Gas Mileage Dependence on Area and Drag Coefficient

Michael Risch-Janson

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Dr. Jim Crumley

Abstract

While many factors contribute to the gas mileage of a car, air resistance is one which is completely independent of the internal engine components and therefore can be compared between all types of different vehicles. Factors which affect air resistance include velocity of the vehicle, density of air, cross sectional area as well as the drag constant (aerodynamics specific to each vehicle). Varying cross sectional area as well as the aerodynamics of a vehicle will change the amount of air resistance drastically and therefore the fuel efficiency. This program allows for the comparison of any cross section with a base vehicle with area of 16 ft^2 as well as the comparison of specific vehicles/drag coefficients with that of a base vehicle (5.0 ft^2 drag * area coefficient). A 10.7 ft^2 drag- coefficient compared to 5.0 led to a gas efficiency of 18.69mpg if the base car were to achieve 40mpg. This decrease in gas mileage is only due to an increase in size and decrease in aerodynamics. A plot of the inverse relationship between area and gas efficiency can be seen. Other factors such as velocity and distance which were held constant between the base vehicle and that of the user do not change the percentage of gas mileage of one vehicle to another, but they do affect the overall difference in the amount of energy used between the two.

Introduction

Many factors affect the gas mileage of a vehicle. Some of these factors are internal. They depend on the engine and the internal components of the vehicle. There are other factors which affect gas mileage which are independent of the internal components. The biggest factor externally is air resistance. Air resistance plays a large role in the gas mileage of a car. Factors which affect air resistance are the velocity of the vehicle, the density of the air, the drag coefficient specific to the vehicle, and very importantly the cross sectional area of the vehicle. In my program I have analyzed two of these external factors. Since the velocity and density of air are not specific to a particular vehicle, I didn't consider them. They can just be considered to be the same between different vehicles. The internal factors are also assumed to be constant between vehicles for the sake of comparing only cross sectional area and drag coefficients.

In considering external influences, I originally was going to account for both cross sectional area (air resistance) as well as friction. While rotating friction can change based on a tire's inflation for example, the friction between the car and the road is static friction and not kinetic because each point on the tire is statically in contact with the road. If the car were sliding across the road, then one could consider kinetic friction. Because the car is moving at constant velocity, the static friction doesn't need to be considered because it is not restricting the car's forward motion. Therefore, my comparisons considered only cross sectional area and, in one case, also the drag coefficient. The drag coefficient comparison is important because although some cars might have the same cross sectional areas, different designs will lead different aerodynamics and therefore different gas mileages.

In the first part of the program, I used the cross-sectional area to calculate the gas mileage a vehicle would have as a percentage of a base vehicle with a cross sectional area of 16 square feet. In the second part I used drag – area constants of specific vehicles which I found to get a better representation of the gas mileage. Cross sectional area is not the only factor in air resistance besides velocity and air density, but rather the drag coefficient associated with the vehicle is also a factor.

To account for the drag coefficients, which are usually experimentally determined, I found data which contained the drag coefficient x area constants for around 40 vehicles. The program will calculate the gas mileage of any of these vehicles as a percentage of a base vehicle with a constant of 5.0 ft^2. The exact gas mileage of the base vehicle is of course unknown because of the many other contributing factors, but an estimated 40 mpg is assigned to base vehicle so that gas mileage for the input vehicle can be calculated. This just corresponds to the percentage calculated in the previous step but offers the user actual numbers which might be more meaningful than a percentage. The third part of the program calculates the gas mileage percentage compared to the 16 square feet as a function of cross sectional area. It begins with 16 ft^2 and goes up to 44 ft^2 in steps of 2 ft^2. The results are graphed showing an inverse relationship between gas mileage and area. The force equation for air resistance is:

$F = k * v^2$ where: k=1/2*Cw*ρ*A

v = velocity = 30mph

A = cross sectional area

Cw = drag coefficient

ρ = air density = 1.2 kg/m^3

$$W = \int_0^{1600} F \, dx$$

which is the amount of work done by the resistive force over a mile (1600 meters)

Materials and Methods

In order to figure out how far the base and user cars would travel on a gallon of gas, assuming that air resistance is the only force which needs to be overcome, I took the amount of energy in joules in a gallon of gas and divided that by the amount of work required in a mile (1600m) to overcome air resistance. Although the amount of energy in the gallon of gas may not be exact and will depend on the efficiency of the engine, the comparison is still valid. I was able to ignore these two factors because the cars are being compared to each other as a percentage of the other. Therefore, changing the amount of joules will not affect the results. Similarly to before, I assume that the efficiencies of the two engines are the same for sake of comparing only air resistance. The amount of joules which I used for each gallon of gas was 1.36 x 10^8. Dividing the distance the two cars will travel on a gallon of gas gave me the efficiency of the user's car compared to that of the base car.

