How Tonneau Covers Affect The Coefficient of Drag

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Conclusion

The tests showed that all of the tonneaus improved the coefficient of drag for each of the pickups. The two fiberglass tonneaus and two of the roll-up vinyl covers did the best, with improvements of 6.5% or more. That is not to say, however, that in real-life situations they would always fair the best. For one thing, the two roll-up tonneaus in questions were on the same truck, the Sierra. It could be that for this particular truck, vinyl roll-up tonneaus will reduce drag the most. And for the fiberglass tonneaus, we have to remember that these can weigh much more than the soft covers and the result of adding the weight to the truck could decrease or even negate any improvement in C_d. Because each pickup on the market has its own distinct design features, it is very likely that different covers will do differently on different trucks. The most important result to take away from this wind tunnel test is the fact that the covers did reduce drag, which would likely help to improve fuel economy.

On average, it is safe to say that a tonneau cover will reduce the coefficient of drag by 5.73% (based on the thirteen different tonneaus we tested.) We tested a variety of covers, from soft vinyl, to folding two-piece to fiberglass. As indicated earlier, other tests would need to be conducted in order to determine the exact effect on fuel economy. Aerodynamicists often say that a 10% improvement in aerodynamic performance is good for a 2-3% improvement in gas mileage, based on an EPA road speed of 48 mph. Therefore, an improvement in C_d of 5.73% could account for a 1.8% improvement in gas mileage. The results of this test are positive for tonneau manufacturers. With fuel efficiency on the minds of consumers and automakers alike, it’s great to see that aftermarket products can help improve fuel economy and will keep pickup truck enthusiasts in their pickups.

Introduction

With rising gas prices, fuel efficiency is on the minds of anyone who uses a car or truck for transportation. The segment often most affected by gas prices is the light truck market, which includes the automakers who build the trucks, the consumers who buy the trucks and the specialty equipment companies who manufacturer parts for the trucks.

On January 30 and 31, 2007, I conducted a study on the affect that tonneau covers have on the aerodynamics of pickup trucks. The tests were conducted at the A2 Wind Tunnel of AeroDyne Wind Tunnel, LLC in Mooresville, North Carolina. In this paper, I will discuss everything that was involved in the study including the results.

Setting Up The Project

The first step was to find a wind tunnel which could accommodate full-sized pickup trucks. After some research, I found the AeroDyne facility and it seemed like a perfect match. AeroDyne serves the NASCAR community and is often booked 18 months out. It runs 5 days a week, for 24 hours per day. It expanded in the spring of 2006 with the opening of the A2 Wind Tunnel. A2 was built because of the demand for wind tunnel time, as well as to serve a broader range of customers at a more affordable price.

SEMA members who make tonneau covers and truck caps were invited to participate in the study. Everyone was told up front that individual results would only be distributed to individual companies, with the overall results simply indicating how the products affected aerodynamics in general terms.

Once we had the companies somewhat in place, as well as the wind tunnel on board with the project, I had to set out to secure some trucks. This proved to be the most difficult aspect of the project. I also wanted to find a university professor to participate in the project, to help certify the legitimacy of the project and ensure that to outsiders, the project did not appear self-serving. When it was all said and done, the process from start to finish took about a year.

Process Overview

Nine companies elected to participate in the study. They provided various types of tonneaus, from soft vinyl, to folding to fiberglass. The dates were set for January 30 and 31, 2007. I contacted Dr. Richard Mark French, a professor of mechanical engineering at Purdue University in West Lafayette, Indiana and he enthusiastically agreed to be a part of the project. He has prior experience with wind tunnels as well as the automotive industry. In fact, he worked for Lear Corporation for several years.

I chose the Chevrolet Silverado, Dodge Ram and Ford F-150 for the project vehicles. The balance inside the wind tunnel has a weight limit of around 5,800 pounds, so I needed to make sure that we would have vehicles to test that would meet this requirement. As I set out to secure the vehicles, one of our member companies offered to spearhead the search, using his contacts in the Mooresville, North Carolina area. On our end, we continued to talk with local dealerships as well as member companies in the area. In December, the dealers said that they would have no way of knowing exactly which models would be available at the end of January. This is completely plausible, considering they cannot hold trucks on the lot unnecessarily if a sale can be made. However, as the test dates approached the dealers cited concerns about liability and claimed that their insurance would not allow for the vehicles to be used for testing purposes. In fact, at least one inquired as to which NASCAR team owned the wind tunnel, for fear that it was a wind tunnel run by a team of a competing truck manufacturer. I assured everyone that the wind tunnel was independent and tests vehicles from all manufacturers.

