Glycol Ether Solvents for the Metalworking Fluids Industry

Introduction

Metalworking fluids (MWF) are needed to provide lubrication between sheet metal or metal parts, and the cutting tool or die required to cut or shape them. MWF also remove heat during the cutting or shaping operation, flush metal fines away from the cutting area, and protect metal parts and work equipment from corrosion. MWF capable of forming stable emulsions or true solutions in water have excellent cooling properties, and are widely used by the metalworking industry. Examples of these are soluble oil formulations, synthetic solutions, and semi-synthetic formulations.

Challenges

A common requirement of these water-dilutable MWF is that they must be formulated with biocides and corrosion inhibitors to resist microbial growth and prevent corrosion of metal parts and equipment. These MWF which are usually marketed as concentrates, must be stable when exposed to changes in temperature during storage in typical warehouses and should remain dispersed or homogeneous during use. In addition, MWF should also exhibit a stable pH, low foaming properties, and a good working viscosity.

The Role of Glycol Ethers

Due to the hydrophilic-lipophilic nature inherent in their chemical structure, glycol ethers are able to couple water-oil mixtures in relatively low concentrations, facilitating the formulation of clear, homogeneous fluids. Glycol ethers are also good viscosity-reducing solvents in aqueous media, are able to reduce the surface tension of aqueous solutions improving wetting and disrupting foam formation, and are stable in a wide pH range. Although glycol ethers are not considered nor registered as antimicrobial agents, glycol ethers like DOWANOL™ EPh exhibit some synergistic preservative properties in cosmetic formulations.

Several Dow glycol ethers were evaluated as components for soluble oil and semi-synthetic MWF formulations. The test formulations shown in Table 1 were prepared as concentrates varying only the glycol ether component and then subjected to a battery of tests to compare their performance. Blank formulations without glycol ethers were prepared for comparison purposes.

Table 1 – Semi-Synthetic and Soluble Oil MWF Formulations

Component	Supplier	Functions	Semi-Synthetic MWF Formulation Weight (g)	Soluble Oil MWF Formulation Weight (g)
D.I. water			46.9	1
Triethanolamine 99	Dow Chemical	Corrosion inhibitor	4	---
AMP™ 95	Dow Chemical	Corrosion inhibitor	---	1
Potassium Hydroxide 50%		pH control	1.2	---
Actrafos 110	Georgia Pacific	Lubricant / emulsifier	2.4	---
Hydrocal 100 oil	Calumet Lubricants Co.	Lubricant	10	79
ALKATERGE™ T-IV	Dow Chemical	Corrosion inhibitor / emulsifier	4	---
Xtol 304/ or PAMAK4	Georgia Pacific	Lubricant	8	2.4
Glycol Ether (See Table 2)	Dow Chemical	Coupler / defoamer / viscosity reducer	8	1.6
Actrabase PS-470	Georgia Pacific	Emulsifier	14	14
TRIADINE 3 microbiostat	Arch Chemicals	Antimicrobial	1.5	---
BIOBAN™ P1487	Dow Chemical	Antimicrobial	---	1

Stability Tests

Each MWF formulation was evaluated in a three-day stability test that included a heat/cool cycle, a freeze/thaw cycle, and room temperature observations. The heat/cool samples were placed in a 50ºC oven for 16 hours, then removed and allowed to cool to 25ºC. This cycle was repeated twice. The same procedure was followed with the freeze/thaw samples except the samples were placed in a -10ºC freezer. Observations made with each formulation after the completion of the stability tests are shown in Table 2. The MWF formulations from this test were then used in subsequent foaming tests.

