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Tribological Evaluation Report – 5/16/2014

By: Ted McClure

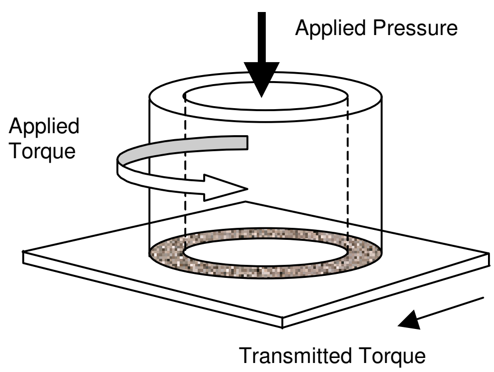
To: Qualice, LLC
Atten: James MacNeil

1. Objectives

The objective of this evaluation is to evaluate the tribological characteristics of the lubricants submitted using Twist Compression tests. (Table 1)

Test Method

The Twist Compression Test was used to evaluate the lubricants. The 25mm ∅ annular cylinder rotates between 6 - 18 rpm or 7- 20mm/s and pressure is set to best simulate the process.



The coefficient of friction is calculated from the ratio of transmitted torque to applied pressure.

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2. Test Matrix (Table 1)

Test	Lubricant	Sheet Material	Tool
1	MCCP	CRS	D2
2	W50	CRS	D2
3	W50AO	CRS	D2

Dynamic tests were run on the TribSys Twist Compression Tester at 10 RPM and 20,000psi interface pressure. The samples were tested diluted in naphthenic basestocks to contain approximately 10% chlorine (w/w) at 30 cSt. at 40˚C. Compositional details are supplied separately. Lubricants were run until breakdown. Test results are summarized in tables below. The time until breakdown was set based on a large positive change in slope, or the onset of instability, in the COF vs. time graph. The initial peak friction is the coefficient of friction when the test first reaches full pressure. The average coefficient of friction is the average coefficient of friction between the initial peak and the time until breakdown. The friction factor is a way to include all of the other results into one number. It is the time until breakdown divided by the weighted average of initial peak friction and average friction. The weights assigned are 20% initial peak and 80% average friction. All of the individual graphs are supplied separately. The tables below summarize the test results.

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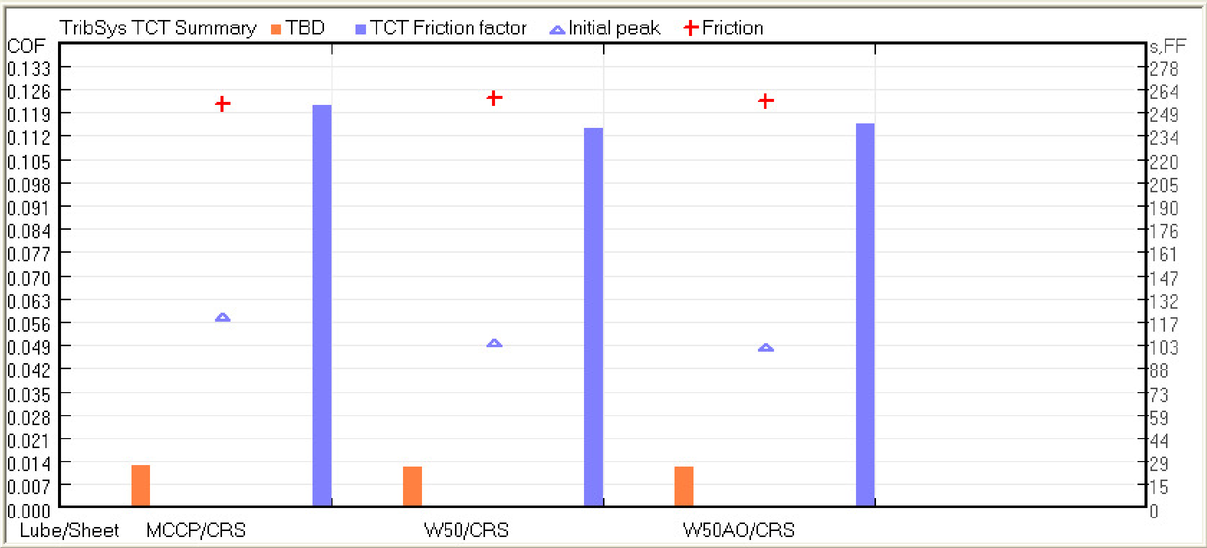
3. Summary of Results: Tables 1a and 1b