The week before the test, I did not have any trucks to use. I decided to start contacting the car rental facilities in the area. I contacted everyone from U-HAUL to Enterprise. In the end, I was able to secure three trucks from the Enterprise Rental Car in Mooresville. The Enterprise representative that was helping me called on Monday while I was at the Dallas airport waiting for my connecting flight. She told me that I would not have a Silverado to rent. I decided to take two F-150s and one Dodge Ram, since we had more covers for the F-150. However, when Dr. French and I picked the trucks up on Tuesday morning, the F-150s did not have 6 ft 5 beds. They had the 5 ft 5 beds, and we had tonneaus for 6 ft 5 beds.

We started testing around 8 a.m. on Tuesday morning. We went ahead and tested one of the F-150s, since one of our members happened to bring a tonneau to fit the 5 ft 5 bed. By the end of the day, we took possession of another F-150, this time from Hertz Rental Car. And this one did have the 6 ft 5 bed. Hertz even delivered the truck to us at A2 from the Charlotte Airport. We also thought we would be able to test a 2007 Silverado that we were able to borrow from a dealer for the afternoon, but because it was 4-door and 4 wheel drive, it was too heavy for the balances. In the end, we were able to test four different vehicles: a 2006 Ford F-150 with a 5 ft 5 bed; a 2005 Ford F-150 with a 6 ft 5 bed; a 2006 Dodge Ram 1500 with a 6 ft 5 bed; and a 2007 GMC Sierra with 6 ft 5 bed, which Bob Smith from A2 was able to secure for us on Wednesday.

Each of the trucks was tested for a baseline coefficient of drag (C_d). In other words, the trucks were tested for C_d values without a tonneau installed and with the tailgates in the upright position. The baselines were normalized to 1 for two reasons. First, we weren't concerned with the actual coefficient of drag for each one of the vehicles. In fact the distance between the sides of the trucks and the walls of the test area could have contributed to an increase in the coefficient of drag for each of the trucks. We did not want to publish a paper saying, for example, that the coefficient of drag for a 2007 GMC Sierra is X. Secondly, normalizing C_d was done in the interest of the SEMA member companies participating. Normalizing to 1 makes it easier to discuss the changes in C_d in absolute terms. We were interested in relative percentage changes, not absolute values.

We tested to see whether a change in speed contributed to a significant change in C_d. Because this was determined not to be the case, we decided that reporting the results from the 85 mph tests would be our main objective. We did, however, test each of the products at speeds of 40 mph, 68 mph and 85 mph.

A2 Wind Tunnel

This wind tunnel was designed specifically for automotive applications. The cross-sectional area of the test section is approximately 109 feet and there is a force measurement system mounted in the floor to record lift and drag. Because of the heavy weights of the pickups used, the measurements for lift cannot be considered as the balances were visibly maxed out. Fans are mounted at the rear of the tunnel and the outer room is used as an air return. Vehicles were run at speeds ranging from 30 mph to 85 mph. The roof of the tunnel has a movable section that allows the cross sectional area to be increased.

In automotive aerodynamic testing, it is important to control the boundary layer along the floor of the tunnel. When a vehicle is moving down the road, air does not move with respect to the road so there is no boundary layer. Because vehicles in a wind tunnel are fixed with respect to the floor and air is moving, a ramp is put in place to reduce the growth of a boundary layer, which could affect net drag.

All runs were viewed from a control room via a video camera monitoring system. After each run, the results were uploaded to Excel spreadsheets on computers in the room. Dr. French and I sat at one computer making notes, while Bob Smith, who ran all of the tests, sat at the other.

Results

Aerodynamic drag is generally assumed to be a function of velocity squared.

$$\boldsymbol{f = C_d \tfrac{1}{2} \rho V^2 S}$$

where C_d is the drag coefficient, ρ is air density, V is velocity and S is a reference area. For the purpose of this paper, we are only concerned with C_d. Furthermore, we cannot extract any information on fuel economy from the coefficient of drag. Determining the effect on fuel efficiency would require knowing the rolling resistance and drivetrain efficiency. If the coefficient of drag is reduced, and the tonneau does not add a significant amount of weight to the vehicle, the fuel efficiency could be improved.

