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THE IMPACT ANALYSIS OF CUTTING FLUIDS AEROSOLS ON WORKING ENVIRONMENT AND CONTAMINATION OF RESERVOIRS

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Subject review

Cutting fluids play a significant role in machining operations and impact shop productivity, tool life and quality of work. They are also key factors in machine shop productivity and production of quality machined parts. Today's cutting fluids are special blends of chemical additives, lubricants and water formulated to meet the performance demands of the metalworking industry.

Keywords: *fluid contamination, metalworking, cutting fluids*

Analiza utjecaja tekućih aerosola za rezanje na radno okruženje i onečišćenje rezervoara

Pregledni članak

Tekućine za rezanje imaju značajnu ulogu u operacijama obrade i utjecaju na produktivnost, vijek trajanja alata i kvalitetu rada. One su također ključni čimbenik u produktivnosti i proizvodnji kvalitetnih obrađenih dijelova. Današnje tekućine za rezanje posebne su mješavine kemijskih aditiva, maziva i vode formulirane da performansama zadovolje zahtjeve metalske industrije.

Ključne riječi: *onečišćenje tekućine, obrada metala, tekućine za rezanje*

1 Introduction

Monitoring and maintaining fluid quality are crucial elements of a successful fluid management program. A fluid must be monitored to anticipate problems. Important aspects of fluid monitoring include system inspections and periodic measurements of fluid parameters such as concentration, biological growth and pH. Changes from optimal fluid quality must be corrected with appropriate adjustments (such as fluid concentration adjustments, biocide addition, tramp oil and metal cuttings removal, and pH adjustment). It is important to know what changes may take place in your system and why they occur. This allows fluid management personnel to take the appropriate steps needed to bring fluid quality back on-line and prevent fluid quality problems from recurring.

The new metalworking cutting fluids generation brings also higher requirements for the system of fluid performance monitoring and control.

2 Samples and analysis

Exposure of workers to aerosols of cutting fluids was measured from samples of multi-hole filters after collecting gravimetric analysis to determine the total number of total inhalable particles (TIP). Filters were further analyzed for reconsideration of mineral oil mist content in cyclohexane solvent and the mix of water cutting fluid samples were analyzed by elementary methods. This method involves measuring the elementary particles (usually boron or potassium) by spectrometric analysis. If are available data of cutting fluid concentration in the tank for liquid then it is possible to calculate the concentration in the air. The majority of the cutting fluid samples were taken at the site of the workpiece or cutting tool. In some cases, where the central tank is used, one sample was collected. Temperature and pH of the aqueous mix of cutting fluid were measured on the spot.

Water mixes cutting fluids were analyzed to detect the bacteria content. A substantial portion of the water mixes of cutting fluids was used for calibration of aerosol samples for analysis. Bacterial contamination of fluids was determined by dip-slide analysis. This analysis lies in the fact that the agar-coated plastic rod is immersed in a liquid sample, placed into a sterile container and then placed in an incubator. At stable temperature after 48 hours the amount of bacteria on the bar is determined by comparing. Dip-slide analysis provides a simple, inexpensive and reliable method of determining bacterial growth. For evaluation was used Grubb's test, a statistical test which is used to detect outliers in a univariate data set assumed to come from a normally distributed population.

3 The results of measurements

Exposure to aerosols of cutting fluids can happen in contact with the skin (such as through contaminated areas), or inhalation of spray droplets in the air. The aerosol is created when the cutting fluid is exposed to high shear

Table 1 Summary statistics of the valued mean of air samples over 8 hours

Analyzed sample	Samples amount	Min	Max	Median	Mean	Geometric mean	Mean deviation
Mineral oil (TIP) /mg/m^3	30	0,06	4,38	0,55	1,11	0,61	3,26
Mineral oil /mg/m^3	30	0,03	3,74	0,78	1,23	0,67	3,76
Water mix (TIP) /mg/m^3	30	<0,04	23,06	0,32	0,67	0,33	3,05
Water mix concentrate	30	<0,01	13,2	0,12	0,35	0,13	3,9

Table 2 Summary statistics analysis of tanks

Analyzed sample	Matrix	Samples amount	Min	Max	Median	Mean	Deviation	Geometric mean
pH in tank	Water	30	5,4	10,5	8,8	8,7	0,7	8,7
Temperature in tank /°C	Water	30	10,7	44,1	21,6	21,9	3,8	21,6
Fine particles /mg/l	Water	30	<4	2200	18	56	165	20
Fine particles /mg/l	Mineral oil	30	80	1230	395	464	291	385
Amount of bacteria /10^6	Mineral oil	30	<10	195	0,109	11,992	30,926	0,01774

Table 3 Percentiles of cutting fluid samples

Analyzed sample	90^{th} percentile	95^{th} percentile
Aerosols		
Mineral oil (TIP) /mg/m^3	2,8	3,3
Mineral oil fog /mg/m^3	2,8	3,4
Water mix (TIP) /mg/m^3	1,4	1,9
Water mix fog /mg/m^3	0,8	1,6
Tank		
Mineral oil fine particles /mg/l	900	970
Water mix fine particles /mg/l	90	270
Amount of bacteria /10^7/ml	4,3	8,3

strength or excess heat during the application process. Aerosol properties depend on itself, cutting fluid and the type of operation, but the fog may be relatively stable and usually does not last long. Summarized statistical results for the analyzed air samples are listed in Tab. 1, analytical results from the tank in Tab. 2 and percentiles in Tab. 3.

