A study of supercharger belt failures

An engineering approach to understanding and solving the problem of broken supercharger drive belts

**by Jim Shepherd, Manager
Power Transmission
Product Application
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With special support from
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About this article

The Gates Rubber Company does not sell belts to the public. It sells belts to the three qualified original-equipment manufacturers of blower drivers — RCD Engineering, Blower Drive Service, and SSI. They, in turn, market their products either directly to the racers or to a third level of distribution.

The Gates Rubber Company does not have competition in this market. It is the sole source and has the only product capable of sustaining the conditions of this application. According to the author, "The three-year test project described in this article was not the result of competitive pressures. It was initiated because of our desire to put the best product possible into this application. The information gained will be of use to us in the industrial market, and that's the only true 'benefit' we get from the program."

I. Background

Until the last few years, blower belts have reliably served the necessary function of driving the superchargers for racing engines. In the recent past, blower belts have received some negative press because of an increasing number of failures, particularly in the Top Fuel and Funny Car classes.

This article will address the history of blower belts and a thorough engineering program whose analysis and development were aimed at providing satisfactory performance in this demanding application. It also will detail the actions taken by the belt supplier and the items the team should check to significantly improve drive reliability.

The drag-racing blower-drive history has paralleled that of synchronous (timing) belt development. In the late 1950s, superchargers were added to various drag-racing cars (Gilmer timing belts were first available during the same period). Many of the first units were driven directly off the front of the engine (Fig. 1). A typical run for a dragster of that era would be 8.5 seconds at 150 mph.

The need for overdriving the blower, together with the obvious "piping" problems, has resulted in blowers being placed on top of the engine and driven by a rubber timing belt. Blower size has at least doubled, and the blower speed has gone from a 1:1 ratio with the engine to as much as 1.6 times the engine rpm (Fig. 2).

Belts for top-mounted blowers have gone from a 1-1/2-inch-wide H (1/2-inch pitch) Gilmer belt to a 2-inch rubber HTD belt, and more recently to a 75mm-wide, 14mm-pitch HTD profile special-construction Poly Chain belt. Patents for these belts are held by The Gates Rubber Company. The Poly Chain belt is made of a highly compounded urethane material and has more than twice the horsepower capacity of a rubber belt (Fig. 3).

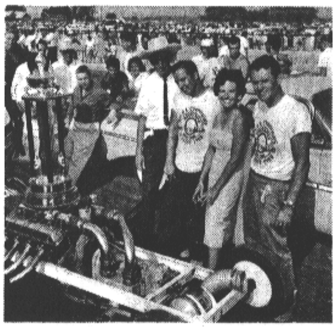

Fig. 1

Many early blower-drive units were driven off the front of the engine. A good example is the blown Lincoln that Rodney Singer took to the '59 U.S. Nationals title.

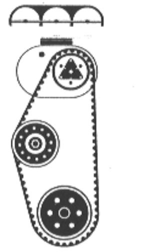

Fig. 2

Modern blowers are on top of the engine and driven by a rubber timing belt. The size has at least doubled from early models, and blower speed now can be as much as 1.6 times engine rpm.

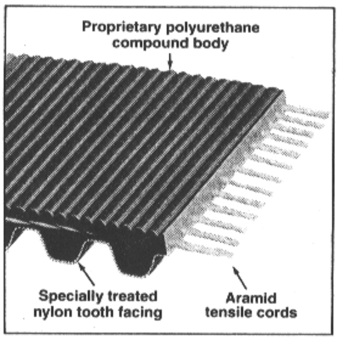

Fig. 3

This modern 75mm-wide, 14mm-pitch HTD profile special-construction Poly Chain blower belt is made of highly compounded urethane material and offers more than twice the horsepower capacity of a rubber belt.

The Poly Chain belt was introduced as the Cragar belt in 1975. At the time, Don Garlits held the NHRA National speed Record at 250.69 mph with an elapsed time of 5.63 seconds. The construction and tooth profile are the same as those introduced on Harley-Davidson's 1980 Sturgis-model motorcycle.

The belt construction remained unchanged (until this year; more on that later), yet the records are now faster than 300 mph and dipping well into the four-second range. It seemed obvious that newer technology should be considered to keep pace with the huge performance increases and the resultant demands placed on the belt drive.

II. Field observations

In 1989, The Gates Rubber Company began devoting significant engineering resources to determining why some teams were experiencing premature failures and to determine whether newer product developments would improve reliability.

The first step was to attend several races and interview blower-drive-component suppliers and racers. Extensive observations and detailed records were made. The following facts and opinions were developed during the process:

1. Fuel cars are much harder on the belts than alcohol cars, even though alcohol cars run blowers up to 50 percent faster with resulting higher loads.

2. Virtually all of the teams run the belts very loose.

3. Engine/blower acceleration is very fast (2,500 to 7,000 rpm in 0.2-second). See Fig. 4.

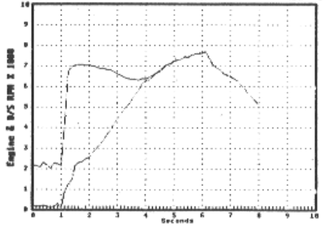

Fig. 4

Engine/blower acceleration goes from 2,500 to 7,000 rpm in 0.2-second.