TribSys TCT Summary



IP (psi) 20084.88	Initial Peak (Weight=0.20)		Friction (Weight=0.80)		Time to Breakdown (s)		TCT Friction Factor
Lube/Sheet	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Higher is better
MCCP/CRS	0.059	0.003	0.122	0.002	27.92	2.455	255
W50/CRS	0.051	0.001	0.124	0.004	26.30	0.659	240
W50AO/CR	0.050	0.001	0.123	0.004	26.38	1.647	243

Auto Scales ☐ White BKColor ☑ Weight of Initial Peak 0.2 Open... Save... Remove Close

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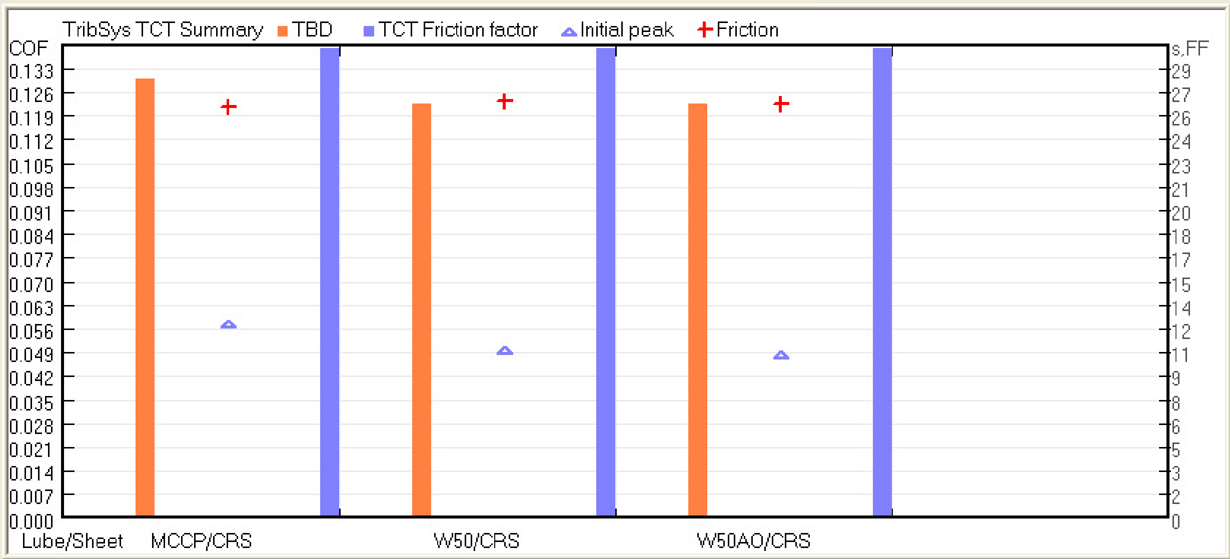
TribSys TCT Summary



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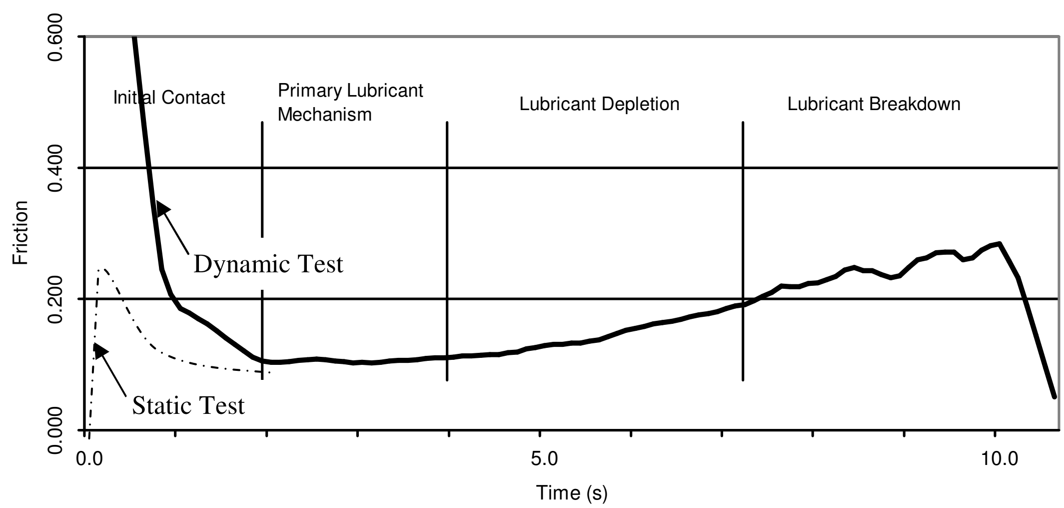
4. Analysis

Understanding TCT Results

The frictional force transmitted by the tool to the workpiece changes as the lubricated interface changes with tool rotation under the applied load. In a typical test, the following stages can be identified.