The first truck we tested was a 2006 Ford F-150 with a 5 foot 5 bed. Because we had not planned for this truck, we only had one tonneau to use. As mentioned, we normalized C_d to 1. At 40 mph, this tonneau decreased C_d to 0.956. At 68 mph, the tonneau decreased C_d to 0.942. And finally, at 85 mph, C_d was decreased to 0.943. Because we determined that the change in speed did not have a significant impact on C_d, we decided to focus on the 85 mph values. Therefore, in this case, C_d improved by 5.7%. We also tested the truck with the tailgate down to see how C_d compared to that of the baseline runs. In this case, lowering the tailgate actually created a slight increase in C_d from 1 to 1.001 at 85 mph. This is not significant enough to say that it would affect fuel economy. However, it is interesting, considering many consumers lower the tailgates of their pickups in the hopes that they will get better gas mileage. Chart 1 shows the data for the F-150 tests.

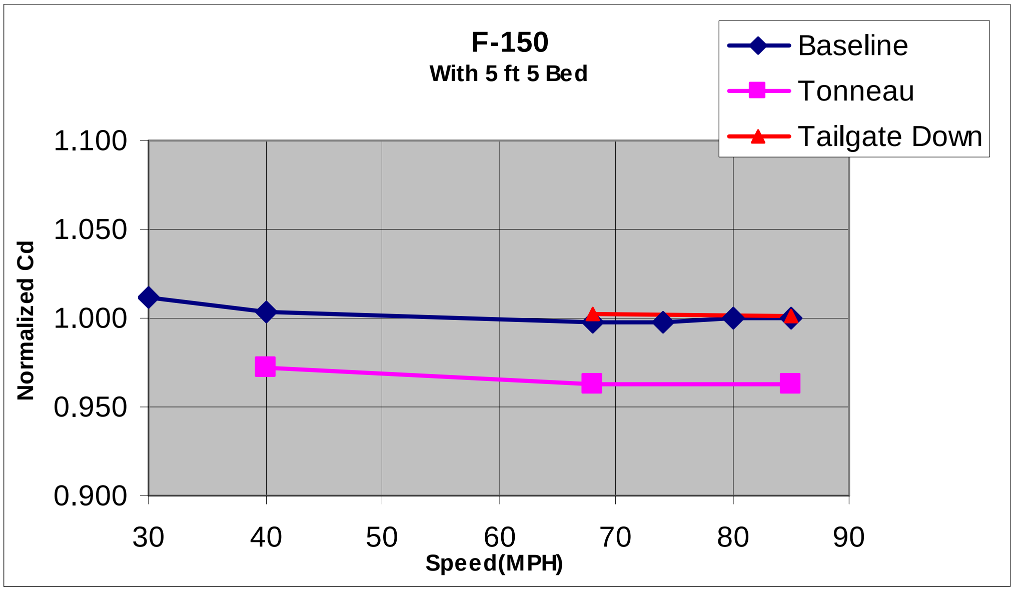

Chart 1

Ford F-150 with 5 ft 5 Bed

Next we tested the 2006 Dodge Ram 1500. This truck was equipped with a 6 foot 5 bed. We were able to test three tonneau covers on this truck. We did not, however, run this truck with the tailgate down.

The first tonneau we tested was a folding, vinyl tonneau. Again, C_d for the Dodge was normalized to 1. The tonneau reduced C_d to 0.966 at 40 mph, 0.952 at 68 mph and 0.950 at 85 mph. In summary, this tonneau improved C_d by 5%.

The second tonneau was a fiberglass product. This tonneau improved C_d to 0.947 at 40 mph, 0.938 at 68 mph and 0.935 at 85 mph. This resulted in a 6.5% improvement in C_d.

The third tonneau was a folding, two-piece hard tonneau. At 40 mph, C_d improved to 0.963. At 68 mph, C_d had a value of 0.951. And at 85 C_d had a value of 0.950, an improvement of 5%.