4. Several cars had significant misalignment between the blower pulley shaft and the crankshaft, always with the engine side of the drive being farther apart. It is believed that this condition gets worse as the load on the blower increases during the run due to various parts deflecting.

5. All pulleys are aluminum or magnesium, and some have significant wear. In most cases, misalignment causes the wear to taper across the face of the pulley.

6. Belt failure generally occurs either early or late in the run, seldom during the middle.

7. Most belt failures appear to be the result of other part failures or unusual conditions during the run.

8. There are three major failure modes: tensile break (both jagged and sharp, straight across cord failures); tooth shear; and edge-cord unraveling.

9. Many idler brackets appear to have insufficient structural strength to support the loads; several cars have significant idler misalignment.

10. Pulley quality was generally good when supplied by industry-recognized vendors. Some cases of homemade or modified pulleys were known to have caused problems.

III. Failed-belt analysis

A concerted effort was made to obtain as many failed belts as possible, along with information about each belt. For the most part, the belts were easy to obtain, but their history was rather obscure. In the last three years, more than 200 belts have been tested and inspected.

The predominant cause of failure seems to be tensile break. When the tensile cord is jagged or frayed, it generally is a sign that the belt has experienced significant fatigue cycles. This failure mode is expected, particularly if the belt has been used on many runs. Several belts were returned with sharp tensile-cord breaks directly across the cords with no fraying.

Originally, such failure was thought to be caused by damage to the belt in storage or installation (i.e., the belt had been sharply bent in the forward or reverse direction). Laboratory testing indicates that handling is not a major factor if the belt is treated in a reasonable manner. The sharp tensile break appears to be a direct result of an engine malfunction where the belt has experienced extremely high tensions.

Tooth shear is the second most common failure mode. The number of teeth sheared has been as low as two, but in some cases, all teeth are sheared off the belt. In most cases, 10 to 30 teeth are missing or loose. In every case, the tensile cord is exposed and generally is fairly "clean." The cleanliness of the cord sometimes is attributed to poor tensile-cord-to-urethane adhesion. In fact, extensive tests have indicated that the adhesion of the remaining teeth on all of the inspected belts is very good and the failure did not result from a belt-quality problem. The general consensus is that tooth failure can be attributed to fatigue (a result of many runs), or is the result of belt ratcheting (belt slipping over the sprocket teeth). The subject of belt ratcheting will be discussed later.

The last typical failure mode is fraying of the tensile member on the sides of the belt (i.e., the tensile cord pops out or unravels from the belt). Field observations indicate that this almost always takes place on the engine side of the belt. In rare instances, the front cord will come out, particularly when the belt has had many runs and is beginning to show signs of a fatigue failure.

The loosening of edge cords on the engine side of the drive is considered to be a sign of excessive misalignment between the blower and crankshaft. In some instances, it is possible that the edge cords have been loosened by the belt tracking hard against the idler flange (because of blower or idler misalignment) or because the belt has hit some part of the engine. Any edge cord protruding from the belt should be trimmed immediately. Left exposed, the cords become an effective "weed whacker," often damaging external engine parts. Excessive occurrences of exposed edge cord around the belt are a sign of pending failure; the belt should be replaced.

IV. Engineering analysis

Once the field observations had been made and the failed belts analyzed, the Gates engineering staff began to research the drive characteristics that could affect belt performance. This was done using computer programs and mathematical methods developed for belt-power transmission analysis. The criteria investigated included blower-horsepower load; blower-acceleration loads; torsional-vibration ("impact wrench") loads; and the operating differences between fuel and alcohol cars.

The first effort was to investigate existing research work on blower-horsepower requirements. For the most part, our reliance was on the work done by Norm Drazy during his development of the PSI blower (data from June 3, 1988 *ND*). Based on his work, plus confirmation by others in the field, it was estimated that a supercharger on a fuel car would require between 750 and 1,000 horsepower to drive. This load may seem high for a rather small belt, but it is effectively the same torque load that the belt is subjected to in accelerated laboratory tests (corrected for belt width). Because the belt lasts far longer than 100 hours in laboratory tests, this certainly would suggest that blower horsepower in itself is not sufficient to cause premature belt failures.

Because blower belts are operating at much higher speeds than typical timing belts in the industrial environment, close attention was paid to the effects of centrifugal tension on the belt. It was determined that an engine operating at 7,500 rpm has approximately 600 pounds of centrifugal tension while an alcohol car running at 10,000 rpm has more than 1,100 pounds of centrifugal tension. It should be noted that the belt "feels" the centrifugal tension while the hardware (idler, blower, and crankshaft) does not.

