Challenges and Opportunities for Future Engine Oils

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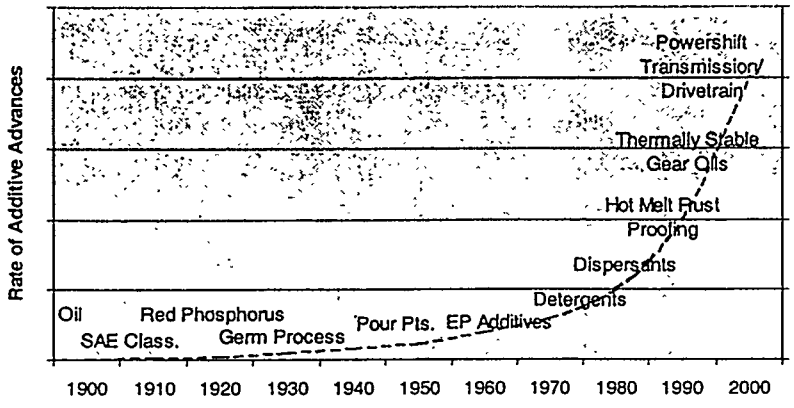
OUTLINE

- Chronological additive technology advances
- Traditional lubricants development approaches
- Composition of typical crankcase lubricants
- Future lubricants development approaches
- Future lubricant concepts
  - Examples
  - How a lubricant can function differently

Additive Advances in the 20th Century



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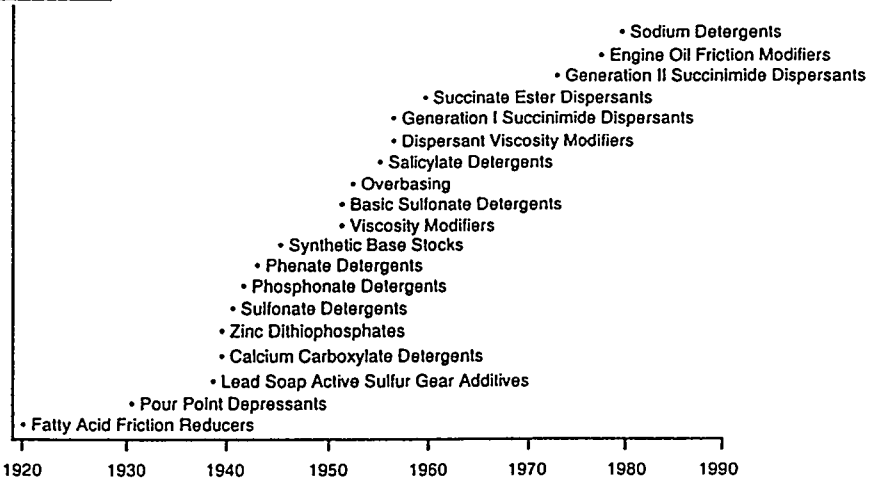
Additive Component Chronology



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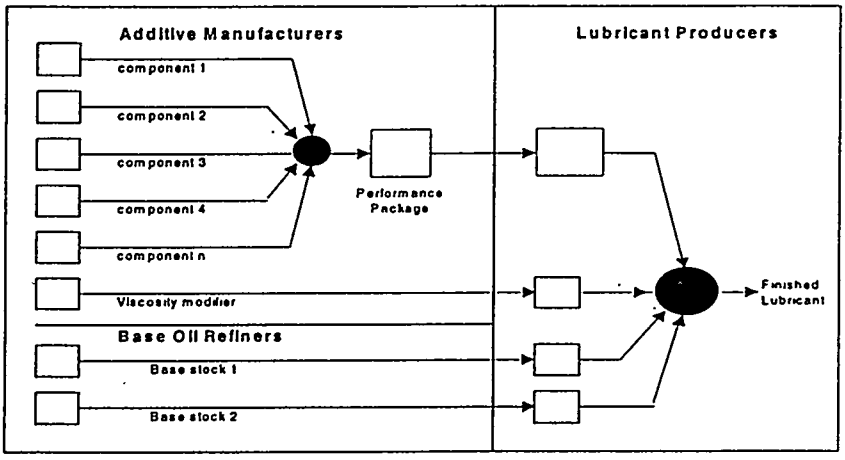
Traditional Additive Development Approaches

