FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

www.functionalproducts.com

Metal Working Fluids: Quench Additives for Straight Oil

May 16, 2023

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Agenda

- Background
  - Types of MWF
  - What is Quench Oil?
- Performance Testing
  - Cooling Tests
  - Oxidation Tests
  - Residue Tests
- Additive Performance
  - Additive Properties
  - Formulated Performance

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Types of MWF

- Straight Oil – Prepared from mineral oil, no water present
- Emulsifiable Oil – Oil blended with water in opaque macroemulsion
- Semisythetic Fluid – Oil blended with water in translusent microemulsion
- Synthetic Fluid – Prepared from water, no mineral oil present

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Types of MWF

- Straight Oil – Prepared from mineral oil, no water present
- Emulsifiable Oil – Oil blended with water in opaque macroemulsion
- Semisythetic Fluid – Oil blended with water in translusent microemulsion
- Synthetic Fluid – Prepared from water, no mineral oil present

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

What is Quench Oil?

- Quench fluids control cooling process
- Controlling cooling rate of metal adjusts hardness and ductility
- "Cold" Oils – Quench oils used between 27C and 93C
  - Refers to oil temperature, not part temperature
- 3 types of cold oil based on cooling speed:
  - Fast = 7-9 sec to 354C
  - Medium = 10-13 sec to 354C
  - Normal = 14-16+ sec to 354C

5

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

What is Quench Oil?

- Straight Oil quench fluids comprised of:
  - Mineral Oil – Majority component, transfers heat from metal surface
    - Lower Viscosity gives faster cooling

$$\text{Cooling Capacity} = \frac{\rho \lambda C_P}{v}$$

  - Quench Accelerator – typically polymeric, increases cooling rate
    - Polymer size and chemistry chosen to optimize cooling without contributing to varnish
  - Quench Package – blend of additives to protect against oxidation, rise in acid number, tarnish/sludge, and other negative effects

6

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Cooling Tests

- ASTM D3520 – GM Quenchometer
  - Nickel ball heated to 882C and cooled in quenching oil
  - Time to 354C (Curie point of nickel) measured
    - Nickel becomes magnetic at Curie point and stops timer
- GMQS (seconds to Curie point) defines cold oil type
- Large variability in test results
  - Not suitable for fluid monitoring

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Cooling Tests

- ASTM D6200 – Quenchalyzer (Cooling Curve) Test
  - Metal cylinder heated to 850C and cooled in quenching oil
  - Cylinder monitored with thermocouple
- Measures temperature and cooling rate across entire temperature range
- Sensitive to differences in used and unused quench oil
  - Appropriate for system monitoring

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Oxidation Tests

- ASTM D6186 – Oxidation Induction Time
  - Oil heated to 180C in pressurized oxygen environment
  - Oil monitored by PDSC to determine onset of oxidation
- Reported in minutes to start of oxidation process
- Oxidation in a quench oil can lead to higher acid number, part staining, and sludge formation
  - All have negative effect on finished parts
  - Higher OIT means longer oil lifetime

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Residue Tests

- Panel Coker Test – several internal versions across companies
  - Clean metal panel exposed to quench fluid at elevated temperature for hours, days, or weeks
    - Visual inspection (subjective)
    - Weight change
- ASTM D189 – Conradson Residue
  - Oil heated in high temperature until evaporated to create coke
  - % of sample weight left as coke is reported
  - Ash-forming additives may skew result
- Low coke/residue is desired to prevent part staining and reduction in cooling efficiency

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional Q-249

- Quench package for Normal and Medium "Cold" Oils

Physical Properties Functional Q-249		
Color	--	Dark Amber
KV 100, cSt	ASTM D445	111.7
KV 40, cSt	ASTM D445	3,275
Density, lb/gal	ASTM D1475	7.98
Flash Point, C	ASTM D92, COC	224

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional Q-249

- Quench oil performance with and without accelerator

Performance in 70N Group II		
	No Accelerator	1% Accelerator
Treat Rate	3%	3%
Type	Normal Cold Oil	Medium Cold Oil
ASTM D3520, Quenchometer	13.4 sec	11.2 sec
ASTM D6200, Quenchalyzer		
- Maximum Cooling Rate	74 C/sec	92 C/sec
- Time to 600C	10.6 sec	8.3 sec
- Time to 400C	14.5 sec	12.0 sec
- Time to 200C	44.6 sec	44.1 sec
ASTM D6186, OIT @ 180C	84 min	76 min
ASTM D189, Conradson	0.12%	0.07%

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional Q-249

- Compare formulated performance to Lubrizol LZ5941S

Performance in Formulated Quench Oil (No Accelerator)		
Test Method	**Functional Q-249**	**LZ5941S**
ASTM D3520, Quenchometer	13.4 sec	17.4 sec
ASTM D6200, Quenchalyzer		
- Maximum Cooling Rate	74 C/sec	71 C/sec
- Temp @ Max Rate	551C	485C
- Rate @ 300C	6.4 C/sec	10.1 C/sec
- Time to 600C	10.6 sec	11.8 sec
- Time to 400C	14.5 sec	16.4 sec
- Time to 200C	44.6 sec	41.6 sec
ASTM D6186, OIT @ 180C	84 min	43 min
ASTM D189, Conradson	0.12%	0.29%

