Automotive Legislation Increases CO_2

Tailpipe legislation has backfired, causing an increase in carbon dioxide (CO_2) greenhouse gas emissions.

Automotive legislation focusses on tailpipe emissions, ignoring the energy consumed and the CO_2 discharged during vehicle manufacture. This solitary focus on tailpipe CO_2 compels automakers to increase their use of low-density materials, like aluminium and plastics, instead of cast iron or steel. For engine production, the use of aluminium does trim weight, reducing fuel consumption and on-road CO_2 emissions. But the upstream production of aluminium emits significantly more CO_2 than cast iron and steel. It rarely pays back.

Researchers at the Sustainable Manufacturing Systems Centre at Cranfield University in the UK conducted a landmark cradle-to-grave study to establish the total energy and CO_2 impact of passenger vehicle engine production. The study collected production data and interviewed over 100 manufacturers and industry experts, addressing every step of the process, from mining through to engine production and on-the-road use. The study focussed on a 1.6 litre four-cylinder engine; the most representative powertrain in the global market today. Researchers compared aluminium and cast iron engines with the same driving performance, for both diesel and petrol power units.

Despite the lighter weight of an aluminium cylinder block, it is the production phase that dominates the life cycle energy efficiency. And the production of each aluminium cylinder block consumes 1.8 to 3.7 times more energy than the production of cast iron.

The nearly twofold increase in energy consumption occurs when the aluminium components are produced in re-usable metal moulds, referred to as high pressure die casting. The almost fourfold energy increase results when the aluminium cylinder blocks are produced by sand casting; where the components are produced in expendable sand moulds. The sand casting technique is similar to the production of cast iron, but aluminium consumes five times more chemically-bonded sand than the moulds used to produce cast iron. The energy required to produce the heavier chemically-bonded sand moulds, and the longer times to maintain the aluminium in the liquid state prior to casting were the main reasons for the higher energy consumption with sand casting.

The aluminium industry notes that the highest energy consumption occurs during the production of virgin aluminium from ore and that cylinder block production primarily uses recycled aluminium. But the Cranfield study took this into account, adopting the best-case scenario for aluminium – infinite recycling.

In order to provide a net benefit to society, the higher energy consumed in the manufacturing phase must be recovered during the on-the-road use phase, through reduced fuel consumption. Using the fuel saving ratio adopted by the US Environmental Protection Agency (4.6% fuel saving for each 5 to 10% of weight saved), the breakeven distance for petrol engines ranged from 185,000 km for die casting to 395,000 km for sand casting. For the diesel engine, the breakeven distance ranged from 270,000 to 560,000 km.

Of the six different aluminium production techniques, only one provided energy breakeven before the global average vehicle lifetime of 210,000 km. For most production conditions, the use of aluminium results in a net energy penalty to society.

According to the World Aluminium Organisation, China accounts for about 55% of the global primary aluminium production. The Gulf States are second with nearly 10%. More than 90% of the primary aluminium production in China is produced using coal-derived electricity. All of the aluminium production in the Gulf States is produced using electricity derived from natural gas.

Overall, more than 70% of the global aluminium production is based on fossil fuels. Under these conditions, the energy intensive production of aluminium generates over 10 kg of CO_2 per kilogram of aluminium. This up-front CO_2 burden presents a significant hurdle opposing on-the-road emissions breakeven.

Once again, even with the favourable assumption of infinite recycling, the production of an aluminium cylinder block releases up to 2.25 times more CO_2 than a cast iron cylinder block. This corresponds to CO_2 breakeven distances ranging from 105,000 km to 470,000 km. Again, only the production of aluminium from metal moulds provided a CO_2 breakeven within the average vehicle lifetime.

The Cranfield University study has wide ranging implications for larger V6 and V8 engines. With more complex design, most V-type cylinder blocks are produced by sand casting. For V-engines, the CO_2 and energy breakeven distances of aluminium engines far exceed the vehicle life.

Scratch the surface and a new reality appears. Legislation compels engineers to use low-density materials, forcing them to swim in dirty water. It's time for legislators to dive beneath the surface and establish holistic policies that actually reduce CO_2 emissions.