I Could Have Designed That

by Bryan Lundgren

My confession: I've never owned an automatic transmission car. Choosing to drive little economy cars comes with being at an impressionable age during the 1977 Jimmy Carter U.S. energy crisis. Hypermiling is a little avocation of mine; hence the infatuation with manual transmissions.

Hypermile is a relatively new dictionary word meaning: exceeding a vehicle's Environmental Protection Agency (EPA) fuel economy rating. The EPA rating on my 2010 Ford Focus in miles per gallon (MPG) is 24-city, 28-combined, and 35-highway. I average 38.8 MPG (over ⅛ million miles) without risky drafting of big tractor-trailer rigs.[1]

The first effort to improve fuel economy was to install my electronic "lean circuit" discussed in a previous *Vidya* article (292/293, Oct 2012). Surprise… surprise… Ford's engine is designed to run lean at highway speed. It misfired at light loads such as on a gentle downgrade. Not one to give up, I noticed that air-drag reduction was a common improvement category on hypermile web sites.

Decades ago I modeled my cars' drag using the following equation (see "Drag (physics)" in Wikipedia). Other simple formulas can graph required horsepower and MPG at any given speed. In my experience, this formula predicts steady-state, calm-wind, flat-road, MPG performance accurately.

$$D = (u * w) + (C_d * a * q)$$

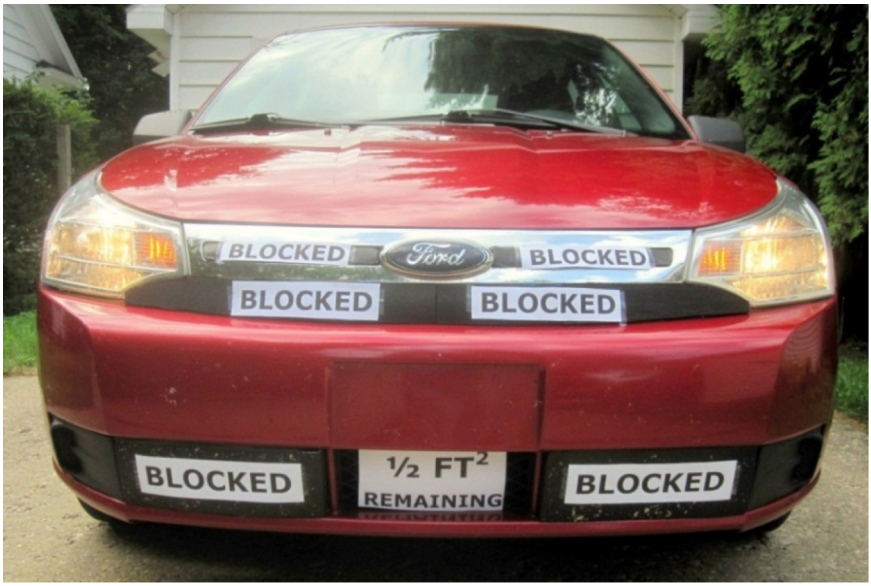
2010 Ford Focus Data and Assumptions:

u = tire friction coefficient = 1%
w = vehicle weight (lb) = 3138
C_d = coefficient of air drag = 0.32
a = frontal area (ft*ft) = 23.6
q = dynamic pressure = $\frac{V_{\text{mph}}{}^2}{391(lb)}$

Fairings, added structures that reduce air drag, are what hypermile websites recommend. A parabolic raindrop shape has a low drag of less than 0.1 C_d. The 1996-1999 General Motors EV-1 electric car had a coefficient of drag (C_d) of 0.2; a great accomplishment for a practical application. Simple fairings easily reduced my car's C_d from 0.32 to 0.30.

[1] Note that the numbers given are US MPG. To convert into UK MPG, just multiply by 1.2; to get $^{l}/_{100km}$ simply divide 235 by the US MPG. So Bryan's 38.8 MPG translate to 46.6 MPG (UK) and 6.1 $^{l}/_{100km}$

The Focus has a Flat Plate Drag Equivalent of 7.6 (ft*ft), found by multiplying the car's frontal area 23.6 (ft*ft) by the C_d of 0.32. The photo below identifies one square foot of frontal area that was faired. This area is blended into the car's shape using three black foam kneeling pads purchased from Lowe's garden supply aisle. The pads are cut to fit and mounted with double-sided foam tape.



The identified openings greatly decelerate entering air-flow. Thus their 1 sq.ft. contribution to drag is assumed to have started with a poor 1.0 C_d. The next guess is that blocking or fairing these openings reduces their drag contribution to a more slippery 0.4 C_d. This is simply explained as smoothing poor air flow by conforming to the car's overall shape. By eliminating 0.6 sq.ft. from the Flat Plate Drag Equivalent, the car's C_d is reduced to 0.30. Yes, seat-of-the-pants engineering, and even "real engineering", makes assumptions. That's why we apply safety factors and test… especially for bridges!

This project cost $26. Three kneeling pads reduce total wind drag 6 pounds at 70 MPH and eliminate one horsepower from the engine's load. This, along with inflating tires to 40 psi and a few other minor tweaks, result in a 2+ MPG increase or ½ cent per mile savings. Over 1/6 million miles of travel, $800 less gasoline was consumed.

So, why was the "I Could Have Designed That" title chosen? In 2012, Ford

Motor Company offered a Grill Shutter to block intake air and thereby improve MPG (media.ford.com/article_display.cfm?article_id=33939). I borrowed the idea elsewhere. Engineering is all about proudly adapting best practice concepts.

Various heat flow assumptions and calculations are not discussed. Blocking ⅔ of the Focus grill still lets sufficient air-mass flow through the radiator. This maintains the engine at a normal 170 °F setpoint with a safety factor of about two. Did the Focus have trouble climbing 4200ft. out of Stovepipe Wells in Death Valley? Well, I tried that with air conditioning on. I bet you expect me to say, "As steam billowed from under the hood, I turned off the A/C, rolled the windows down and turned on the heater." However, the vehicle did not overheat even under extreme ambient heat and engine load conditions.