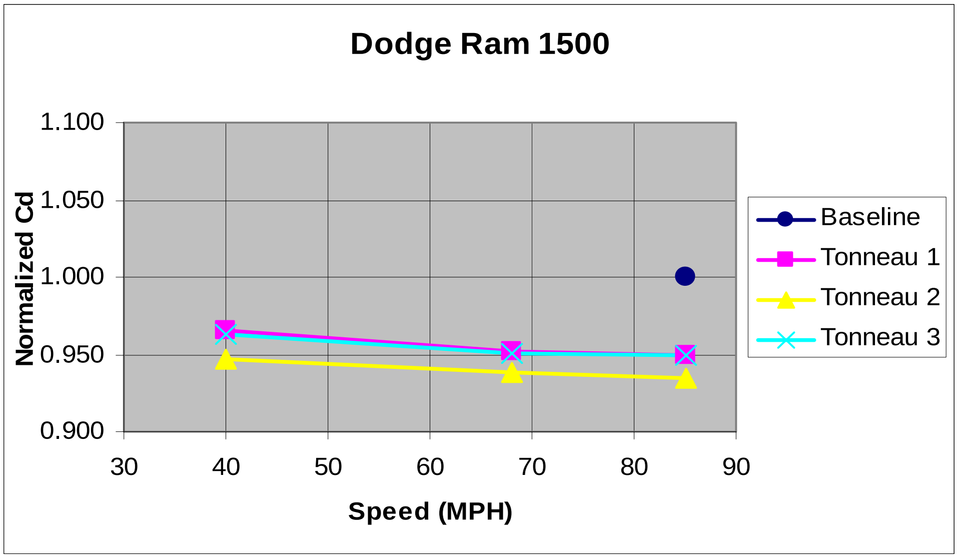

Chart 2

Dodge Ram 1500

We then tested the 2005 F-150 with the 6 foot 5 bed. We were able to test six tonneaus on this truck and again, all of them improved the coefficient of drag. We also tested the truck with the tailgate down, to see the effect if any on C_d. Chart 3 displays these results.

The first tonneau was a one-piece, hard tonneau. At 40 mph, C_d was improved to 0.971. At 68 mph, C_d was improved from 1 to 0.955, and at 85 mph C_d was improved to 0.953 (4.7%). Tonneau 2 was a folding vinyl cover. C_d decreased to 0.962 at 40 mph, 0.955 at 68 mph and 0.958 at 85 mph, an improvement of 4.2%. Tonneau 3 was also made of vinyl. The coefficient of drag was 0.953 at 40 mph, 0.940 at 68 mph and 0.941 at 85 mph, which represents an improvement of 5.9%.

Tonneau 4 was a folding vinyl cover. C_d was 0.961 at 40 mph, 0.946 at 68 mph and 0.944 at 85 mph. This represents an improvement of 5.6%. Tonneau 5 was a retractable hard tonneau. In this case, C_d improved to 0.973 at 40 mph, 0.959 at 68 mph and 0.958 at 85 mph. This is an improvement of 4.2%. And the final cover, Tonneau 6, was made of fiberglass. It improved C_d by 7.8% at 85 mph with a value of 0.923. The values at 40 mph and 68 mph were 0.938 and 0.922, respectively.

For all six tonneaus, the value for C_d decreased significantly above 40 mph, but leveled off at 68 mph. We also tested the truck with the tailgate down, to see if there was any difference in C_d. In this case, C_d did decrease, but not in a significant way. Its value was 0.992 at 68 mph and 85 mph, an improvement of 0.8%.