- Chemical
- Formulating
- Testing

Lubricant Development



Common Additive Components for Engine Lubricants

Additive	Gasoline Engine Oils	Diesel Engine Oils	Natural Gas Engine Oils	Two Cycle Engine Oils
Dispersant	•	•	•	•
Detergent	•	•	•	•
Antiwear/EP Agent	•	•	•	•
Oxidation Inhibitor	•	•	•	•
Corrosion Inhibitor/ Metal Deactivator	•	•	•	•
Friction Modifier	•			
Pour Point Depressant	•	•	•	
Foam Inhibitor	•	•	•	
Viscosity Modifier	•	•		

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Functions of a Passenger Car Lubricant

Lubricant Marketer	Formulation Component	Possible Elements
Fluidity	Mineral or synthetic oil	H,C,O
Additive Supplier		
Multigrade	Viscosity modifier	
Low temperature flow	Pour point depressant	
Suspend contaminants	Ashless dispersant	N, B
Rust protection Cleanliness Acid neutralization	Detergent	Ca, Mg, Na
Wear control Oxidation protection	Zinc dithiophosphate Ashless antioxidants	Zn, P, S N
Friction reduction	Friction modifier	Mo, S
Foam control	Antifoam	Si

- *Functions of the performance package*

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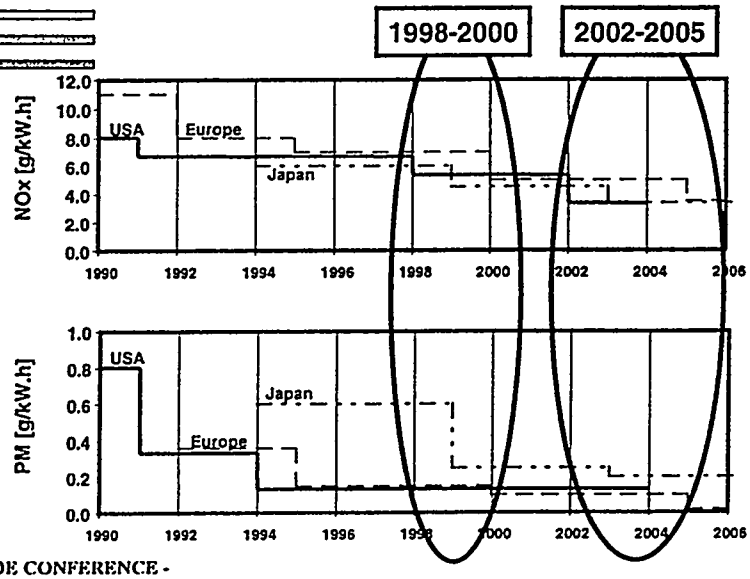
Current Market Drivers

- Extended life, improved durability
- Environmental/societal issues (such as emissions) and concerns
- Economics - more for less
- Product Stewardship - cradle to cradle

Diesel Engine Emission Regulations



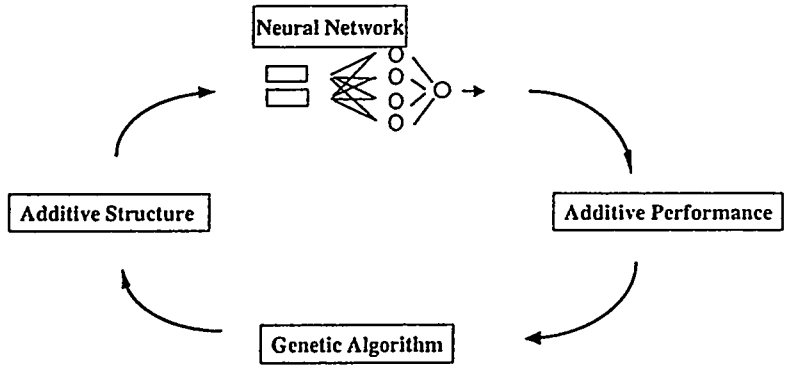
Future Additive Development Approaches

- Chemistry → Combinatorial Chemistry
- Formulating → Artificial Intelligence
- Testing → Diagnostic Systems, Virtual Testing

Combinatorial Chemistry

A technology by which large numbers of structurally distinct molecules may be synthesized in a time and resource-effective manner and rapidly tested for desirable properties.