Formulations presented all 3% treat package in 70N API Group II mineral oil

13

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional Q-249

- Compare formulated performance to Lubrizol LZ5941S

Performance in Formulated Quench Oil w/ Accelerator		
Test Method	**Functional Q-249**	**LZ5941S**
ASTM D3520, Quenchometer	11.2 sec	11.9 sec
ASTM D6200, Quenchalyzer		
- Maximum Cooling Rate	92 C/sec	93 C/sec
- Temp @ Max Rate	596 C	584C
- Rate @ 300C	6.3 C/sec	6.0 C/sec
- Time to 600C	8.3 sec	8.8 sec
- Time to 400C	12.0 sec	11.8 sec
- Time to 200C	44.1 sec	41.3 sec
ASTM D6186, OIT @ 180C	76 min	43 min
ASTM D189, Conradson	0.07%	0.3%

Formulations presented all 3% treat package and 1% treat accelerator in 70N API Group II mineral oil

14

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional Q-145

- Economy quench package for Normal and Medium "Cold" Oils

Physical Properties Functional Q-145		
Color	--	Dark Amber
KV 100, cSt	ASTM D445	6.1
KV 40, cSt	ASTM D445	37.4
Density, lb/gal	ASTM D1475	7.5
Flash Point, C	ASTM D92, COC	226

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional Q-145

- Quench oil performance with and without accelerator

Performance in 70N Group II		
	No Accelerator	2% Accelerator
Treat Rate	3%	3%
Type	Normal Cold Oil	Medium Cold Oil
ASTM D3520, Quenchometer	19.9 sec	11.5 sec
ASTM D6200, Quenchalyzer		
- Maximum Cooling Rate	60 C/sec	94 C/sec
- Time to 600C	12.3 sec	8.4 sec
- Time to 400C	18.3 sec	12.0 sec
- Time to 200C	48.3 sec	43.9 sec
ASTM D6186, OIT @ 180C	36 min	--
ASTM D189, Conradson	0.12%	--

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional Q-145

- Q-145 requires more accelerator to meet competitive performance
- Additional accelerator offset by reduced cost of Q-145 package

Performance and Formulation Comparison for Functional Q-145			
	Q-145	Q-249	LZ5941S
% Treat	3	3	3
% Accelerator	2	1	1
ASTM D3520, Quenchometer	11.5 sec	11.2 sec	11.9 sec
ASTM D6200, Quenchalyzer			
- Maximum Cooling Rate	94 C/sec	92 C/sec	93 C/sec
ASTM D6186, OIT @ 180C	36 min	76 min	43 min
ASTM D189, Conradson	0.12%	0.07%	0.3%
Relative Cost of Package ($/lb)	1.000x	1.405x	--

17

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional V-731

- Functional V-731 is a viscosity modifier and quench accelerator for straight oils

Physical Properties Functional V-731		
Color	ASTM D1500	1.0
KV 100, cSt	ASTM D445	1,100
KV 40, cSt	ASTM D445	19,000
Density, lb/gal	ASTM D1475	7.14
Flash Point, C	ASTM D92, COC	280

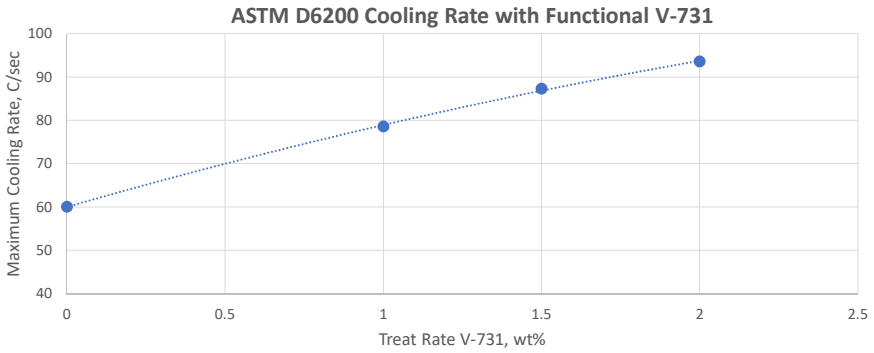
18

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Functional V-731

- Functional V-731 has a strong effect on maximum cooling rate and ASTM D3520 GMQS

ASTM D3520 Quenchometer Results				
% Treat	0%	1%	1.5%	2%
GMQS	19.9 sec	14.9 sec	12.7 sec	11.5 sec



19

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Topics We Covered

1. Quench Oil Basics and Performance Measurements
2. Functional Straight Oil Quench Packages
3. Functional Quench Accelerator

20

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Summary

- Quench fluids allow for controlled cooling of metals
  - Determines hardness/ductility of worked metal
- Quench fluids are evaluated based on quench times, oxidation stability, and cleanliness of finished product
- Functional Products offers additive packages and accelerators for blending straight oil quench fluids
- Functional performance is comparable to leading additives on the market

FUNCTIONAL PRODUCTS INC.
Innovative Chemistry for Lubricants

Thank you for attending today's session!

Contact:
Email
www.functionalproducts.com