Table 2 – Stability of MWF Formulations

		Semi-Synthetic Formulations			Soluble Oil Formulations		
Solvent	Code	Heat/Cool	25ºC	Freeze/Thaw	Heat/Cool	25ºC	Freeze/Thaw
Blank		3	3	3	1	1	1
DOWANOL™ PM	PM	1	1	1	1	1	1
DOWANOL™ DPM	DPM	3	2	1	1	1	1
DOWANOL™ TPM	TPM	1	1	1	1	1	1
DOWANOL™ PnB	PnB	3	3	3	1	1	1
DOWANOL™ DPnB	DPnB	3	3	3	1	1	1
DOWANOL™ TPnB	TPnB	2	3	2	1	1	1
DOWANOL™ PnP	PnP	1	1	1	1	1	1
DOWANOL™ DPnP	DPnP	1	1	1	1	1	1
DOWANOL™ EPh	EPh	1	1	1	1	1	1
DOWANOL™ PPh	PPh	3	3	3	1	1	1
PROGLYDE™ DMM	DMM	1	1	1	1	2	2
Hexyl CARBITOL™ Solvent	HexCb	3	3	3	1	1	1
Hexyl CELLOSOLVE™ Solvent	HexCs	*	*	*	1	1	1
Butyl CELLOSOLVE™ Solvent	BuCs	1	1	1	1	1	1

1 = Clear 2 = Hazy 3 = Cloudy * = Not Miscible

All glycol ethers yielded clear, homogeneous soluble oil formulations that where not affected by heating or cooling. Stable semi-synthetic formulations were obtained with several glycol ethers including DOWANOL™ EPh, DOWANOL DPnP, Butyl CELLOSOLVE™ and PROGLYDE™ DMM.

Foaming Test

A foaming test was performed on the various MWF formulations after the three-day stability test. Formulations were diluted 20:1 in tap water, and then 50 ml of each dilute formulation was added to a 100 ml graduated cylinder. The cylinder was plugged and shaken by hand 60 times over a one minute period. Foam heights were recorded at time = 0, and after 1, 2 and 5 minutes. Results of these tests are shown in Charts 1-6.

It can be seen that a blank semi-synthetic MWF formulation without glycol ether produced stable foam that persisted after five minutes. By contrast, foaming subsided within one minute in all formulations containing glycol ethers with the exception of the formulation containing Hexyl CARBITOL™. Foaming in all soluble oil MWF formulations subsided almost immediately after the initial reading.

