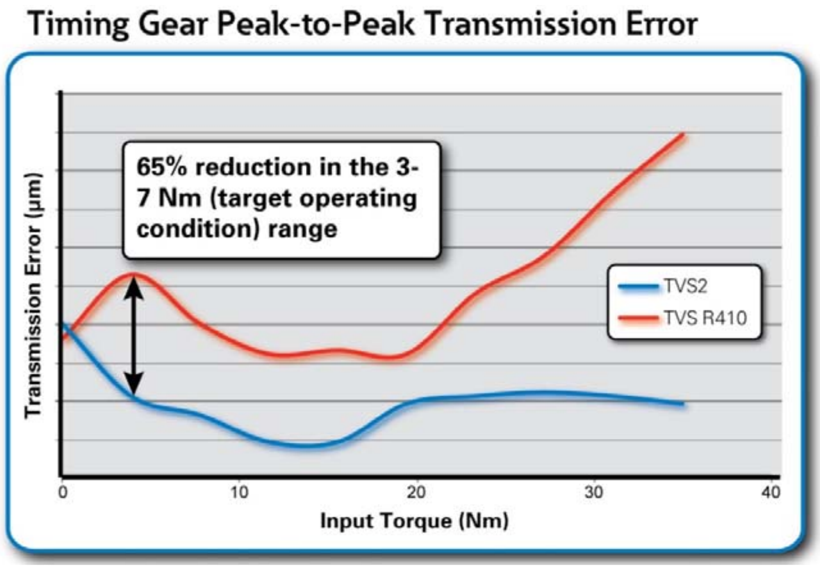

Figure 33: TVS2 peak-to-peak timing gear transmission error reduction as compared to TVS R410 improves gear whine throughout the entire operating range

3.3.2 Rear Rotorshaft Ball Bearings

While the primary reason for using only ball bearings on the rotorshafts is for improved speed capability, they also provide an NVH benefit. In existing TVS superchargers, needle roller bearings are used as the rear rotorshaft support and can cause NVH complications due to the required clearances between the shaft diameter and under roller diameter of the bearing. Press fitting and preloading a small ball bearing stabilizes the rotorshaft during operation, especially at lightly loaded operating conditions where the shaft would traditionally be more free to move about within the needle roller bearing clearances. The bearing and spring configuration for the TVS2 supercharger is depicted in Figure 34 below. This architecture is a deviation from Eaton's existing superchargers as the bearings are now assembled from the opposite side of the rotor cavity, a design choice that was made to allow the bearings to be pre-loaded in the direction of boost loads.

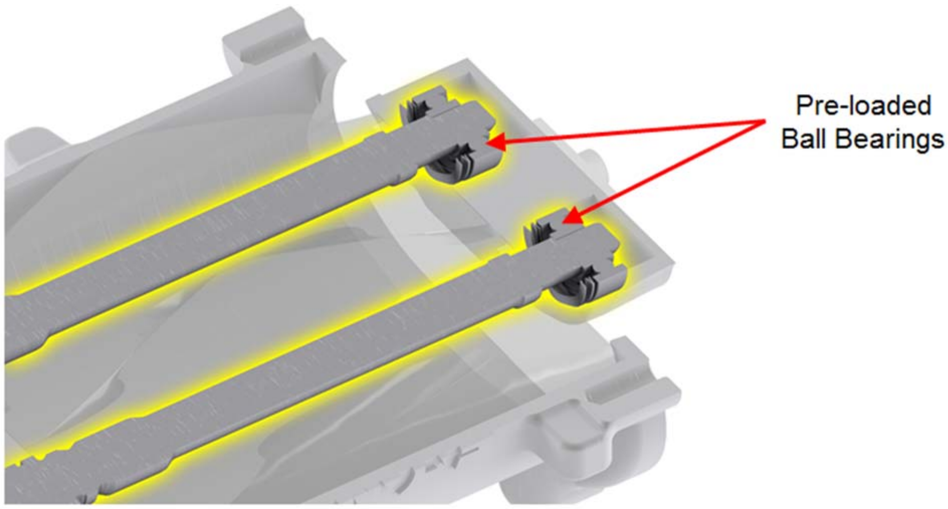

Figure 34: Rear ball bearing design configuration helps prevent mechanical NVH concerns, especially at light loads

The NVH benefits of this configuration are particularly apparent at lightly loaded conditions where microphone and accelerometer measurements show areas of improvement throughout, but primarily at the high speed range of the supercharger, as shown in Figure 35 below.