The next step was to determine the effect of acceleration loads. From engine charts on Gary Ormsby's Top Fueler (Fig. 4), it was determined that the engine accelerated approximately 4,500 rpm in 0.2-second. The acceleration loads on the belt were determined by taking the inertia of the blower and applying typical engineering formulas. Table 1 shows the effect of those calculations. The tension described in the table is the tension "felt" by the belt. Comparison of those tensions to the accelerated laboratory testing noted earlier showed that none — either singularly or combined — was sufficient to explain the low number of runs experienced by some teams.

As a result, other elements of the drive were investigated to determine their possible effect on the belt. Those factors include: torsional vibration (acceleration/deceleration due to high cylinder pressures); the effect of misalignment; the effect of starter loads; and block growth.

Torsional vibration is the phenomenon by which the crankshaft twists slightly as each piston fires and thus produces an "impact wrench" effect on the belt. It was felt that this was a significant factor because it also reduces crankshaft life.

It is impossible to determine the actual crankshaft-velocity fluctuations or torsional vibration on this type of engine, so engine crank data, obtained from a development diesel engine with very little crankshaft damping, was used. This was known to be one of the engines that most affected belt life.

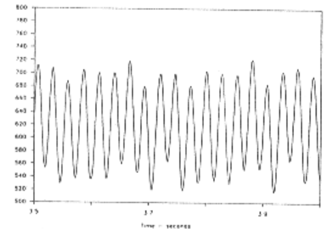

Fig. 5

This graph shows the instantaneous acceleration and deceleration rate for each rotation of the crankshaft in a blown fuel racing engine.

The methodology involved determining the instantaneous acceleration and deceleration rate for each rotation of the crankshaft (Fig. 5). These diesel-engine data, together with the inertia of the blower, were used to determine the acceleration/deceleration loads. The analysis would not suggest that this is a major factor in the belt fatigue. However, most people involved with the project believe that the fuel engine's "impact wrench" effect on the belt is far greater than the analysis indicates and is a highly probable cause of premature belt failures. This is particularly true when one compares performance of an alcohol-car belt to a fuel-car belt (discussed later).

Blower-shaft/crankshaft misalignment was considered to be a significant factor in belt failures, particularly when edge-cord failure was prevalent. Field measurements indicated a typical misalignment of 0.020-inch in center distance in a three-inch pulley width. Based on the very high modulus (resistance to stretch) of the tensile cords, this produced a significant tension differential across the belt (400 pounds).

The higher tension would be on the engine side when the pulleys were misaligned such that the center distance was greater close to the engine. It should be noted that the misalignment measured in the car obviously was a static measurement, and that dynamic tensions on the shafts (more than 3,000 pounds in some cases) undoubtedly would result in even further misalignment, perhaps doubling the 400-pound value. Further observations of worn pulleys usually revealed more wear closer on the engine side, which is a strong sign of misalignment.

Part of the analysis involved investigating the effect of starting the engine with the electric starter located on the blower pulley. This results in a tight strand tension across the idler. Based on actual test data from starter motors, it is estimated that the belt tension across the idler is more than 1,000 pounds during the starting operation — and this is assuming a smooth start! Tension of this magnitude is considered significant because many of the idler brackets appear to be rather low in strength and are heavily cantilevered. Recently, outboard support devices have been offered; they are highly recommended for this application (Fig. 6).

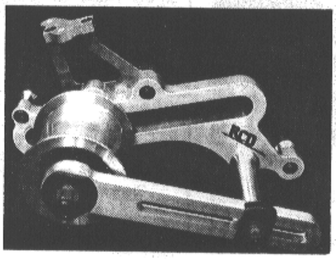

Fig. 6

An outboard support device can help reduce belt tension across the idler.

A typical symptom of a bent idler bracket is a belt that tries to track toward the engine. At least one national television broadcast showed a belt riding over the blower pulley and idler flange during a starting operation. Inspection of many idlers and idler brackets revealed a large number of misaligned idlers, most often a result of insufficient idler-bracket strength.

The last mathematical analysis investigated the effect of block growth on belt tension. Block growth was measured on one fuel engine at approximately 0.050-inch (from cold engine to hot engine at the end of the track). The analysis assumed zero tension on a cold block and calculated the effect of the growth. This amounted to approximately 1,000 pounds of belt tension.

Table 1

CALCULATED DRIVE TENSIONS

	Belt tension (pounds)
Blower HP 1000 HP @ 7500 RPM	2700
Centrifugal Tension	
7500 RPM	600
10000 RPM	1100
Acceleration of blower 2200-7500 RPM (0.2 Sec.)	200+
Velocity fluctuations (impact-wrench effect)	100 to ?
Alignment (Static) .020 in 3"	400
Starter	1200
Block Growth (.050)	1000

The effects of each of the analyses also is shown in Table 1. It should be noted that not all tensions are additive; the values are shown merely for comparison. It is reasonable to predict that shaft loads on the blower and crank reach 3,000 pounds under some conditions (Fig. 7) — the equivalent of hanging a midsize car on the end of the blower pulley!