Chart 1 – Semi-Synthetic MWF Foam Test, Room Temperature

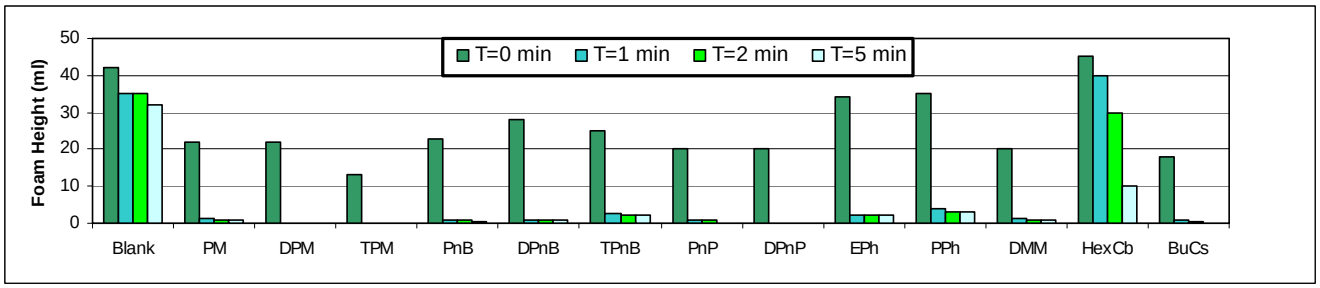


Chart 2 – Semi-Synthetic MWF Foam Test, Heat/Cool

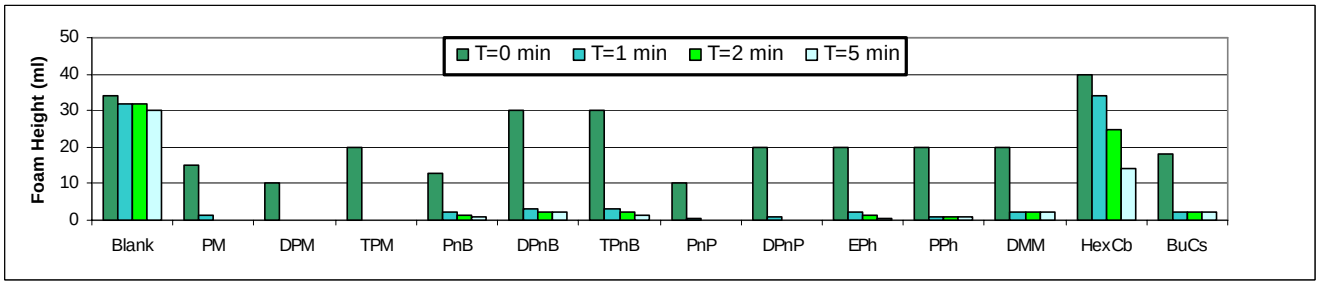


Chart 3 – Semi-Synthetic MWF Foam Test, Freeze/Thaw