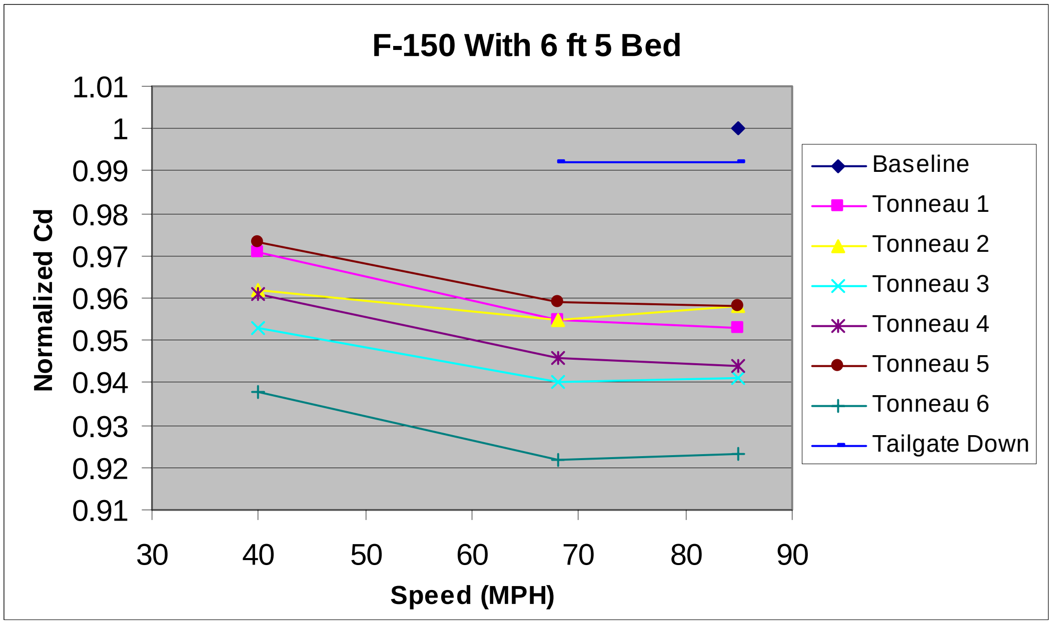

Chart 3

Ford F-150 with 6 ft 5 Bed

The fourth and final truck tested was a 2007 GMC Sierra with a 6 foot 5 bed. We were fortunate enough to be able to borrow this truck at the last minute, and were equally as fortunate that the covers sent for a 2007 Silverado fit on this vehicle. In all, we tested three tonneaus on the Sierra. As with the other trucks, the C_d for the Sierra was normalized to 1.

Tonneau 1 was a vinyl, roll-up cover. At 40 mph, C_d was reduced to 0.953. At 68 mph, C_d was reduced to 0.950. And at 85 mph, C_d was reduced to 0.950, or a 5% improvement. In this case, C_d improved above 40 mph, with the value constant for 68 mph and 85 mph.

Tonneau 2 was also a roll-up vinyl cover. The coefficient of drag at 40, 68 and 85 mph also improved, to 0.944, 0.930 and 0.926, respectively. This represents a 7.4% improvement at 85 mph. In this case, C_d improved with an increase in speed.

And finally, Tonneau 3, also a roll-up vinyl, was tested. C_d was reduced to 0.941 at 40 mph, 0.928 at 68 mph and 0.925 at 85 mph. Overall, this cover improved the coefficient of drag by 7.5%. As with Tonneau 2, C_d improved with an increase in speed.

The Sierra was tested in the wind tunnel with the tailgate down. For this truck, the C_d actually increased with the tailgate in the down position. The value of C_d increased to 1.019 at 68 mph and 1.018 at 85 mph, an effect of -1.8%.

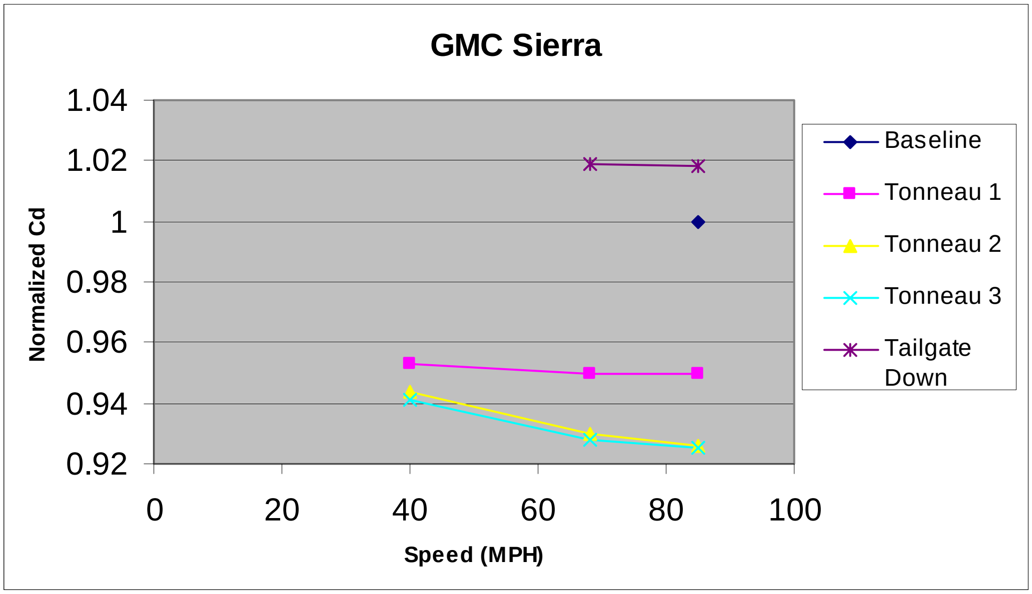

Chart 4

GMC Sierra