An analysis of the belt tensions was carried to the tension-per-cord level to determine the impact on an individual tensile cord within the belt. The results are shown in Table 2, page 75. Most interesting to note is the effect of misalignment. Theoretically, the belt is like a piece of sheet steel wrapped around two misaligned flat pulleys. The edge of the steel band or, in the case of the belt, the edge cord on the longest center distance, carries virtually all of the tension caused by misalignment. In the real world, the cords probably share the misalignment alignment tension more than is shown in the table, but it is obvious that the impact of misalignment is very dramatic. The cord tensions in the chart, with the exception of the misalignment, are considered to be reasonable values when compared to our laboratory tests.

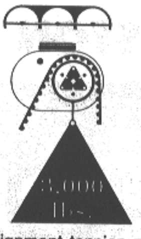

Fig. 7

Shaft loads on the blower and crank can reach 3,000 pounds, the equivalent of hanging a midsize car on the end of the blower pulley.

Table 3

COMPARISON: FUEL VS ALCOHOL ENGINES

	Fuel	Alcohol
Max. engine RPM	8000	9500
Engine speed at green light	2000-2500	5000
Fuel used per run	5 Gal	2 Gal
Blower-speed ratio	130%	140-160%
Smallest blower pulley	27T	25T
Detonation	Frequent/severe	Seldom
Belt width	75mm	65mm
Runs per belt	6-10	30 or more

During the field observations, it became apparent that most alcohol cars have significantly better belt lives than fuel cars. A comparison was made of the typical operating characteristics of these two types of cars (Table 3). Engineering judgment would strongly suggest that the alcohol car should be significantly more detrimental to the belt for several reasons: The engine operates at a higher speed and the overdrive to the blower is greater, therefore the blower horsepower should be significantly greater, plus the number of flex cycles is higher; the blower pulley is usually smaller, so the fatigue of the belt should be greater over the smaller-diameter pulley; and in many cases, the belt width is slightly narrower than that used on the fuel car yet a significantly higher number of runs result.

The only logical explanation for this anomaly is that fuel-car torsion vibration is far greater than calculations indicate and is much greater than that of alcohol cars. This makes sense because of the fuel engine's extreme cylinder pressures and the greater tendency to detonate.

As a result of the field-observation and engineering-calculation portions of this study, several potential causes for belt failure were theorized. They are shown in Table 4.

Table 4

FACTORS AFFECTING BLOWER BELT LIFE

- Blower horsepower and effects of large amounts of fuel into top injector
- Centrifugal tension
- Sprocket and idler size
- Sprocket pitch system and tolerances
- Sprocket wear
- Tension (too low, ratcheting)
- Alignment
- Handling of belt
- Detonation/crankshaft torsionals
- Engine or run problems (i.e., tire spin, burst-plate failure, etc.)

V. Laboratory tests

The laboratory testing program evaluated the following variables: vendors' pulleys; belt-construction variables; and belt tensioning.

Pulleys from each of the three pulley manufacturers (Blower Drive Service, RCD Engineering, and SSI) were obtained for this laboratory test. Prior to the dynamic testing, each pulley was submitted to a computer-controlled coordinate-measuring machine, which accurately determines the various dimensions of the pulleys. Though some pulleys were out of the normal tolerance as specified by The Gates Rubber Company, they appear to be adjusted for this application.

The equipment used for dynamic testing was an electric dynamometer (Fig. 8). This is a highly sophisticated testing apparatus combined with a high-resolution video camera and computer data-acquisition equipment. Belts were tested at torque loads similar to the application, corrected for belt width.

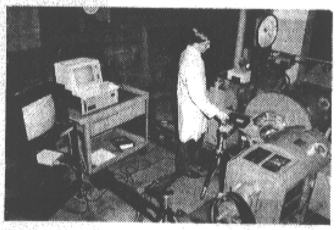

Fig. 8

The electric dynamometer is used for testing the various blower pulleys, belt-construction variables, and belt tensioning.

The first part of the tests evaluated the dynamic fit of the belt in each of the vendors' pulleys. Results were inconclusive; all vendors' pulleys appeared to function equally well.

The next part of the evaluation consisted of looking at tensile-cord and tooth-profile variables; these variables reflect recent technology developments. They will be described in more detail later in this article.

As was the case with the vendors' pulleys, these dynamic tests offered no conclusive evidence that one construction was better than another. It should be noted that none of the tests were fatigue tests (i.e., the belts were not run to failure). The tests were intended merely to determine dynamic meshing, fit, and tension characteristics.

The last part of the dynamic test involved determining the effect of various installation tensions on belt operation. By far, this was the most important part of the laboratory test. A high-resolution camera was focused on the entrance of the belt into the driven pulley, where the slack side of the belt enters. The belt was installed at various initial installation tensions and the torque was increased to the point of maximum tester capability.

It became obvious that the low installation tensions typical of the racing application produced extremely large amounts of belt rideout, to the point where the belt actually ratcheted on the pulley (i.e., skipped teeth). The illustration in Fig. 9 shows the type of belt rideout experienced. Figs. 10-14 show the results of this testing.