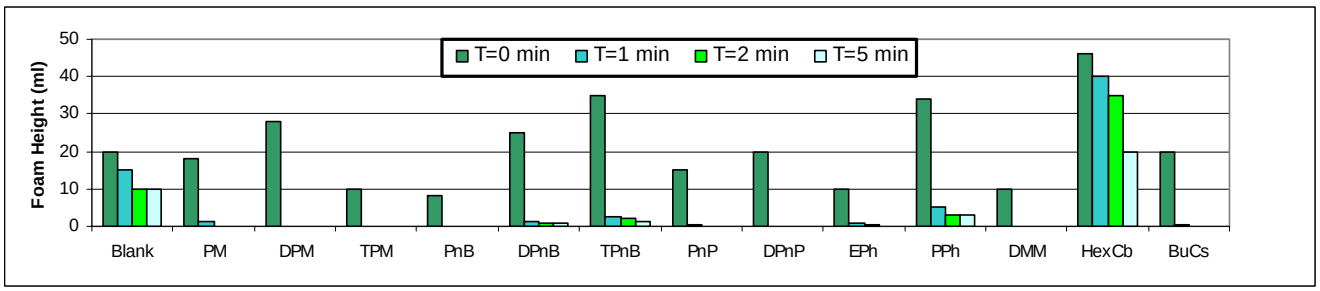


Chart 4 – Soluble Oil MWF Foam Test, Room Temperature

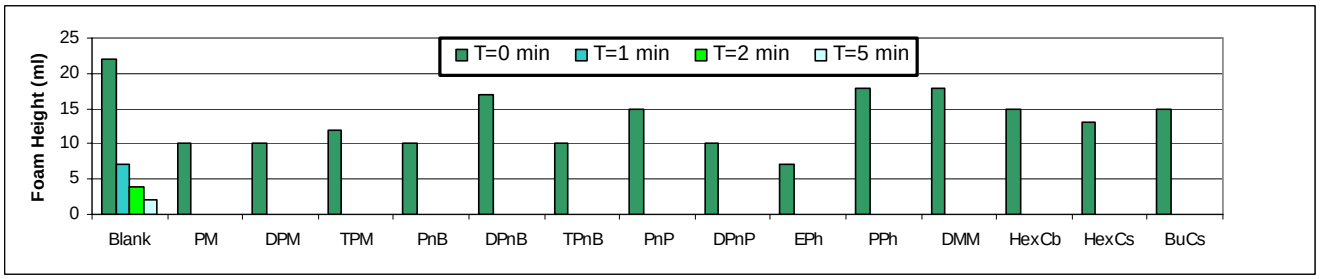


Chart 5 – Soluble Oil MWF Foam Test, Heat/Cool

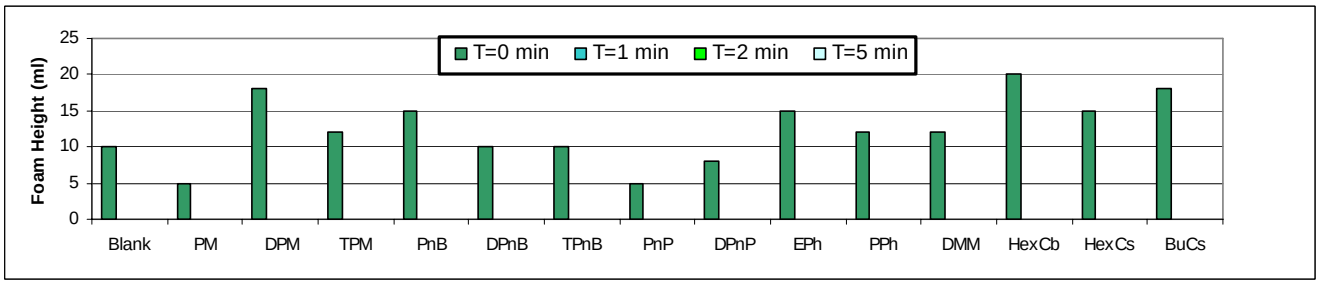
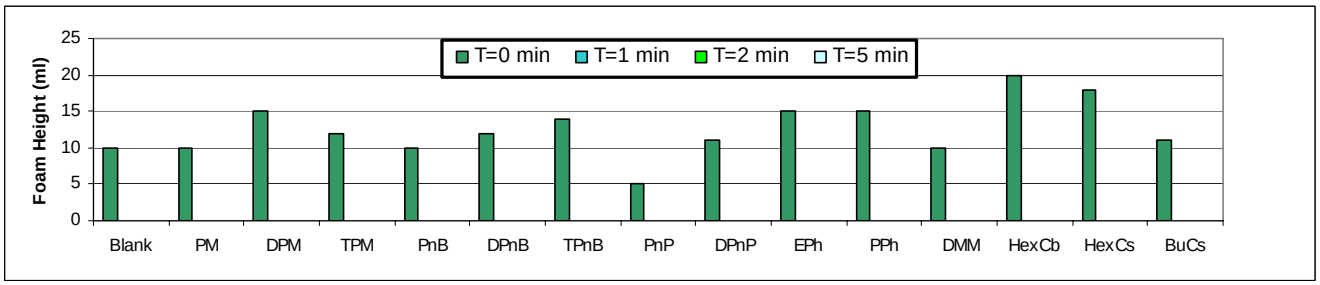