Twist Compression Test Output



Stage 1. Initial Contact –

Dynamic Test - The rotating tool is brought slowly into contact with the lubricated sheet. The rotation of the sheet holder on low friction bearings is measured by the torque sensor. The transmitted torque increases rapidly as pressure at the interface builds and the lubricant is displaced. This stage is governed by the following parameters:

- sheet and tool characteristics (roughness, hardness, etc)
- lubricant viscosity
- contact pressure (develops gradually as the tool and sheet are brought together)
- speed of rotation (typically does not change)

Static Test – The tool is brought into contact with the sheet before rotation, once the desired pressure has been achieved the tool is rotated. In the static test, the initial friction is the coefficient of static friction. Since the tool and the workpiece are in contact before rotation viscosity effects are minimized.

Stage 2. Primary Lubricant Mechanism – In most cases, the interface will reach a period of stability and exhibit a stable frictional force. This period of stability can be extremely brief or continue for many revolutions depending on the primary lubricant mechanism and the lubricant effectiveness. The following primary lubricant mechanisms are dependant on physical characteristics of the lubricant and require little or no 'activation' time or temperature.

- Hydrodynamic lubrication – may occur briefly in TCT results, would require very high speeds or very viscous lubricants at low pressure.
- Boundary lubrication – common in TCT results, the full load of the tool is carried by the points of contact with the sheet. Boundary additives such as acids and alcohols may serve to reduce friction. Viscosity will have little effect on friction.
- Mixed lubrication – also common in TCT results, pockets of lubricant trapped in the sheet surface are pressured and reduce the pressure at the sheet tool contacts. The pressurized lubricant replenishes the lubricant at the sheet/tool interface.
- Solid film lubrication – the sheet and tool are separated by a solid film of wax, polymer, or inorganic compound such as graphite. Similar to hydrodynamic lubrication but sheet and tool separation is maintained by the solid film.

Stage 3. Lubricant Depletion – With continued sliding contact the lubricant is depleted and the above mechanisms may fail. In the presence of EP additives, the heat generated at the contact points may be sufficient to cause a reaction between the additive and the metal surfaces. In such cases low strength chlorides, sulfides, or phosphides will form on the surface(s) and reduce the severity of contact.

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Stage 4. Lubricant Breakdown – When lubricant mechanism failure occurs friction rises dramatically and becomes unstable as pickup and galling form. The test is usually stopped at this point to preserve the tool and sheet specimens.

A number of quantities can be measured or calculated. The most common are:

- initial peak friction (end of Stage 1)
- average friction (Stage 2)
- time to breakdown (time from test start to beginning of Stage 4)

Pickup and galling can be qualitatively evaluated from the tool and sheet specimens for timed tests.

Contact area can be measured from the sheet specimens using optical microscopy and image analysis. Contact area is best examined at the end of Stage 1 or early in Stage 2. If contact area is of special interest a fourth specimen is run and the test interrupted at the appropriate point.

a. Comparison of Tests

Analyses of the test results are presented here. The TCT is best used as a comparative rather than absolute test. As with all tribological evaluations the influence of uncontrolled (and in many cases unknown) may cause unexplained shifts in data. These shifts may be due to seasonal differences or very minor tooling variations. Consequently, it is advisable to include a reference lubricant and material for all evaluations.

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5. Discussion:

Test Results:

There was not much difference between the lubricants tested under these conditions. The only statistically significant difference was in initial COF, where the MCCP resulted in a higher initial COF than the others.

A good way to visualize how the lubricants behaved in the tests is to overlay a "typical" repeat from each lubricant test on one COF vs. time grid. Please see the graphs below. One can see the similarities and how the MCCP is initially at a slightly higher friction level than the others.

MCCP (Red), W50 (Orange), W50AO (Dark Green)