Fig. 10 is a graph showing the shaft load in pounds of force versus the torque in pounds-feet for various installation tensions. At zero torque, the effect of the installation tensions is quite dramatic.

As torque increases, all timing belts generate their own tension and the advantage of low installation tension begins to disappear. But the effect of installation tension on the belt is drastic, as shown in Figs. 11-14. For this test condition, the equivalent torque to a blower-drive application is in

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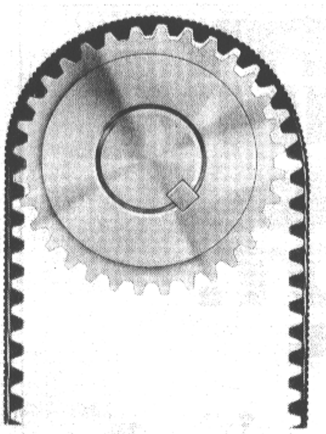

Fig. 9

Illustrated is belt rideout, where the blower belt ratchets on the pulley, resulting in skipped teeth.

Supercharger belts

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the 200 to 250 pounds-feet range.

Figs. 11-14 are photos taken by the high-resolution video camera. The torque and tension values are recorded by transducers on the dynamometer and sent to the video display through a computer interface. Fig. 11 shows the belt at approximately 210 pounds-feet of torque and 1,000 pounds installation tension (proper for this application). Figs. 12-14 show the effects of reduced tension at the same torque load. Fig. 14 shows that, despite an initial tension that was only 10 percent of the ideal tension, the belt has self-tensioned to the point where the shaft load is approximately the same as the test with the proper tension, and the belt is almost completely out of the pulley.

What does all this mean? A loosely tensioned belt does not reduce the shaft loads on the crank and blower at race operating conditions. It does, however, produce a condition where the belt is very close to ratcheting. On the actual application, where the shafts are not as rigid and the operating conditions are considerably more severe than those created by the laboratory equipment, it is quite likely that the belt can and will ratchet.

The ratcheting theory becomes even stronger when you read the following excerpt from *National DRAGSTER* (Oct. 25, 1991), which describes the final round at the Chief Nationals between Kenny Bernstein and Don Prudhomme:

"Prudhomme marched away to post the easy win, 5.00 to 5.12, despite losing a blower belt on the top end.

" 'About three-quarters of the way down, I could see pieces flying off his belt,' said Bernstein. 'I was already three or four cars back going, "Oh, come on, baby!" hoping it would come off. It finally did, but he was at the finish line by then.'

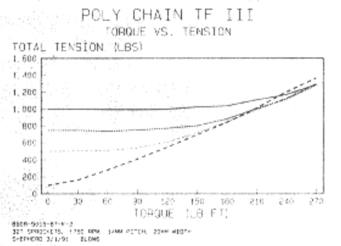
" 'I felt some vibration,' Prudhomme related, 'but I'd already gone by Kenny and I wasn't going to lift.' "

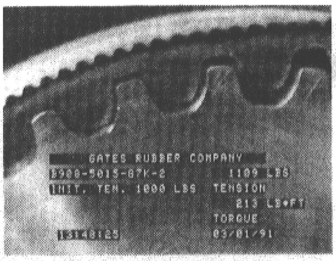
It is our opinion that the vibration and tooth shear noted by Bernstein and Prudhomme are the result of belt ratcheting.

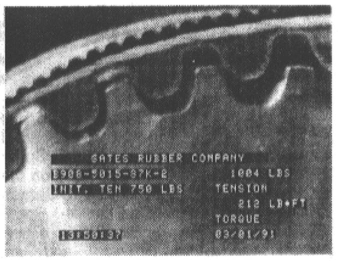
VI. Field-test program

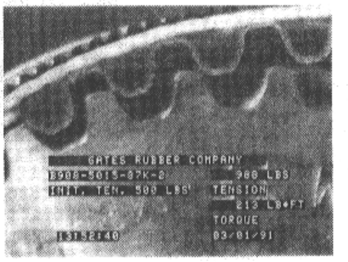
The details of the belt variables in the field-test program are described later in this article. However, two general types of belts were tested. The first type is the commonly used 111-tooth HTD profile. The second was a 112-tooth belt with a new generation curvilinear profile as described in U.S. patent 4,605,389. This belt will be referred to as the TF III profile belt.

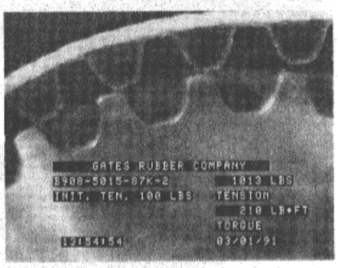
The first field-test program began in 1990 on Ormsby's Top Fuel car. This program involved 16 111-tooth HTD belts reflecting 77 runs with no belt failures. The variables involved a control belt with standard construction and two tensile-cord variations. Both cord variations had higher tensile strength and greater modulus (greater resistance to elongation).