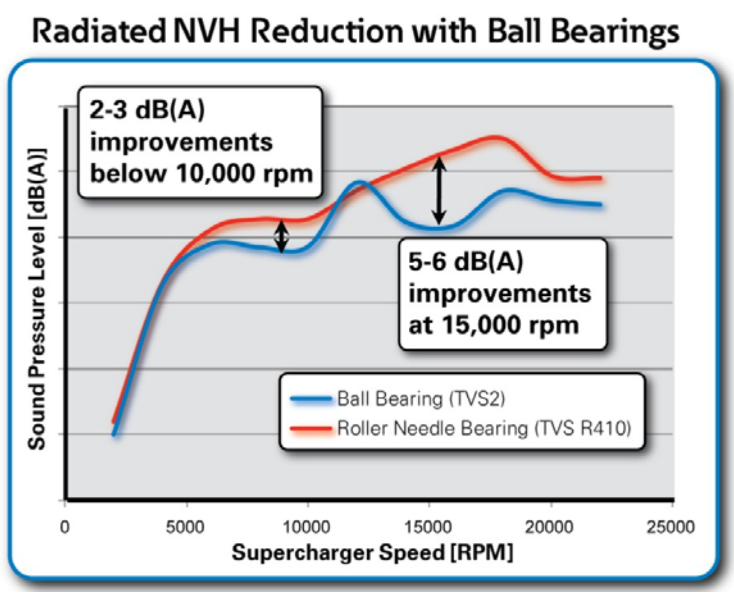

Figure 35: Ball Bearing rear rotor support significantly improves supercharger radiated noise especially at high speed

4 System Performance

The combination of the TVS2 technologies has resulted in a significantly improved thermal efficiency map. The TVS2, Figure 36, thermal efficiency in both the steady state and transient operating regions has increased significantly compared to the TVS R410 supercharger, Figure 37, where peak thermal efficiency is achieved in the core of the steady state operating region. The maximum transient operating speed of the TVS2 unit, highlighted in Figure 37, has been increased from 24,000 rpm to 30,000 rpm allowing the supercharger to remain engaged to higher engine speeds. For example, a 6:1 drive ratio between the supercharger and engine would enable the supercharger to remain engaged up to 4,000 engine rpm with a 24,000 supercharger rpm limit or up to 5,000 engine rpm with a 30,000 supercharger rpm limit.

