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CHALLENGES OF MODERN MACHINING PROCESSES ON METALWORKING FLUID COMPOSITION

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ABSTRACT
At machining processes high temperatures and high pressures on contact surfaces between the tool and the workpiece cause unwanted occurrences, such as chips welded to the tool cutting edge, uncontrolled metal microstructure below the worked area, increased tool wear, etc. Application of proper metalworking fluid decreases those tribological effects, and also increases process productivity. At high speed operations there are additional requirements on working fluid properties like are low foaming, low misting and extreme stability. When an emulsion separates, many problems occurs such as decreased tool life, corrosion and rust production, unpleasant odour and scum separation. All this leads to increased costs of total metalworking process. Selection of suitable components for metalworking fluid production can avoid problems and extend the service life of working fluid. In this paper are presented laboratory examination results of emulsifying metalworking fluid and also application properties at modern metalworking machine.
Keywords: metalworking fluid, emulsion, high speed machining, cooling through tool

1. INTRODUCTION
Besides of human health and environmental protection, and customer requirements for cost reduction, development trend of metalworking fluids is dependent of new metalworking tool and machines' designs [1]. Modern machining processes like are high speed machining, high speed feed machining or cooling through tool generate high fluid pressure that can cause unwanted accuracies [2]. Those are increased foaming, emulsion separation, and quick contamination what decrease working fluid properties as are lubrication, cooling and flushing chips away from the cutting zone. Separation can cause sticking all over machine, growing microorganisms count, and require additional maintenance. So, the working fluid for those processes should have extreme concentrate and emulsion stabilities [3]. From the numerous types of metalworking lubricants emulsifying fluids has advantages at processes required cooling and also lubrication [4]. Emulsifying fluids consist of mineral oil, emulsifiers, corrosion inhibitors, EP-additives (extreme pressure), biocides, defoamers and other components in order to satisfy application and also physical chemical properties [5]. According to safety and environmental requirements mostly of common used components in formulations are changing with new less harmful components [6,7,8]. Emulsifying fluids are produced as concentrates and in metalworking shops mixed with water forming either emulsions or microemulsions. It is very important to keep metalworking fluids stable since they have a direct impact on customer's productivity. Microemulsions are known to be thermodynamically stable systems. Emulsion stability in a customer application is affected by many factors such as water hardness, pH value, bacteria, temperature, contamination and also metalworking condition as are properties and geometry of the cutting tool, material being machined, rigidity of the machine tool, etc. [9].

2. EXPERIMENTAL

2.1. Objectives

The objective of this work is development of new watermiscible metalworking fluid for application at high speed and also high pressure operations. Requirement on that working emulsion are high stability, low foaming, good lubrication and cooling, as well as all other common fluid properties. Physical chemical and working properties of new fluid should be better than former fluid EM-B-E in application at CNC SPINNER machine.

2.2. Test methods

At laboratory development of fluids and also for monitoring during application we used standard DIN, ASTM, IP, Internal test (of Maziva-Zagreb Ltd.), user's methods as well as standard test kits [9]. Stability of additives, metalworking concentrates and their emulsions were tested at different temperatures by Internal test 1. Changes of original samples as separation, sedimentation or turbidity after 24 hours are examined visually. Foaming properties we examined on three tests: cylindrical shaking tests Internal test 2 and IP 312 and circulating Cnomo test. According to Internal test 2, into 100 mL graduated glass cylinder is added 50 mL of test emulsion (in hard water 14 German hardness), and is then turned twenty times through 15-20 seconds. Foam volume is measured immediately and after five minutes (mL). At method IP 312 test emulsion (synthetic hard water 200 ppm of $CaCO_3$), 100 mL, is shaken for 15 sec. in a graduated test cylinder of 250 mL. After shaking foam volume measured immediately and in intervals of 5 minutes. After 5 minutes, the foam volume expressed as foam stability or foam decrease, if it disappears over a short period of time (seconds). Foaming tendency according to Cnomo test D 655212 (NF T60185) is examined in 2000 mL glass cylinder with fluid flow rate 250 L/h, and fluid downfall 390 mm. Volume of fluid is 1000 mL, and time of examination is 300 minutes at normal temperature. If foam volume reaches maximum level of graduated test cylinder, time of foam increase is measured. For examination of fluid EP-Properties (Extreme Properties) we used two mechanical dynamical machines. First is known as Four-ball wear test machine, ASTM D 4172. Four metal balls are placed in test fluid, heated to 75 ^{0}C and then the top ball is rotated at standard load for 60 min. After one-hour test running, scar area diameter of test balls are measured and showed as average value. The second test is known as Reichert balance machine. Basic construction consists of static metal roll and rotated ring immersed in test fluid. Wear scar area on test roll is measured. For microorganism count we used Easicult Combi deep slides and S tubes. The results are expressed as Total number of colonies CFU per one mL of emulsion.