Figs. 10-14

A high-resolution video camera catches the blower belt on a torque-producing pulley at various stages of installation tension. The torque versus tension curve is above left.

The belts were installed in the manner to which then crew chief Lee Beard was accustomed, then returned to Gates for teardown tests. These tests consisted of slitting two 20mm-wide "belts" from each outside edge of the 75mm-wide belt. Care was taken to note which of the two belt specimens was running closest to the engine so that the effect of belt misalignment could be determined.

The specimen "belts" were then subjected to tests for tooth-shear strength, cord adhesion, tensile modulus, and tensile strength. The reduction of these physical properties was compared to an untested belt and the database from our normal laboratory test programs.

The variables of tooth shear, cord adhesion, and tensile modulus did not seem to be as sensitive as the tensile strength in this project.

The tensile-strength results of the two specimens from each belt did not show a major effect of misalignment, although the Ormsby crew was careful to maintain alignment as close as possible. The major factors of this test program were tune/run variables, tire spin, and loose idler.

Of the factors listed above, tire spin seemed to stand out as significantly reducing the tensile strength. Also, the Ormsby crew was experiencing loosening of the idler, which seemed to impact the test values. The belt that was used at the Mopar Parts Mile-High Nationals appeared to have more fatigue damage due to the smaller blower pulley that was necessary for more air at the Denver, Colo., track.

It should be noted that, even with a relatively controlled test program, the variables in drag racing are so random that it is extremely difficult to determine the impact of each variable.

In 1990, an informal test program also was conducted with Lou Gasparrelli's Alcohol Funny Car to observe the new TF III-type belt. The results were very encouraging and pointed to the need to gather more data.

In 1991, the test program was expanded to include Darrell Gwynn's Top Fueler. This program centered on another tensile-cord variable (described in U.S. patent 4,652,252) and the new tooth profile (TF III). Both variables were considered to be significant improvements in the commercial industrial market (i.e., fan drives, pump drives, and so on). However, because of the unique operating characteristics of these engines, it was not known if the new technology would produce similar results.

The 1991 test program involved the following:

- Number of belts tested: 29
- Total number of runs: 199
- Highest number of runs per belt: 14 on Gwynn's car, 42 on Gasparrelli's car.
- No belt failure.

As was the case with the 1990 program, the testing crews were permitted to install and operate the belts in their normal fashion. In the case of the Gasparrelli test, the belts endured several burst-plate explosions and three engine failures, yet the belts remained in excellent condition.

The returned belts were tested in the same manner used in the 1990 program. In addition, the test specimens were carefully examined for signs of failure in the same location, which would indicate installation or storage damage.

All three cars began the season with the TF III profile, but the Ormsby car returned to the 111-tooth HTD belt at midseason because of some tune-up changes that did not permit use of the longer TF III belt. It also should be noted that operating a belt for 14 runs on Gwynn's car was highly unusual; the team had been changing belts after four runs maximum prior to the test program.

The teardown examination of the returned belts did not show any significant new factors. However, the data for the new TF III belt strongly suggested that it is less susceptible to damage from various run variables. For example, two of the Gwynn belts were damaged during engine or blower explosions. Still, the belts remained intact and able to be tested, showing good retention of physical properties in the undamaged areas.

A 1992 test program has been established. It involves three Top Fuel cars, one fuel Funny Car, and one Alcohol Funny Car. The objective is to better understand the effect of run variables on the TF III belt. Special emphasis will be put on determining the effect of blower-pulley diameter and backside idlers.

VII. General findings

Of all of the possible causes effecting blower-belt-drive life listed in Table 4, the following items are considered to have minimal impact:

Blower horsepower — The horsepower transmitted by the belt is well within the belt's capacity, provided that the fuel is not heavily diverted into the injectors above the blower.

Centrifugal tension — While the belt speed is very high on these drives, centrifugal tension is not considered to be "fatal."

Sprocket wear — This is not considered to be a major factor as long as the teeth retain their shape or profile. This can be determined by comparing the worn surface on the sprocket to an unworn area at the edge (if available).

Handling of the belt — As long as the belt is stored in a relaxed position and not forced to bend around small diameters (i.e., crimped), the product is sufficiently robust to withstand normal handling.

The following major factors are considered to have a dramatic effect on belt performance:

Alignment — As shown in Table 2, misalignment can significantly overload the cords and produce early edge-cord pullout. In addition, misalignment affects where the belt rides on the pulleys and easily can force a belt into the flange, accelerating the edge-cord failure.

Installation Tension — This is considered to be one of the major factors. Examination of many failed belts reveals that tooth shear is a frequent failure mode, and all evidence points to the very low tension run by many teams as a cause for failure. It cannot be stated strongly enough that proper installation tension (as compared to the calculated 3,000-pound tension resulting from the power transmitted) is not considered to be detrimental to either the crank or the blower. Further observations of many Top Fuel cars suggest that those who run their belts on the tighter side have fewer belt problems. Fig. 15 shows the method of measuring the minimum recommended tension for a warm engine.