In the second part of the program I read in a list of drag-area coefficients. These are drag coefficients multiplied by cross sectional area. The base car had a constant of 5.0 ft^2. A comparison of the gas mileage of one of these cars to that of the base car involves only comparing the drag-are coefficients because all other factors were constant. A similar approach to before could have been followed if more than a percentage between the two was wanted. Taking the percentage and multiplying it by the chosen

40mpg of the base car gives the gas mileage of the user's car. Again, this number is not exact, but only a rough estimate and a means of comparing actual numbers and not just percentages.

The third program takes cross sectional areas between 16 and 44 ft^2 and compares them to the base vehicles which has a 16 ft^2 cross sectional area and drag-area coefficient of 5.0 ft^2. It then graphs the data. This section of the program again is very simple mathematically because of the constants of all other factors but area. But, the graph is meant to give a visual representation of the differences which cross sectional area causes in gas mileage.

Data and Results

The following is one example run of the program with all input and output included:

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What is the cross-sectional area in square feet?
26

The gas mileage efficiency of your car based on the cross sectional area is:  61.54%
 of that of a baseline car with cross sectional area of 16 square feet.

 Please press enter to continue.
 A list of drag coefficient - cross sectional area constants for various vehicles will be displayed.

 5.10   1999 Honda Insight
 5.71   1990 Honda CRX Si
 5.76   1968 Toyota 2000GT
 5.80   1986 Toyota MR2
 5.81   1989 Mitsubishi Eclipse GSX
 5.88   1990 Nissan 240SX
 5.92   1994 Porsche 911 Speedster
 5.95   1990 Mazda RX7
 6.00   1970 Lamborghini Miura
 6.13   1993 Acura NSX
 6.17   1995 Lamborghini Diablo
 6.27   1986 Porsche 911 Carrera
 6.27   1992 Chevrolet Corvette
 6.54   1991 Saturn Sports Coupe
 6.40   1990 Lotus Esprit
 6.57   1985 Chevrolet Corvette
 6.77   1995 BMW M3
 6.79   1993 Toyota Corolla DX
 6.81   1991 Subaru Legacy
 6.90   1993 Saturn Wagon
 6.93   1982 Delorean DMC12
 6.96   1988 Porsche 944 S
 6.96   1995 Chevy Lumina LS
 7.02   1992 BMW 325I
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7.04 1991 Honda Civic EX
7.10 1995 Saab 900
7.14 1995 Subaru Legacy L
7.34 2001 Honda Civic
7.39 1994 Honda Accord EX
7.48 1993 Chevy Camaro Z28
7.57 1992 Toyota Camry
7.69 1994 Chrysler LHS
7.72 1993 Subaru Impreza
8.70 1990 Volvo 740 Turbo
8.70 1992 Ford Crown Victoria
8.71 1991 Buick LeSabre Limited
9.54 1992 Chevy Caprice Wagon
10.70 1992 Chevy Blazer
11.70 1993 Jeep Grand Cherokee
16.80 2006 Hummer H3
26.30 2003 Hummer H2

Please type in the drag coefficient-area constant associated with your vehicle or the vehicle which most closely resembles yours:
10.70

The gas mileage efficiency of your vehicle based on the drag coefficient-area constant you selected and compared to the base vehicle constant of 5.0 is:
46.73%

This means that if the base vehicle gets 40 mpg that your vehicle would achieve about: 18.69 mpg

Please press enter to continue.
A graph of gas mileage efficiency vs cross sectional area will be displayed with 16 square feet as the base.

The graph of the data can be viewed below. (Fig.1)

Analysis/ Discussion

The results this program outputs are what one would expect, that there is an inverse relationship between cross sectional area and gas mileage und likewise between drag-area constant and gas mileage. This inverse relationship produced a graph similar to that of y=1/x, where x is multiplied by a constant which flattens the graph out. One can also see from the program that vehicles such as a 2003 H2 Hummer would get gas mileage less than half of 1992 Chevy Blazer which was used for the second part. This is based only on aerodynamics and doesn’t even account for different engine energy requirements, which the H2 will most likely exceed the Blazer in.

