

Lecture 19
3rd Semester M Tech. Mechanical Systems Design
Mechanical Engineering Department
Subject: Advanced Engine Design
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Lecture 19 – Alternative Fuels In SI Engines
Topic: Natural Gas – CNG – LNG – 29-10-2020

Alternative Fuels For SI Engines

Natural Gas

- Natural Gas Is One Of The World's Most Abundant Fossil Fuels And Currently Supplies Over 25% Of The Energy Demand In The U.S.
- Natural Gas Is A Very Good Spark-Ignition Internal Combustion Engine Fuel And It Was Used As A Fuel In The Very Early Days Of Engine Development.
- However , Relative To Liquid Petroleum Fuels , The Ability To Store Sufficient Amounts Of Natural Gas For Onboard Vehicles Has Presented A Significant Barrier To Its Broad Use As A Transportation Fuel. Significant Advances Have Been Made In High Pressure Cylinders That Can Store Natural Gas At High Pressures(Upto 3600psi) That Are Made Of Light Weight Materials Including Aluminium And Carbon Fiber.

Compressed Natural Gas. (CNG).

- Compressed Natural Gas (CNG) Is The Preferred Method Of Natural Gas Storage On Vehicles.
- Storing Natural Gas As LNG Enables Heavy Duty Vehicles To Have The Same Operating Range As When Using Liquid Petroleum Fuels. Typically Storing Natural Gas As LNG Instead Of CNG Results In Fuel Storage System That Is Less Than Half The Weight And Volume Of A CNG System.
- Regardless Of The Method Of Storage , The Cost And Emissions Advantages Of Natural Gas Make It A Very Popular Alternative Fuel.

Production Of Natural Gas.

- Natural Gas Is Present In The Earth And Is Often Produced In Association With Production Of Crude Oil. However Wells Are Also Drilled For The Express Of Producing Natural Gas.

Vehicle Emission Characteristics.

- Natural Gas Is Composed Primarily Of Methane Which Dominates Its Emissions Characteristics.
- Methane Mixes Readily With Air And Has A High Octane Rating Which Makes It A Very Good **Spark Ignition Engine** Fuel.
- It Has High Ignition Temperature That Makes It Unsuitable For Use In Compression – Ignition Engines , Though It Can Be Made To Work In Such Engines.
- Because Of Its High Hydrogen-To-Carbon Ratio, The Combustion Of Methane Produces About 10% Less Carbon Dioxide Than Combustion Of Energy Equivalent Amount Of Gasoline Or Diesel Fuel.

Light Duty Vehicles.

- Light-Duty Vehicles Are Capable Of Very Low Gaseous Exhaust Emissions. In The CNG Vehicles Developed By The Auto Manufacturers To Date , Individual Port Fuel Injection With A Three Way Catalyst System Has Been Used To Simultaneously Oxidize Exhaust Hydrocarbons And Carbon Monoxide While Reducing Oxides Of Nitrogen.
- Because Natural Gas Readily Mixes With Air , Emissions Of Carbon Monoxide Are Typically Low When Using Natural Gas , Assuming The Air-Fuel Ratio Is Kept On The Lean Side Of Stoichiometric.
- Optimization Of The Catalyst Precious Metals For Oxidation Of Methane , Have Resulted In Vehicles With Very Low Exhaust Emissions.

Heavy-Duty Vehicles.

- The Heavy-Duty Engine Manufacturers Have Taken A Slightly Different Approach To Natural Gas Engine Development Compared To Light Duty Engine Manufacturers.
- Heavy Duty Natural Gas Engines To Date Have Been Spark-Ignition Adaptations Of Diesel Engines.
- To Improve Engine Efficiency To Be Closer To That Of Diesel Engines , The Heavy Duty Natural Gas Engines Use Lean-Burn Combustion.
- For Emissions Control They Use An Oxidation Catalyst To Control Methane And Carbon Monoxide Emissions. **Oxides Of Nitrogen Are Kept Low Through Lean Burn Combustion** And Particulate Emissions From Natural Gas Are Not A Concern.