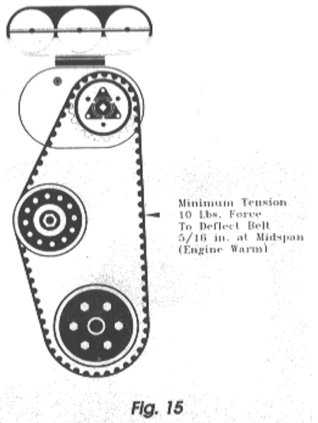


Fig. 15

This is the recommended blower-drive tension for a warm engine. Many Top Fuel teams that run their belts on the tighter side have been known to have fewer belt problems.

Detonation/crankshaft torsionals — This is considered to be a major factor by far on fuel-type cars. Though the engineering calculations would suggest minimal impact, it is the only explanation for the difference between alcohol- and fuel-car belt performance. Indeed, it is a reasonable explanation of the difference in belt performance on various cars that have significantly different tuning techniques. It also is reasonable to believe

Table 2

CALCULATED DRIVE TENSIONS

	Belt Pounds	Tension per Cord (Pounds)
Blower HP 1000 HP @7500 RPM	2700	90
Centrifugal Tension		
7500 RPM	600	20
10000 RPM	1,100	37
Acceleration of Blower 2200-7500RPM (0.2 Sec.)	200+	7+
Velocity fluctuations	100 to ?	2 to ?
Alignment (static).020 in 3"	400	400
Starter	1200	40
Block growth(.050)	1000	33

that the energy that causes forged crankshafts to fatigue in less than 20 runs also would cause belt problems in four to five runs, especially considering that the belt is driven off the shaft.

Tire spin and unusual race phenomena — These factors can significantly impact belt life. The exact explanation is not obvious, but in virtually every case where tire spin or very unusual conditions (such as burst-plate failure, radical tuning, or bearing damage due to detonation) occurred, all seem to significantly impact the blower belt.

Belt and sprocket pitch — These factors, too, can have a drastic effect on belt performance. Though the majority of the drives in existence today use the 111-tooth belt with a 13.9mm pitch, some sprockets and belts have a 14.0mm pitch. Care must be taken to separate these two pitch systems because mixing them will cause immediate failure.

Sprocket and idler size — Testing of the longer, 112-tooth TF III belt has allowed larger pulley sizes. One team was able to run a 44-tooth pulley on the crank after machining a slight relief in the fuel-pump mounting housing. This permitted the use of much larger blower pulleys and has resulted in significantly better test results.

Idler size can have a drastic effect on belt life. One test team used 3.2-inch inside and backside idlers (backside idler systems are described later in this article), resulting in immediate failures on two consecutive runs. An examination of the belt revealed devastating cord fractures between every tooth.

The new cord technology is fantastic, but it has its limitations, and small-diameter pulleys absolutely cause havoc. Any backside idler *must* be at least 4.5 inches in diameter. Though many cars run inside idlers as small as 3.2 inches, it is recommended that they be no smaller than 4.0 inches.

VIII. Changes as a result of test program

As a result of the extensive test programs, two major belt changes have been made. First, the 111-tooth HTD belt has been changed to include a newer-technology tensile cord. Second, the TF III belt, based on a new tooth-profile system plus improved cord-processing technology, has been released to the racing market.

As noted earlier, the Poly Chain belt was introduced to this market in 1975 and its construction had not been changed since that time. In the field-test programs, two belt components were evaluated: Tensile-cord material and tooth-profile systems.

All tensile-member variables tested were of the generic aramid family, but they have a significantly different set of physical properties (U.S. patent 4,838,843) as compared to the standard belt. With the newer version of the aramid material, the tensile strength is increased approximately 25 percent while the modulus of the belt is increased by 30 percent. Both changes are in the correct direction; the increased tensile strength helps the belt to sustain some of the very high tensions generated in the drive, and the increased modulus reduces the stretch of the belt, helping it to maintain proper fit with the pulleys.

This new material has now been incorporated into all 111-tooth 65mm- and 75mm-wide belts. The belts can be identified by the HT designation at the end of the part number on the product. The Gates Rubber Company believes this to be a significant improvement to the existing 111-tooth blower belt.

By far the most dramatic impact on belt performance is the change from the original 111-tooth belt configuration to the new 112-tooth TF III belt. The original 111-tooth belt was based on the HTD profile. The TF III belt takes advantage of a new tooth-profile system (U.S. patent 4,605,389). In addition, it is designed around a further tensile-cord improvement (U.S. patent 4,652,252). With these two new advancements, the TF III belt has vastly different characteristics with even higher tensile strength and tensile modulus (compared to the upgraded 111-tooth HTD belt), plus a significantly improved belt-and-sprocket system. The new geometry of the TF III system is compared with the HTD system in Fig. 16. The TF III is based on a gear profile that produces uniform tooth loading and tensile-cord load distribution.