Chart 6 – Soluble Oil MWF Foam Test, Freeze/Thaw



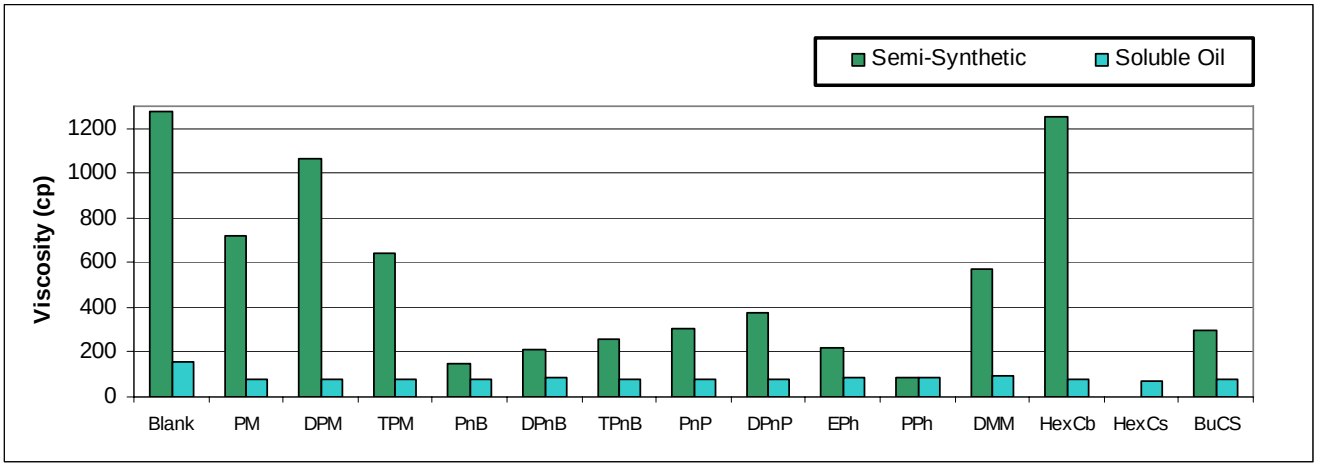
pH Measurements

The pH of the various MWF (formulation and dilutions) was measured. The pH of the semi-synthetic formulation concentrates ranged from 8.2-8.7, and the pH of the diluted samples ranged from 8.4-8.8. The pH of the soluble oil formulation concentrates ranged from 10.2-11.5, and the pH of the diluted samples ranged from 9.3-9.6. Overall, these values fall within the acceptable pH range for typical MWF formulations.

Viscosity Measurements

The viscosity of the various MWF formulation concentrates kept at room temperature was measured at 25ºC using a Brookfield Programmable DV-II+ Viscometer equipped with a Brinkmann MGW Lauda RM6 circulating water bath. Each sample was measured initially and after two weeks. There was no significant difference in viscosity of the formulations from initial and two week measurements. Data collected after two weeks are shown in Chart 7.

Chart 7 – Viscosity of MWF Formulations



All soluble oil MWF formulations containing glycol ethers displayed lower viscosity than a blank MWF formulation without glycol ethers. A noticeable reduction in viscosity was observed in the semi-synthetic MWF formulations containing hydrophobic glycol ethers such as DOWANOL™ PPh, DOWANOL EPh, DOWANOL PnP and several others.

Corrosion Test

This test method, based on ASTM D-4627-92 *Standard Test Method for Iron Chip Corrosion for Water-Dilutable Metalworking Fluids,* covers the evaluation of the ferrous corrosion control characteristics of the test MWF formulations. Samples of the various test formulations encompassing a range of glycol ether hydrophilicity were tested at various concentrations using hard water as a diluent. Chart 8 shows the weakest concentration at which no corrosion was detected by the test (breakpoint).

All the formulations evaluated had the same or lower breakpoint for corrosion as the blank without glycol ether. These results show that the addition of glycol ethers to the formulations did not have a detrimental effect on the corrosion inhibitor package and some may have actually improved the corrosion protection of the inhibitor package.

Chart 8 – Evaluation of Corrosion

Glycol Ether in Formulation	Semi-Synthetic Formulation Breakpoint*	Soluble Oil Formulation Breakpoint*
Blank	5%	5%
DOWANOL™ DPM	3%	4%
DOWANOL™ DPnB	4%	5%
DOWANOL™ DPnP	4%	4%
DOWANOL™ EPh	5%	5%
DOWANOL™ PPh	5%	5%
PROGLYDE™ DMM	3%	4%
Butyl CELLOSOLVE™ Solvent	4%	4%

*Breakpoint is defined as the weakest MWF concentration tested that leaves no rust stain on the filter paper.

Summary

Glycol ethers have been found useful in the formulation of homogeneous, stable metalworking fluids. Glycol ethers suppress foaming, decrease formulation viscosity, and do not have a negative effect on pH or corrosion inhibition. In addition, most glycol ethers are also biodegradable which makes them well suited for water-based formulations that may ultimately be processed through a waste water treatment facility.

For More Information

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