Forced Air Induction Essay, Research Paper

The Garret Aviation VNT-25 The idea of forced air induction by turbine, or

turbo, is not new and has it’s mass production roots in WWII fighter planes.

What is new, however, is its application to passenger automobiles. Unlike a near

constant high RPM fighter engine, an automobile requires wide-open throttle (WOT)

power availability throughout its entire operating range. Previous automotive

turbo applications acted like an on-off power switch with a five second delay,

decreasing drivability, rather than providing the smooth linear powerband of a

normally aspirated engine. Because the turbine is in a fixed position in the

exhaust stream, it was plagued with sometimes uncontrolled production from the

compressor at high engine speeds, commonly referred to as boost creep, and a

significant decrease fuel economy versus a similar, but naturally aspirated

engine. The Garret Aviation produced VNT-25 solved all of these problems with

its innovative Variable Nozzle Turbine. Hands down it is the most advanced turbo

ever mass-produced and it was the first of its kind on production cars. One of

the most talked about problems with turbo charged engines is the lengthy time it

takes for the turbo itself to accelerate to operational speeds. This is commonly

referred to as turbo lag or turbo spool up time. Under WOT, turbo lag results in

a seemingly underpowered engine that suddenly comes to life as a delayed tire

melting rush of acceleration. Previously, turbo lag was limited by decreasing

the size of the turbo itself. This resulted in lower rotating mass and more

importantly, a smaller cross sectional area, which accelerated exhaust gasses at

lower engine speeds. Although the turbo is able to spool quicker due to its

size, for the same reason its ability to move and compress large amounts of air

efficiently is significantly reduced. Inherently a smaller turbo will produce

less maximum horsepower than if it were replaced by larger turbo on the same

engine. Previous turbochargers also used a fixed position turbine that powered

the centrifugal compressor directly. Because the turbine is located directly in

the exhaust stream, the turbine is a huge exhaust restriction. This restriction

creates a constant exhaust backpressure that decreases fuel economy even when

the turbo is not in use. At high engine speeds, the restriction creates enough

pressure in front of the turbine (back pressure) that the wastegate can no

longer limit turbine power by bypassing the exhaust around the turbine. The

result is that turbo compresses more air into the engine than is wanted. For

example, a turbo was set to produce a maximum 12psi boost pressure, but during a

period of sustained wide open throttle high engine speeds the turbo is now

producing 14.5psi of boost and still rising. This unwanted phenomenon is called

boost creep. The VNT-25 solves all of these problems with an innovative turbine

called a Variable Nozzle Turbine. Rather than a fixed turbine the VNT-25 uses a

ring of 12 moveable paddles aligned around a central, but very small turbine

wheel. The entire exhaust charge is then directed to the small turbine by the

paddles. Moving the paddles varied the crossectional area that the exhaust must

pass through. When the paddles are nearly closed the exhaust is accelerated

towards the turbine wheel to increase power. Decreasing the crossectional area

of flow accelerates normally slow, low engine speed, gasses and nearly

eliminates turbo lag while allowing a large and efficient compressor wheel for

excellent maximum engine power. Opening the paddles allowed the exhaust to flow

slower and bypass the turbine to limit power. This unique arrangement

significantly reduced backpressure, greatly improved fuel economy, and allows

excellent control turbine power at sustained high engine speed, without the use

of a bulky external wastegate. The Garret VNT isn’t without its drawbacks. In

high performance applications it is a turbo that has little to be desired. The

engineers of this turbo, in their effort to reduce turbo lag as much as

possible, kept the compressor and turbine as small as possible. The smaller size

of the turbine and the compressor decreases the size and therefore the weight of

the turbo internals. Keeping the weight as light as possible reduces rotational

inertia to an absolute minimum, which results in a much more responsive turbo.

Because the exducer, that is the compressor, is of a compressor type,

operational speeds are very high. It is not unlikely for a VNT to reach maximum

operational speeds of 173 thousand revolutions per minute even though resting or

"cruise" speed of the turbine is only 2000-6000 RPMs. It is this

latency of the turbo to accelerate to operating speeds that is referred to as

turbo lag. Although the small size of the turbine is ideal for a moderate

performance car, its size is a handicap in racing situations. Inherent with a

small compressor is its ability to quickly reach operating boost pressure. This

does not come with out a penalty. Effectively this small compressor trades

efficiency for speed. As any gas is compressed the temperature of it rises.

Smaller compressors will tend to heat the compressed air more than would a

larger turbo for a given pressure. Bernoulli’s principal states that as a gas is

compressed the temperature increases as the volume decreases. The inefficiency

of the VNT at pressures over 15 pounds per square inch increases the temperature

of the gas more than it is possible for it to compress, or decrease the volume.

The result is that the increase in boost pressure is inversely proportional to

the volume of air moved. As the compressor works to decrease the volume of air,

the rise in temperature works to increase the volume. Eventually the volume of

air is expanded by heat more than it can be compressed. The point at which this

happens is referred to as the stall speed. Because a larger turbo, although slow

to respond, is much more efficient at higher pressures it will result in a much

cooler charge at a given pressure. A smaller compressor also cannot move large

quantities of air at high pressures as would a larger turbo be able to. The size

of the VNT, although ideal for 12psi as it was intended for, suffers greatly in

high performance applications from stall speed of psi. The turbine also suffers

from a small and compact A/R ratio. The A/R is the ratio at which the turbine or

compressor housing is cast. The A/R is the ratio at which the volume of the

housing as gasses enter the housing to the volume it exits. For instance, the

size of connection on the intake side of the compressor is two and one quarter

inches inside diameter and has a volume of 323 cubic centimeters until it

reaches the compressor. The exit side is also two and one quarter inches inside

diameter and contains a volume of 155cc’s. The volume of each path to the

compressor is misleading and cannot be determined from the diameter of the exit

or intrance alone. The intake passage is a direct and simple path to the

compressor cartridge. The exit, however, is fluted from the from a very wide and

narrow, almost rectangular, passage at the side of the compressor to a standard

2 ? inch inside diameter round pipe fitting. This fluted shape insures that the

speed of the compressed charge is kept relatively high. The high speed maintains

that the compressed charge is kept away from the compressor. If it were allowed

to back up near the compressor, the compressor would have to work much harder to

move the already dense air. The result would be that the clready compressed air

would be further compressed and heated. Although the small inlet and outlet

sizes contribute to increased velocity With the introduction of the Garret

VNT-25 it is now possible for a small displacement turbo charged engine to

operate and perform nearly identical to a much larger engine. The ON/OFF switch

of turbo power is gone and is now replaced by the safer, smoother, and much more

linear acceleration comparable to naturally aspirated engines of much larger

displacement. A VNT-25 equipped engine also has the potential to, and usually

does, produce much more power than engines twice its size. However, with

disciplined drivers, it does not loose the fuel economy characteristics inherent

with small, normally aspirated engines when the turbo is not in use. The VNT-25

combines the responsiveness of a small turbo with the efficiency and performance

of a much larger turbocharger. Simply stated, the VNT-25 is the ideal

turbocharger. It allows great power almost no turbo lag, great responsiveness,

retains engine and compressor efficiency, and allows excellent turbine control

from boost creep.

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