4 Interpretation of results

During the period of 8 hours neither mineral oil aerosols exceeded 5 mg/m^3 on average. Results of total inhalable particles (*TIP*) and fog are well correlated. Regression line equation is given by: oil mist 0, 0889 + 0,892·*TIP* and the correlation coefficient r = 0,927, suggesting that the *TIP* may provide a good estimate of the impact on the environment of oil mist for these samples (Fig. 1).

$$x = 0{,}0889 + 0{,}892 \cdot TIP, \qquad (1)$$

x – equation of the regression line, mg/m^3
TIP – total inhalable particles, mg/m^3.

A result of measurements of water mix suggests that most emissions are below the limit of 2 mg/m^3. The chart of mist of cutting fluid concentrate with total and inhalable particles (Fig. 2) shows a high degree of dispersion, which

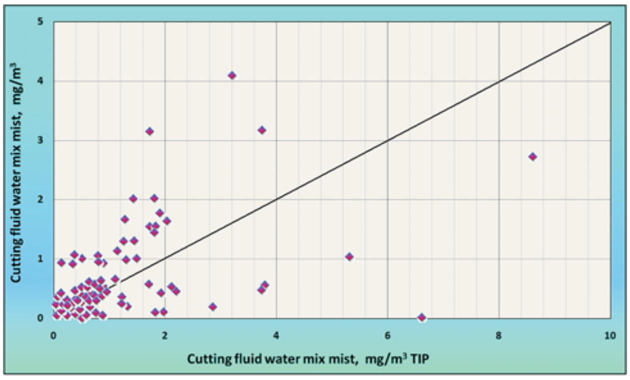

Figure 1 Mineral oil mist and mist of total inhalable particles

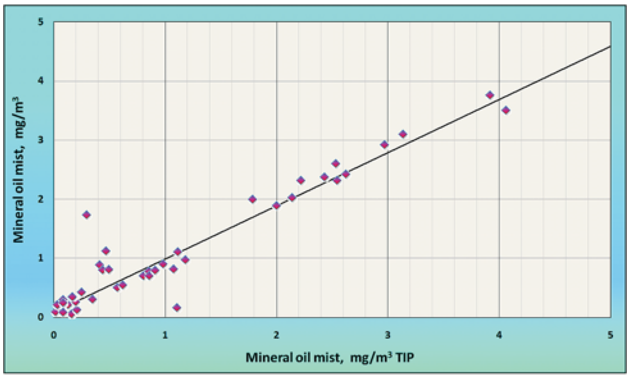

Figure 2 Mist of cutting fluid water mix and mist of water mix with total inhalable particles

Table 4 Results of measurements at various operations in the application of water mist cutting fluid mix (mg/m^3)

Process	Samples amount	Min	Max	Median	Mean	Geometric mean	Geometric deviation
Turning	30	<0,01	1,82	0,06	0,15	0,07	3,32
Milling	30	<0,01	0,92	0,07	0,13	0,08	2,84
Drilling	30	<0,4	0,9	0,14	0,22	0,16	2,29
Grinding	30	<0,02	13,22	0,35	0,73	0,29	3,87
Sawing	30	<0,05	0,61	0,23	0,27	0,18	3,23
Combined operations	30	<0,01	3,22	0,2	0,71	0,28	4,81

shows, with the exception of the mentioned scattered values, the correlation coefficient is $r = 0,978$.

Differences in effect during machining are characterized as turning, milling, drilling, cutting and grinding (or combination of these operations in some cases). According to the values in Tab. 4 it can be concluded that the results of measurements at various operations (geometric grinding, sawing operations and the combined operations) in the application of water mist cutting fluid mix (mg/m^3) lead to a higher impact of fog water mix as in turning or milling.

Further analysis of these data shows that the growth of bacteria in a water tank with a mix of cutting fluids depends on the pH and temperature of fluid (Fig. 3, Fig. 4), but also on other factors. From the previous analysis it can be stated that it is necessary to control the consumption of cutting fluids in machining processes wherever they are used. Mist and aerosols creation causes leakage of small particles of liquid into the operator working area or production line equipment.