2.3. Test metalworking fluids

In Table 1 is presented approximate composition of final test metalworking fluids – concentrates. In that work are presented two types of emulsifying metalworking fluids: EM-B-E and EM-HSP. Components for production test metalworking fluids we used from the market and from different producers (C and R). Mineral oil paraffinic type (40 %) contains lower quantity of aromatics, emulsifiers are natural carboxylic acids and compounds which does not contain aromatic ring.

Table 1: Composition of test metalworking fluids -concentrates

COMPOSITION, % Approx. (+100 % other additives)	EM-B-E	EM-HSP
ADT1 - alkanol amide	-	15
ADC1 - Tall oil fatty acid monoizopropanolamide	10	-
ADT2 - borate, 10 %	-	15
ADC3 - Boric acid MEA salt, 15 %	24	-
ADT3 - poliglykol ether	-	4
ADC2 - Fatty alcohol polyglycol ether C16/C18 + 2 EO	7.2	-
ADC4 - Na petroleum sulphonate, neutral	10	-
ADT4 – Trimethylolpropane trioleate	-	5

3. RESULTS AND DISCUSSION

Test fluids are semisynthetic emulsifying metalworking fluids with 40 % of mineral oil. They form transparent (EM-B-E) and opalescent (EM-HSP) microemulsions. Both fluids – emulsions have good anticorrosion properties, and also storage stability. As emulsifiers are molecules changing the properties of fluids both on the surface and in the fluid itself and thus have enormous influences on emulsion stability at high speed operations. Emulsion EM-HSP has better foaming characteristics even at Cnomo test. Cnomo test condition simulates application conditions, and it is possible that emulsion EM-HSP will satisfy at real metalworking operation with high speeds. In Table 2 are presented physical chemical and working properties of test fluids - concentrates and emulsions.

Table 2: Properties of test metalworking fluids –concentrates and emulsions

PROPERTIES / METHODS	EM-B-E	EM-HSP
Appearance, Visually	clear, dark yellow	clear, yellow
Density at 15^0C, g/mL, ISO 3675	0.981	0.955
Viscosity kinematic at 40^0C, mm^2/s, ISO 3104	140	60
Stability, 0-70^0C/ 24h, Internal test 1	stable	stable
Emulsion, 5 % in tap water (TW=14 DH)		
Appearance, Visually	transparent, yellow	opalescent, white
Stability, 20^0C/ 24 h, Internal test 1	stable	stable
Alkalinity reserve, mL 0.1nHCl, ASTM D 1121	5.51	6.5
pH-Value, ASTM D 1287	8.72	9.0
Corrosion, Herbert, DIN 51360/I, 1.7 % emulsion	R0/S0	R0/S0
Corrosion, Filter, DIN 51360/II, 2.5 % emulsion	0	0
Scar diameter, av., mm, ASTM D 4172	0.69	0.60
Scar area, mm^2, Reichert balance	30	31.1
Foam volume, mL/after 5 min, mL, Internal test 2	25/0	no foam
Foam volume, mL, after 5 min, mL/stability, IP 312	150, 0/1’	no foam
Foam volume, mL/time, Cnomo, 3% TW	1000/35 sec.	100/300 min.

