Hybrids for Heavy Duty Use

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Agenda

• What is a Hybrid?
  – Hybrid definition
  – Hybrid automobiles
  – REGENERATION

• Hybrid Automobiles
  – Hybrid Electric Vehicle (HEV)
  – Generator + Batteries
  – REGENERATION
  – Storage of regenerated energy
  – HEV powertrain types

• Hybrid On Road Trucks

• Hybrid Construction Equipment
  – Hybrid components
  – Hydraulic excavator
  – Hybrid Excavator
  – Performance
What is a Hybrid?

• Definition can be interpreted to mean mixing two things together / a composite / compound

• As a noun this can be in reference to:
  – genetics -> plants, animals
  – Language -> words derived from different languages

• As an adjective it is used to reference a mixed product

Purpose of Hybridization:

To combine favorable characteristics of two items
What makes an automobile a hybrid?

- Internal combustion engine.
- Electrical power source.

Purpose of Hybridization:

**To improve fuel consumption and reduce emissions—travel more miles per gallon of fuel while reducing pollutants.**
Industry Terms

- **EV** – Electric Vehicle – uses an external power source to charge on-board batteries that provide power.

- **HEV** – Hybrid Electric Vehicle – uses internal combustion engine & on-board electric power source.

- **PHEV** – Plug-in Electric Vehicle – same as HEV but can also be recharged by an external power source.

  ![Regeneration](image)

  **Regeneration** – capturing energy that would otherwise go unused and make it available to do work.
Hybrid Automobile

HEV

• Internal combustion engine uses fuel.
  – Fuel tank

• Electric motors use electricity.
  – Electric source?

How is power supplied to the electric motors?

• Generator
Hybrid Electric cars use a generator driven by the engine to generate electricity.

What is done with the electricity?
- Sent to power the electric motors
- This would require running the engine constantly to run the generator.
Hybrid Automobile

HEV

• Using batteries to store excess charge from the generator can allow the engine to shut off when enough charge is stored in batteries.

• Car can travel for a certain distance on stored battery power only.

• This set up can potentially reduce fuel use but a key component is missing => REGENERATION
HEV

• **REGENERATION** - capturing energy that would otherwise go unused and make it available to do work

• **REGENERATION** is the key to significant fuel savings.

• What does a car do that creates energy which goes unused?

• Braking
  
  – Electric motors act as generators during car braking -> creating electricity => **Regenerated** energy that was normally dissipated as friction and heat is now sent to batteries for storage.
Hybrid Automobile

HEV

• This regenerated energy from braking is used to charge the batteries allowing the engine & generator to remain off longer.

• The more frequent a car stops, the more energy is available for storage in the batteries.

• Ideal for city stop-n-go driving.

• Highway driving does not involve frequent stopping – less energy is available for charging batteries.
Electrical Storage

• Batteries play a key role in hybrid cars

• Manufacturers work toward a balance between storage capacity, cost and weight.

• Power requirements of cars are met by batteries.

• Acceleration of a car from stop light takes a few seconds.

• Chemical reactions needed to produce electricity require a few seconds.
Batteries produce electrons via a chemical reaction.

Discharging chemical reaction: \[ \text{PbO}_2 + \text{Pb} + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{PbSO}_4 + \text{H}_2\text{O} \]

- Lead Dioxide (Positive plate)
- Sponge lead (Negative plate)
- Sulfuric Acid (electrolyte)
- Lead Sulfate
- Water

- During the charging process, Hydrogen and Oxygen are generated – this is why batteries “lose” water.
- Sealed batteries are actually over filled or “flooded” with extra electrolyte to account for a certain amount of evaporation.

Pictures courtesy of National Renewable Energy Laboratory
Types of HEVs

Series hybrid: Uses an engine to generate electricity to power electric motors which turn the wheels.

Parallel hybrid: Can turn the wheels by using both the engine and electric drive.

Series-Parallel hybrid: have the ability to operate as series or parallel.
A hybrid automobile combines:

- the power from an internal combustion engine,
- the energy from the generator driven by the engine,
- the storage capacity of batteries,
- the benefits of **REGENERATION**

...to increase the miles per gallon traveled and reduce emissions.
Hybrid On Road Trucks

On Road Trucks employ similar systems to Hybrid Electric Vehicles.
How can construction equipment be hybrid?