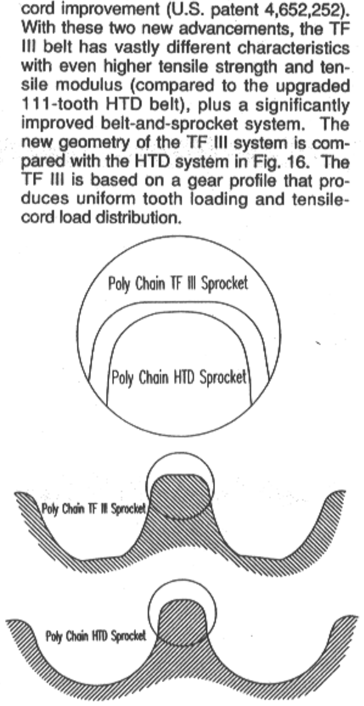


Fig. 16

The new geometry of the 112-tooth TF III system is compared with the older 111-tooth HTD system below. The TF III is based on a gear profile that produces uniform tooth loading and tensile-cord load distribution.

The TF III also has more than 40 percent more land area as compared to the original HTD sprockets. This land area is a major factor in the racing industry because of the extremely high pressure between the tensile cord of the belt and the top of the sprocket tooth.

One further benefit is that the new system has about 40 percent less backlash (i.e., clearance between the back of the tooth and the sprocket). This is believed to help reduce the damage caused by the torsionals on the belt.

The new TF III belt was thoroughly tested in the 1991 race series by the Gwynn, Ormsby, and Gasparrelli racing teams. As evidence of the TF III's durability, the Gwynn car produced a 1991 test belt with 14 runs and a 1992 test belt with 21 runs; the Gasparrelli car produced three belts with at least 25 runs (one recorded 42 runs, including three burst-plate explosions and three engine explosions), all with physical properties in the same general range as belts with two to three runs.

This belt has been made available to the racing industry but requires new sprockets because of the new profile. In both laboratory and field testing, it has proven to be a superior product and should significantly improve the belt reliability on fuel and alcohol cars.

IX. Changes required to improve belt reliability

While The Gates Rubber Company has moved to significantly improve the existing belt and offer a new belt system to the industry, these changes will not improve belt reliability on drives that are not properly set up by the crew. The following four major items must be strictly adhered to:

Alignment — Alignment must be maintained so that there is no more than 0.020-inch center distance difference from the front to the back of a 75mm-wide drive. This can be easily measured with inside micrometers (with the fuel pumps removed). Alignment of idlers is equally important, especially considering the frequent occurrence of bent idler brackets. A straightedge should be used to verify proper alignment.

Idler bracket and geometry — Because of the large number of observed problems with idlers (bending, loosening, and misalignment), it is strongly suggested that the idler bracket be of the modern high-strength design, including an outboard support.

While most engines today use only one inside idler, some teams have had reasonable success with a combination of an inside and backside idler (Fig. 17). The use of backside idlers is of some concern because the belt must undergo a very quick bending reversal with each cycle. To minimize the severe bending damage, backside idlers must be at least 4.5 inches in diameter.

As mentioned previously, the impact of idler size and effect of backside idlers is a part of the 1992 test program. Any significant findings will be reported at the end of the year.

Belt tension — Belt tension is considered to be the most important factor in this drive. Fig. 15 shows the tensioning methods strongly suggested as a result of the field and laboratory testing. This tension will not be sufficient to cause damage to the drive components and, as shown earlier, the shaft loads will be almost equal.

Review data for unusual run conditions — The crew should carefully study the results of each run and the engine condition to see if there are "flags" for changing a belt regardless of whether a failure has occurred. Obvious signals would be excessive engine rpm due to tire slippage or component failure, significant bearing flattening, or a blower burst-plate failure. Any of these would suggest that the belt has undergone excessive loading and may have suffered physical damage.

In summary, the three-year program of field observation, engineering analysis, field testing, and laboratory testing has resulted in significant belt changes and has identified major causes of premature belt failure. Switching to either the upgraded HTD belt or, preferably, the new TF III belt system, together with proper setup of the belt system, should significantly improve the reliability of the blower-belt drive. It cannot be emphasized strongly enough that merely changing the belt construction while maintaining old habits will not assure improvement.

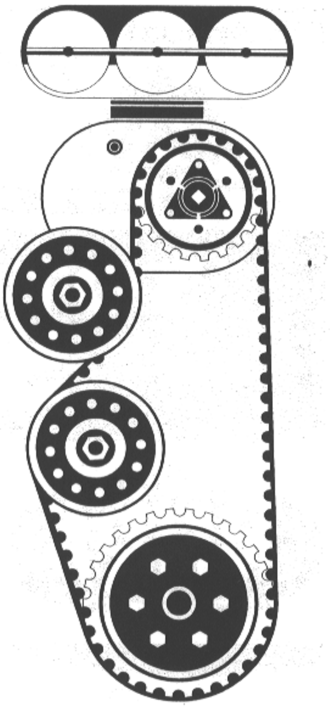


Fig. 17

Just one inside idler is on most modern engines, but some teams have enjoyed success with a combination of an inside and backside idler.

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