After satisfying laboratory results new fluid is examined in metalworking shop. Conditions at machining operation are shown in Table 3. For processes of hole machining (Figure 1) are used modern tools and one is presented on Figure 2 [9]. Working emulsion is prepared with soft water (10.4 DH). During emulsion application we take samples on required frequency and examined theirs properties. The results of working fluid examinations are shown in Table 4. Working conditions at CNC machine are extremely unpleasant. There is high fluid feed pressure, high tool speeds and cooling through tool. Internal coolant supply is always to be preferred in drilling to avoid chip jamming. External supply is acceptable in some cases and can help to avoid built-up edge formation due to a higher edge temperature. Chip evacuation and lubrication between drill and hole-wall are the primary functions which have to be supported. Good lubricity also helps to overcome built up edges. Pressure and volume define the supply to the tool and values are recommended for different tool types. So high-pressure coolant systems reducing temperature and providing chip control.

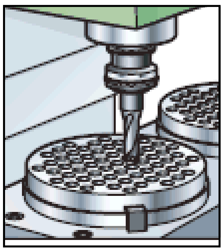

Figure 1. Process of hole making

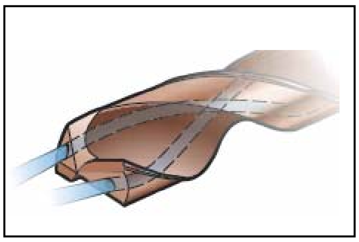

Figure 2. Internal coolant supply

Table 3: Condition at machining operation

MACHINING OPERATION	CNC SPINNER DMH 1212
Working metal	steel
Metalworking operation	deep hole drilling, boring, reaming
Hole diameter, mm	17 - 21
Hole high, mm	60 - 170
Workpieces diameter, mm	800 - 1200
Tool type	in line spindle, emulsion through internal channels
Motor spindle, rpm	up to 24.000
Facilities for fluid maintenance	chips conveyor, step-reservoirs
Fluid quantity, m^3	0.60
Fluid pump pressure, bar	6 (normal process) - 24

Table 4. Results of EM-HSP emulsion monitoring during application

Sample	1	2	3	4
Working day	10	17	25	60
Appearance	opalescent, white	opalescent	opalescent	opalescent
pH-Value	9.04	8.98	9.1	9.0
Reserve alkalinity, mL0.1nHCl	4.7	5.14	5.12	5.2
Concentration refractometer, %	3.8	4.0	4.0	4.2
Herbert test	R0/S0	R0/S0	R0/S0	R0/S0
Filter test	0	0	0	0
CFU/1mL	<100	<100	<100	<100

Working emulsions of EM-B-E and EM-HSP fluids showed satisfying properties at machining operation but EM-HSP emulsion showed better stability during application. Better stability of EM-HSP can be explained by higher quantity of amide compounds content and other additive selection compare to EM-B-E. New emulsion EM-HSP also showed excellent properties as are: corrosion protection of machine elements and worked surface, cooling and lubrication, chips formation as well as cleaning working zone.

4. CONCLUSION

New semisynthetic emulsifying metalworking fluid EM-HSP is developed and examined in laboratory and in metalworking shop. That fluid because of its composition is classified as less harmful to the environment and human health. Old fluid EM-B-E also tested. Both formulations showed good properties at common laboratory tests that are required for metalworking emulsions. Better properties on foaming tests showed new fluid EM-HSP with very low foaming tendency. Emulsions were in application at CNC Spinner DMH machine. In comparison to metalworking fluid EM-B-E, new formulation EM-HSP showed excellent properties at high speed feed cutting operation. The physical chemical properties of working fluid are very stable during whole examination period.

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