• Internal combustion engine
• Generator
• Batteries (electrical storage)

• REGENERATION - What does a specific piece of construction equipment do that creates energy which goes unused?
How can a wheel loader be a hybrid?

A bulldozer?

An excavator?
Hydraulic Excavator

Diesel engine drives hydraulic pumps to power the boom, arm, bucket, swing & tracks.
How the Hybrid Works

The hybrid uses a 4-cylinder diesel engine.

A generator motor is driven by the engine to generate electricity when needed.

For electrical storage an ultra-capacitor is used

**REGENERATION** – is possible via the electric swing motor.

HB215LC-1
How the Hybrid Works

The hybrid uses an electric swing motor instead of a hydraulic motor. During swing braking the electric motor generates electricity and stores it for later use.

Capture

During swing braking
1. Recovers energy
2. Stores electricity

Release

During operation
1. Releases stored electricity
2. Provides power for swing
3. Power up assistance to engine

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How the Hybrid Works

The Hybrid system has 3 main components.
1. Electric Swing Motor
2. Ultra Capacitor
3. Generator / motor

- Electric swing motor
- Ultra Capacitor Assembly
- Generator / motor

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Electric Swing Motor

Component

Electric swing motor is used in place of the hydraulic swing motor used in conventional excavators.

Function

The swing motor uses electricity to swing.

During swing braking the swing motor generates electricity and stores it in the Ultra-Capacitor.
Ultra Capacitor

**Component**

An ultra-capacitor is similar to a battery in that they both store electricity. A battery uses chemical reactions to capture and release electricity slowly. An ultra-capacitor instantaneously captures and releases electricity which is better suited for construction equipment.

Part of the capacitor assembly is the inverter. Electricity from the swing motor and generator motor arrives as Alternating Current (AC) and is stored as Direct Current (DC) in the ultra-capacitor.

**Function**

The ultra-capacitor captures electricity generated from swing braking.

The ultra-capacitor releases electricity to the swing and generator motors.

The inverter switches between the two types of electricity (AC <-> DC) as it travels to and from the ultra-capacitor and the swing motor and the generator motor.

HB215LC-1
Capacitors cannot produce electrons, they just store them.

Capacitors use a static charge that does not require a chemical reaction. Fast charge and discharge of electrical energy.

Capacitors do not use up their electrolyte since there are not chemical reactions involved in the energy flows of charging and discharging.

Pictures courtesy of National Renewable Energy Laboratory
The generator motor is positioned between the engine and hydraulic pumps. It has two functions in the hybrid system.

**Function**

1. The generator motor provides power up engine assistance using electrical power from the capacitor.

2. The generator motor initiates the electrical charge in the ultra-capacitor and maintains the upper level of the ultra-capacitor charge.
Control Logic

Komatsu Low Speed Matching: A highly efficient matching technique between the engine and hydraulic system.

• Low speed matching uses highly advanced control logic to match the hydraulic pump operation at the most efficient engine speed.

• Low speed matching increases engine speed from 700 rpm ultra-low idle as the hydraulic demand increases.

• The low speed matching system is complemented by the Hybrid power up assistance provided by the generator motor using energy from the ultra capacitor.

• Fuel consumption is therefore reduced due to the available electrical power – up to 60 additional HP is provided by the Hybrid system depending on demand.

HB215LC-1
Performance

- The hybrid excavator provides the same or better performance as the conventional PC200LC-8.

- Hybrid uses a 4-cylinder engine (PC200LC-8 uses a 6-cylinder engine)

- The energy stored in the capacitor provides up to an additional 60 hp on demand.

- This allows for an ultra-low engine idle of 700 rpms to be used in the hybrid which helps lower fuel consumption.

- Quick electrical energy discharge provides fast engine assist function to quickly increase engine speed & hydraulic response.

- Lower engine speeds help reduce machine sound levels.

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Hybrid Excavator

The hybrid uses a 4-cylinder diesel engine.

A generator motor is driven by the engine to generate electricity when needed.

For electrical storage an ultra-capacitor is used.

**REGENERATION** – is possible via the electric swing motor.

**Additionally:**

Low speed matching further enhances fuel savings

Average 25% fuel savings with equivalent reduction in CO₂ emissions