Vehicle Performance Characteristics.

- Light Duty Vehicles.
- Light-Duty Vehicle Engines Using Natural Gas Can Increase Their Power And Efficiency By Increasing The Compression Ratio. Compared To Typical Gasoline , Natural Gas Has A High Octane Rating That Will Support Higher Compression Ratios.
- However , There Are Two Detriments To Light Duty Natural Gas Vehicle Performance: The Weight Of The Fuel System And The Decreased Engine Specific Power Output. This Weight Naturally Hurts Vehicle Acceleration And Will Degrade Vehicle Fuel Economy Proportionately.

Light Duty Vehicles.

- Since Natural Gas Enters The Engine Entirely As A Gas , While Gasoline Typically Enters The Engine As Part Liquid And Part Gas , For The Same Displacement , The Gasoline Engine Will Be Able To Ingest More Air And Fuel And Produce Higher Power.
- Natural Gas Engines Can Overcome This Inherent Disadvantage By Increasing Compression Ratio , Cylinder Displacement , Or Increasing Volumetric Efficiency. However , It Is Not Always Possible To Obtain The Same Power Output Without Creating A More Expensive Engine.

Heavy Duty Vehicles.

- Since Heavy-Duty Natural Gas Engines Are Derivatives Of Heavy-Duty Diesel Engines , It Is Possible For Them To Have The Same Or More Power Than The Equivalent Displacement Diesel Version.
- Limiting Factors To Power Output Include Oxides Of Nitrogen Emissions (Increased Power Means Richer Operation And Generation Of More Oxides Of Nitrogen For A Given Displacement Engine) And Exhaust Valve Life (Spark Ignition Engines Experience Higher Exhaust Valve Temperatures Than Diesel Engines).
- Rather Than Acceleration , Heavy Duty Engine Performance Is More A Function Of Maximum Horsepower And Torque Rise. Both Characteristics Can Be Made Equivalent Or Better For Natural Gas Versions Of Heavy Duty Diesel Engines.

Comparison Of Physico-Chemical Properties Of Natural Gas (CNG) And Gasoline.

Fuel Property	Natural Gas (Methane)	Gasoline
Formula	CH_4	$\text{C}_4 \text{ TO } \text{C}_{12}$
Composition, Weight %		
Carbon	75	85-88
Hydrogen	25	12-15
Molecular Weight	16	100-105
Stoichiometric Air-Fuel Ratio.	17.2	14.7
Octane Number		
Research	120	88-100
Motor	120	80-90
Lower Heating Value , MJ/Kg.	50	44
Latent Heat Of Vaporization. KJ/Kg.	510	349
Freezing Point , C	-182	-40
Auto ignition Temperature , C	540	257

Materials Compatibility

- Natural Gas By Itself Is Very Benign And Raises Few Materials Compatibility Problems. Steel Is Frequently Used For Natural Gas Pipelines And Mains While Plastic Lines Are Typically Used To Bring Natural Gas Into Residences Where Pressures Are Very Low.
- When Natural Gas Is Compressed For Use In Vehicles , Several Materials Compatibility Problems Can Arise That Are Not Encountered In Typical Natural Gas Systems. Compressors Can Put Significant Amounts Of Lubricating Oil Into The CNG System Which Can Foul Regulators And Other Devices Where Clearances Are Small. The Compressor Oil Is Probably More Of An Operating Problem Than A Materials Compatibility Problem , Though New CNG Vehicle Fuel Systems That Use Multi-Point Fuel Injectors May Encounter Some Problems.
- The Industry Is Developing Compressors That Put Very Little Oil Into The CNG , Called Oil-Less Compressors.
- A More Serious Threat To The Materials Compatibility Of Cng Fuel Systems Is Condensed Water Vapor. Water Can Cause Steel And Cast Iron To Rust And Aluminium To Corrode. Corrosion Stress Cracking Can Occur Which Can Result In Failure Of The Component With Disastrous Results.
- Natural Gas Dryers Have Been Developed To Help Reach This Goal.

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