Combinatorial Chemistry Quantitative Structure Activity Relationship (QSAR)



Artificial Intelligence New Two-Cycle Additive

Program Input:
Performance Parameters: Piston Varnish >= 8.8, Ring Stick >= 8.6
Intermediate Constraints: 0 % Component A (too expensive)
Cost Targets: Minimum Cost

Program Output:	New TC Formulation:	Predicted Performance:
	23.5% Component H	Piston Varnish = 8.8
	10 % Component D	Ring Stick = 8.60
	1 % Component F	Tot. Treat Wt. % = 35.00
	0.2% Component B	Cost = 20% reduction
	0.3% Component C	

Westbend Test Results:	Predicted Results:	Actual Results:
Piston Varnish	8.88	9.3
Ring Stick	8.60	8.6

Extended Drain Intervals

Benefits

- Consumer friendly - reduced maintenance
- Reduced disposal

Concerns

- Lubricant cost: is synthetic needed?
- Qualification methods
  - Adequate for engine durability
- Fuel economy retention
- Octane requirement increase (ORI)
- Escalating oil consumption with usage
- Diverse use patterns
- Hazardous waste classification

Future Lubricant Concepts

- Consumable lubricant
  - Fuel value
  - Environmentally friendly
  - Fuel quality improvement possible
- Alternative fuels
- Lubricants and fuel additives
- Lubricant/coolant

Extended Oil Drain Interval Concepts

Smart Drain Intervals

- 'based on engine operating and oil condition parameters
- engine operating parameters include
  - revolutions, load, speed, distance/time traveled
- oil condition parameters include
  - temperature, level/consumption, pressure before/after filter
- oil sensors for assessing performance reserve ?

- *e.g.*, Jelden and Paehr (Volkswagen) DE 44 01 835 A1, 1994

Extended Oil Drain Interval Concepts

Increased Oil Volume

- auxiliary reservoir supplements sump oil
- sump level detector triggers automatic leveling
- service interval is increased by increasing the volume of oil in the system
  - oil contaminants are diluted
  - additive level is increased

- Renault (Renault), FR 2 581 700 A, 1986

Extended Oil Drain Interval Concepts

Lubricant Temperature Control

- lubricant temperature is kept constant irrespective of engine load
- heat can be fed or drawn off from the lubricant circuit
- oil temperature sensor / heat exchanger / regulating unit
- higher load temperature can be maintained during lower load operation

- Gasthuber, *et. al.* (Daimler-Benz) GB 2 312 246 A, 1997

Extended Oil Drain Interval Concepts

Lubricant/Coolant

- engine oil also serves as engine coolant
- engine oil volume is increased
  - oil contaminants are diluted
  - additive level is increased
- simplified engine block

- *e.g.*, Valev (Steyr-Daimler-Puch), US 4,926,800, 1990

Extended Oil Drain Interval Concepts

Dual Lubrication Systems

- lubrication system 1 valve train, camshaft (subjected to excessive wear)
  - lubricate with conventional oil (Yasuhara)
  - blowby eliminated, wear reduced
  - lubricant life prolonged
- lubrication system 2 crankshaft, pistons (not subjected to excessive wear)
  - lubricate with diesel fuel (Yasuhara)
  - wear reduced by constant application of fresh lubricant

- Yasuhara (Nissan), US 4,392,463, 1983; Skupien (Renault), FR 2 605 677 A, 1988

Extended Oil Drain Interval Concepts

On-Board Oil Reconditioner

Pinmore Ltd. (UK)

- heated/magnetized stainless steel discs (electronic control)
  - water, fuel, coolant, and corrosive gases flashed from the oil
  - additives remain intact
  - metal particles removed
- functions in partial bypass

- Assali and Ramirez, WO 96/25996

Extended Oil Drain Interval Concepts

Reconditioning Packages

TF Purifiner (US)

- aftermarket retrofit product for Heavy Duty Diesel
  - bypass reconditioner
  - bypass oil filter (> 1 micron)
  - time-release additives in filter
- users change filters, perform oil analysis, and add makeup oil
- 1 million miles without drains in fleet study
- certified as "Pollution Prevention Technology" by California EPA

Extended Oil Drain Interval Concepts

Automatic Oil Change

- spent oil is pumped into holding tank
- new oil is pumped into sump from supply tank
- oil quality stabilized
  - contaminant buildup minimized
  - additives constantly replenished
- pumping operation may be dictated by oil condition sensors

- *e.g.*, Merritt, US 4,674,456, 1987; Nelson, US 5,390,762, 1995

Extended Oil Drain Interval Concepts

Consumable Engine Oil

- spent oil is pumped into fuel system
- new oil is pumped into sump from supply tank
- oil quality stabilized
  - contaminant buildup minimized
  - additives constantly replenished
- pumping operation may be dictated by oil condition sensors