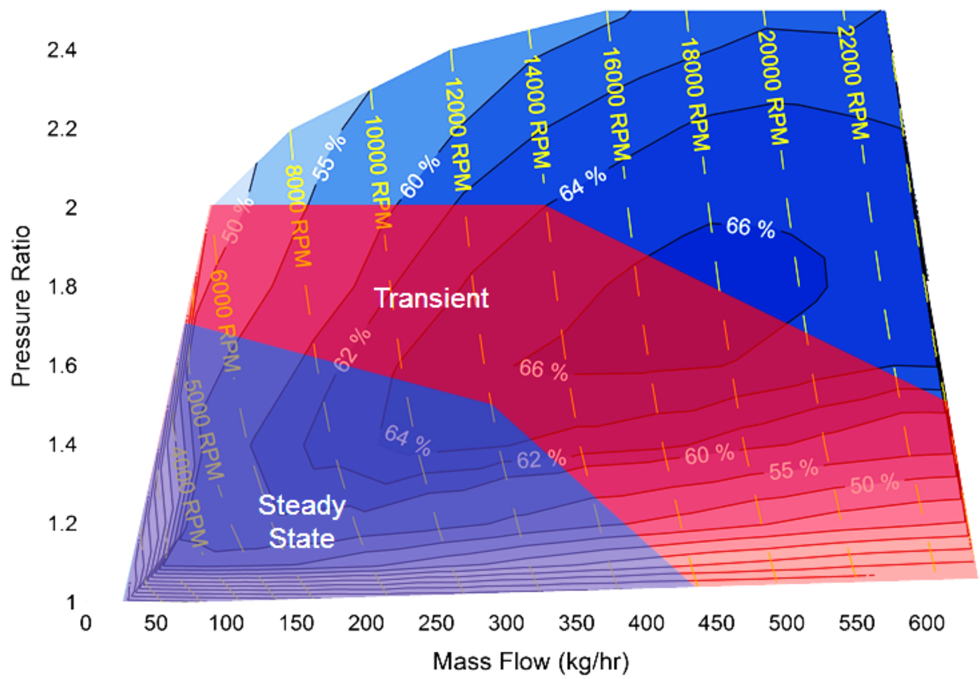

Figure 36: Supercharger operating curves on TVS R410 performance map

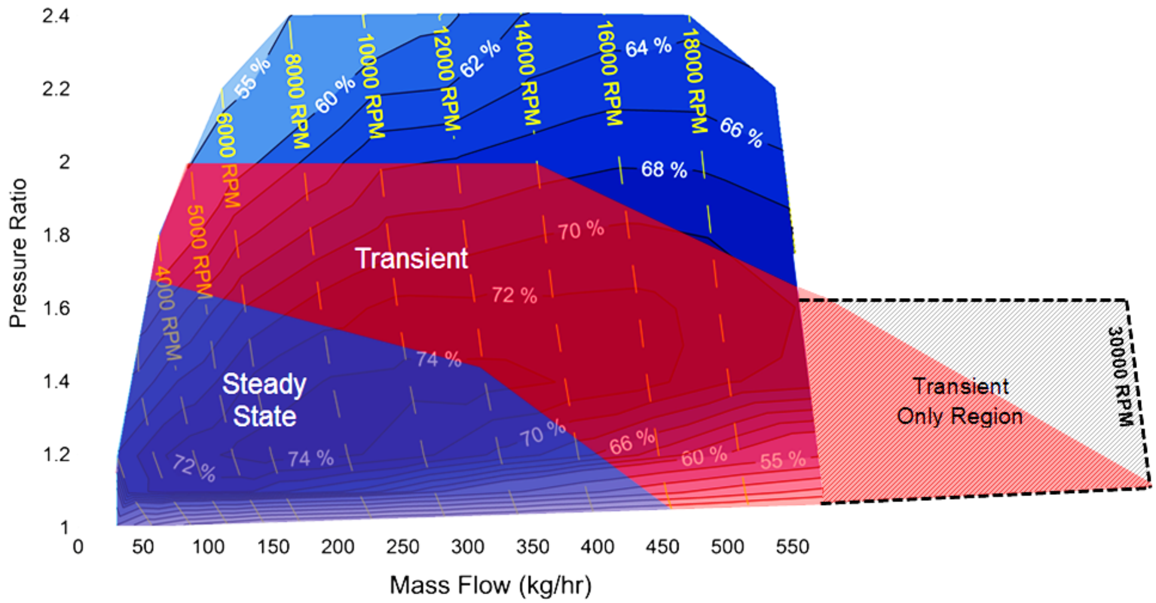

Figure 37: Supercharger operating curves on TVS2 V400

The TVS2 also outperforms the TVS R410 unit from an overall radiated noise standpoint. Figure 38 below shows a significant decrease in sound pressure levels at minimum boost levels, specifically through the first half of the speed range, where there is typically high driver senstivity to noise.

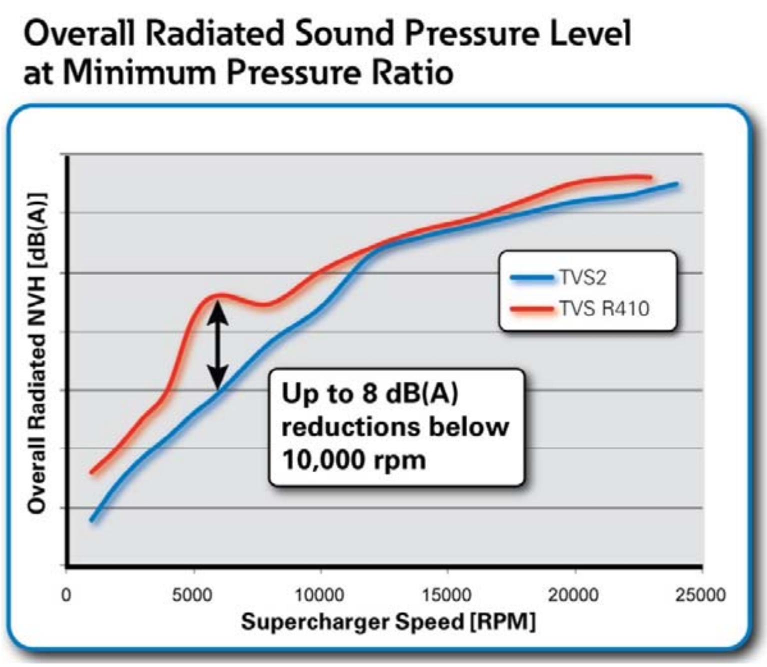

Figure 38: Radiated sound pressure level at minimum pressure ratio

5 Summary

The TVS2 technology has combined into a system that has significantly improved the efficiency and capability of the supercharger. The technologies offer a compelling package for advanced boosting systems of the future. The TVS2 supercharger now offers:

- Capability of operating in high pressure stage in series boosting system
- Mass Reduction of 26%
- Transient speed capability increased from 24,000 to 30,000 rpm
- Thermal efficiency zones matched to a compound boost system
- Improved flow at low speeds reducing drive ratio requirement
- Packaging improvements allowing more compact and flexible installations
- Targeted NVH reduction

The result to the OEM is a product offering that retains the best in class transient performance while reducing the power to drive the supercharger that results in improved BSFC.

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