Another factor which was left constant in the program but which affects air resistance is velocity. Although the percentages would not change, as velocity is increased, the actual difference in resistive force increases in a square relationship, which means the work or energy used changes as well. This is important because it magnifies the difference as does changing the situation so that it is done over many miles instead of only a mile. Although the percentages are the same and a comparison of 1 gallon of gas to 2 gallons might seem minimal, as soon as speed and distance are increased it can quickly become a comparison of 100 to 200 gallons or 1000 to 2000 which is a significant amount of extra energy and resources being used.

References

"Drag Coefficient." *Wikimedia Foundation, Inc.* 2007 <http://en.wikipedia.org/wiki/Drag_coefficient>.

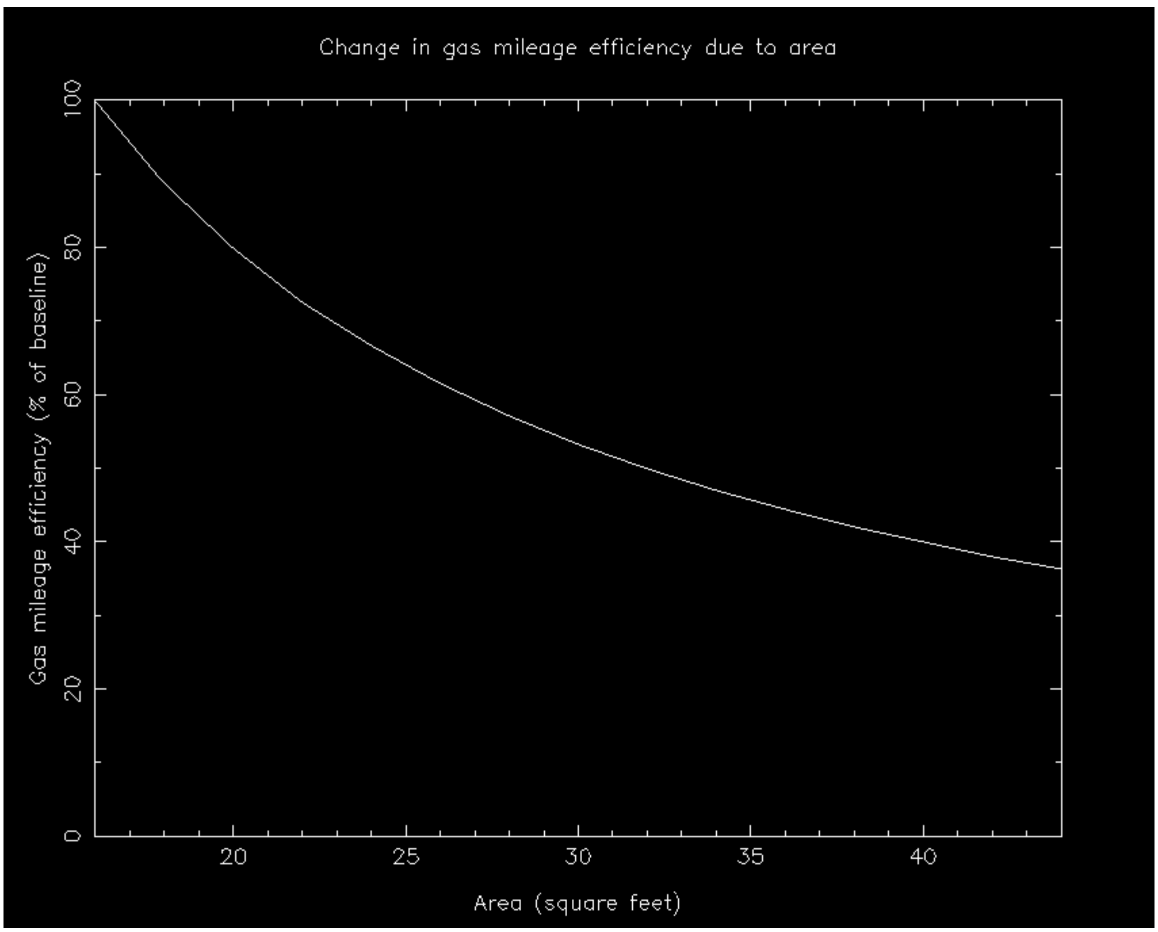

Fig. 1