- *e.g.*, Nelson, US 4,869,346, 1989; Yasuhara (Nissan), US 4,417,561, 1983

Extended Oil Drain Interval Concepts

Consumable Engine Oil

Cummins Centinel

- aftermarket retrofit product for Heavy Duty Diesel
  - crankcase oil pumped into fuel
  - makeup oil pumped to crankcase from supply tank
  - high efficiency oil filters
  - electronic controls constantly monitor the engine and synchronize system with engine's actual duty
- oil drains: 300,000 miles; oil filter changes: 75,000 miles
  (*c.f.* 22,000 miles)

Extended Oil Drain Interval Concepts

Advanced Engine Materials

- diamond-like carbon coatings
- vacuum deposition with an arc created by a laser
- coated piston rings, tappets, conrods
- lubricating qualities of graphite, hard as diamond, durable
- reduce wear
- self-lubricating
  - reduce frictional loss and fuel consumption
  - decreased oil volume, extended oil drain interval

BMW Functional Coatings Group / Fraunholer Institute for Materials and Ray Technology (Dresden) / Federal Institute for Materials Research and Testing (Berlin)

Extended Oil Drain Interval Concepts

Advanced Engine Materials

- solid film lubricant coatings
  - MoS_2, graphite, BN, thermoset polymer base
  - composites of M/MO_x (M = Fe, Ni, Cu, Mo)
- coated cylinder bores, piston rings, valve train components, bearings
- reduce friction, improve wear and corrosion resistance
- promote rapid formation of tenacious oil films
- pores in films serve as lubricant replenishing reservoirs

e.g., Rao, *et al.* (Ford), US 5,313,919, 1994; WO 97/13884

Extended Oil Drain Interval Concepts

Oil-Free Tribosystems

- piston rolling bearings require no, minimum quantity, or lifetime lubrication
- electromagnetic or electrohydraulic valve control requires no lubricant
- main crankshaft and crank pin/connecting rod bearings require:
  - lifetime lubrication in encapsulated form
  - separate lubricant circuit (diesel fuel or synthetic lubricant)
  - ferrofluid lubricant
- no oil changes
- oil consumption, HC, and PM reduced

Gasthuber, *et. al.* (Daimler-Benz) GB 2 315 812 A, 1998; DE 196 30 215 A1, 1998

Consumable Engine Oil

Benefits

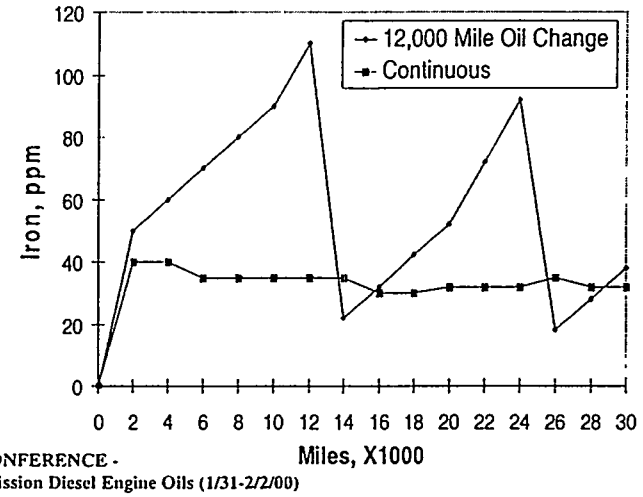
- Consumer friendly - reduced maintenance
- Consistent lubricant quality
- Deposit control: Combustion chamber, injectors
- Fuel value
- Environmental disposal
- Control over fuel additive quality

Concerns

- Vehicle design changes
- Emissions
- Octane effects
- Product distribution
- Governmental regulation

Continuous Consumption

Simulated Data



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Test Lubricants

	Typical	"Fail" Reference	"Pass" Reference
Base Stock	75% 150N 25% 600N	86% 150N 14% 150B	Low S 100N
Viscosity Modifier	7.5%w OCP	14% Hi SSI VM	10% Thickener
Pour Point Dep.	0.2%w Pour Pt.	0.3%w Pour Pt.	0.3%w Pour Pt.
Additive	13.5%w CG-4 Add.	14.7%w Med. Ash	18%w Exp II Add
Viscosities			
@ 150°C, cP	3.91	4.19	2.56
@ 100°C, cSt	13.74	14.59	7.71
@ 40°C, cSt	101.4	113.2	50.5
CCS @ -15°C	2910	3220	2190
CCS @ -20°C	9600	--	3910
Chemical Properties			
% Ash	0.9	1.3	0.9
% Ca	0.15	0.33	0.01
% Mg	0.04	--	0.05
% Zn	0.12	0.12	--
% P	0.11	0.11	0.03
% S	0.66	0.67	0.07