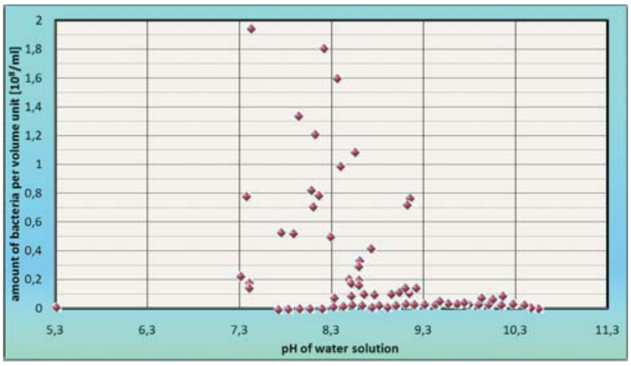

Figure 3 Growth of bacteria per volume unit, depending on the pH of the water mix of cutting fluid, X axis = 10^8

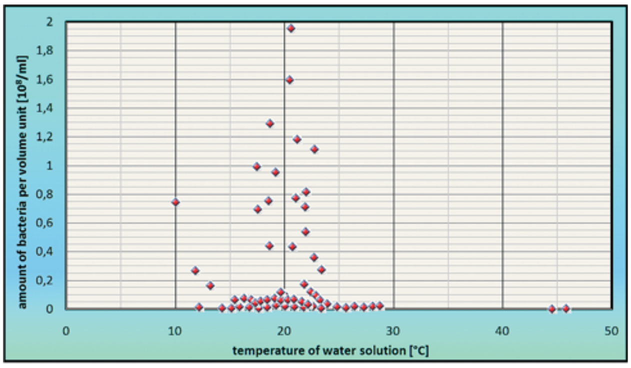

Figure 4 Growth of bacteria per volume unit at different temperatures of water mix cutting fluid, X axis = 10^8, Y axis = °C

This has implications not only for the health of working personnel, but also coating devices that come in contact with those particles. Reducing the impact can be assured not only by controlling consumption, but also constantly monitoring the quality of the media process and thus prevent their degradation and subsequent dispersal of pollutants into the workspace.

5 Conclusion

Fluid monitoring and maintenance are the key element of each successful fluid maintenance program. Fluids must be monitored to prevent problems. An important aspect of fluid monitoring is a system of controls and periodical measurements of the fluids properties, such as concentration, pH and biological growth. Changes to the optimal fluids properties must be compensated by adequate additives (such as fluids concentration increasers, biocides additives, tramp oils, metal parts removers and fluid pH increasers). It is important to know what changes may be caused in the system and what causes them. This allows the personnel in fluid management to take necessary steps to bring the fluid properties and its quality back to optimal values and avoid possible problems recurring. Bacteria have been associated with a serious lung condition, hypersensitivity pneumonitis, when inhaled as part of liquid droplet aerosols generated from large volumes of liquids serving as a culture medium. Therefore these tests are very important for exhaust systems dimensioning from cutting zone during machining in production companies.

6 References

[1] Al Hakim, H.; Blažovský, J. Tribológia a servis strojov, Fakulta výrobných technológií Technickej univerzity v Košiciach so sídlom v Prešove, 2002, 221 p., ISBN 80-7099-875X.

[2] BENZINOL. Rezné kvapaliny a ich použitie pri obrábaní kovov, Svépomoc Praha, 1990, 69 p., ISBN 80-85168-12-X.

[3] Bojtoš, P.; Štekláč, D. The cutting fluids functional properties identification, when grinding. // Zborník 2nd International conference of PhD Students, 8.÷14.8.1999, Miskolc, Hungary, pp. 29-34.

[4] Bránecký, Ľ.; Zajac, J. Rezné kvapaliny vo výrobe ložísk a ostatných strojárenských technológiách. // Strojárska technológia a valivé ložiská 1997. ZU Žilina, 1997.

[5] Coughlin, R. W.; Williams, D.; Seveau, E.; Veith, R.; Howes, T. Enumeration of Microorganism in Metalworking Fluids Using Photometric Methods. // Annals of the CIRP, 41, 1(1992), pp. 357-359.

[6] Pusavec, F.; Stoic, A.; Kopac, J. The role of cryogenics in machining processes. // Tehnički vjesnik, 16, 4(2009), pp. 3-10.

[7] Hatala, M.; Orlovský, I. Sprinkle drying kiln ceramic granulate drying characteristic and experimental measurements of the drying process parameters. // Tehnički vjesnik, 16, 2(2009), pp. 27-30.

[8] IOWA REDUCTION CENTER. Cutting fluid management for small machining operations, University of Northern Iowa 2003.

[9] Leiseder, L. M. Metalworking fluids, Verlag Moderne Industrie AG&Co, Berlín, 1991.

[10] Harnicarova, M.; Zajac, J.; Stoic, A. Comparison of different material cutting technologies in terms of their impact on the cutting quality of structural steel. // Tehnički vjesnik, 17, 3(2010), pp. 371-376.

[11] Zajac, J. Príspevok k riešeniu synergie brúsenia a kvapalín v procesoch brúsenia. // Výrobné inžinierstvo, 2-3(2003), pp. 14-16, ISSN 1335-7972-01, vydáva FVT TU Košice so sílom v Prešove.

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