Cars as particle accelerators

Monaya MaGaurn

October 2025

1 Diesel Engines as Multiscale Particle Accelerators

A diesel engine operates as a compression-ignition system that converts chemical potential energy into mechanical and kinetic energy through a sequence of high-pressure, high-temperature, and plasma-like events. On multiple scales—from molecular to macroscopic—it behaves analogously to a particle accelerator.

1.1 Compression Ignition as Shock-Driven Acceleration

Unlike spark-ignition engines, diesel combustion is initiated by compressing air until it reaches temperatures exceeding 700°C at pressures of 30–50 bar. When atomized fuel is injected into this environment, spontaneous ignition occurs, forming a rapidly propagating shock front. This ignition front accelerates gas molecules, electrons, and ions through steep thermal and pressure gradients.

Each droplet of injected fuel acts as a localized combustion reactor. Within microseconds, the surrounding environment reaches conditions sufficient for partial ionization, resulting in the transient formation of plasma. High-energy collisions between carbon, hydrogen, oxygen, and nitrogen molecules lead to the production of nitrogen oxides (NOx) and other reactive intermediates. In this sense, the diesel combustion chamber functions as a pulsed micro-plasma accelerator.

1.2 Fuel Injection Systems as Hydrodynamic Accelerators

Modern diesel engines employ common-rail or piezoelectric injection systems operating at pressures up to 2,500 bar (36,000 psi). Under these conditions, fuel is ejected through micro-nozzles at velocities of 700–900 m/s, approaching Mach 3 in localized jets. The fuel breaks into droplets with diameters on the order of 10–30 microns.

The injector thus serves as a hydrodynamic particle accelerator, converting the potential energy of compressed fluid into the kinetic energy of microdroplets. These droplets undergo high-velocity collisions with hot air molecules, initiating chemical and thermodynamic reactions analogous to the interactions within a

linear accelerator, where charged particles are accelerated through an external field.

1.3 Electron Acceleration and Ionization Effects

The ignition process generates intense local electric fields and temperature gradients that accelerate free electrons and ions within the combustion zone. Ionization and recombination processes produce transient plasma regions characterized by partial charge separation. Soot particles and combustion products acquire electrostatic charges, forming aerosols with surface potentials of several tens of volts.

These charged nanoparticles act as mobile ions, capable of interacting with local electromagnetic fields. Consequently, diesel exhaust exhibits measurable electrostatic behavior, indicating the presence of a charged particle field. The combustion chamber, in this context, behaves as a non-equilibrium plasma accelerator on a microscopic scale.

1.4 Macroscopic Acceleration: Exhaust and Environmental Effects

Following combustion, expanding gases not only drive the pistons but also accelerate particulate matter and residual combustion products through the exhaust system. Exhaust gases exit the manifold at velocities exceeding 300–400 m/s, entraining and accelerating surrounding air. The exhaust jet functions as a directed particle beam, dispersing ions, soot, and molecular clusters into the environment.

Thus, the diesel engine accelerates a spectrum of particles, from electrons and ions to soot aggregates and macroscopic gas flows.

1.5 Hierarchical Acceleration Summary

The diesel engine operates as a multiscale accelerator, with different processes dominating at distinct physical scales.

Scale	**Accelerated Particles**	**Mechanism**	**Analogy**
Quantum	Electrons, ions	Ionization and plasma formation	Micro plasma accelerator
Microscale	Fuel droplets	Injector jets at supersonic speed	Fluid linear accelerator
Macroscale	Pistons, crankshaft	Pressure-wave-driven motion	Mechanical energy conversion
Environmental	Exhaust gases, soot	Expulsion through exhaust system	Particle beam emission

1.6 Conclusion

In conclusion, the diesel engine constitutes a hierarchical energy transformation system, where chemical potential is converted through successive layers of particle acceleration: electronic, molecular, fluidic, and mechanical. Through this lens, a diesel engine may be viewed as a multiscale particle accelerator, bridging the gap between quantum-scale interactions and macroscopic kinetic motion.