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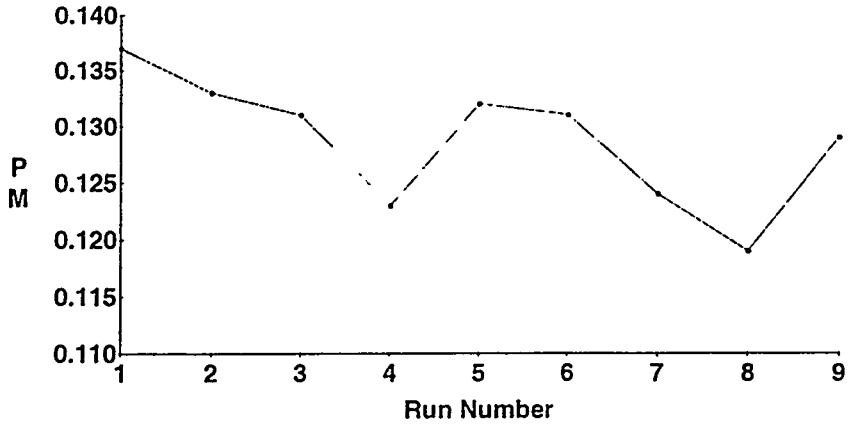
Particulate Matter

Fuel + 3% Lubricant, gm/mile



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Diesel Injector Deposit Test

3% "Fail" Reference

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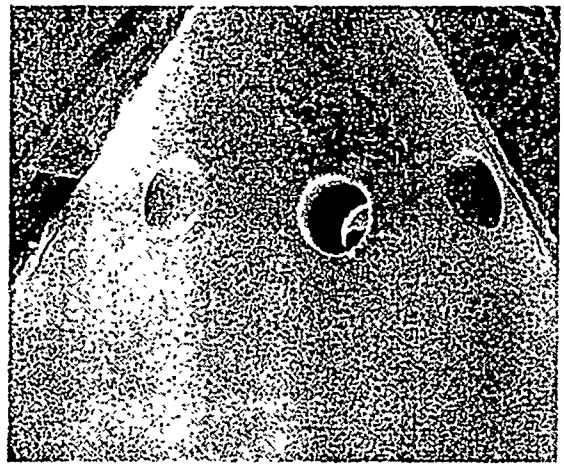
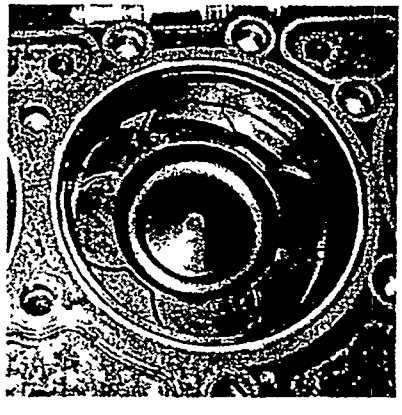
Diesel Injector

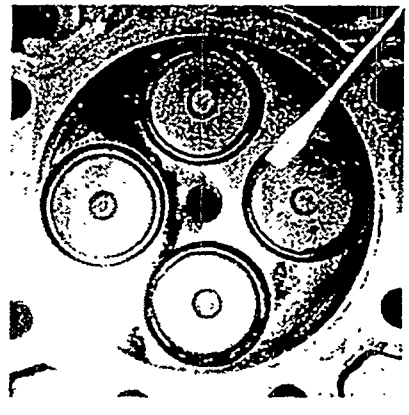
After Transient Emissions Matrix



Combustion Chamber after Matrix



Piston Crown



Cylinder Head

Transient Emissions Cycle

1994 11-Litre HD Diesel, 365hp, 500hr Audit

Fuel Treatment (in LSRD fuel)	Crankcase Lubricant	Particulate Matter	Run Order
1994 Max. Limit		**0.100 gm/hp-hr**	
None	Factory Fill	**0.123**	1
None	Synthetic OEM	**0.111**	6
None	"Fail" Exptl.	**0.111**	3
1% "Fail" Exptl.	"Fail" Exptl.	**0.112**	2
3% "Fail" Exptl.	"Fail" Exptl.	**0.138**	4
3% "Pass" Exptl.	"Fail" Exptl.	**0.126**	5

A Way Forward

- Many new approaches for newer lubrication systems
- Need for a paradigm shift
  - Future lubricants can not be developed in dated hardware
  - Future hardware can not be developed with dated lubricants
- Mechanical, chemical and electronic technology integration is need to create a newer and richer lubricant technology, capable of meeting the market demands of the next decade.