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# TO COMPARE TECHNOLOGIES FOR TREATMENT OF DIFFERENT TYPES OF METAL CUTTING FLUID

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*Abstract* — **The aim of this work is to evaluate the use of electrolytes in the breakdown of waste of cutting fluid emulsion, reusing the recovered phase to develop the reuse in making new cutting fluid, and for the removal of COD FENTON's process was used on the fluid which was left before discharging. The different technologies for different Metal Cutting Fluids (MCFs) were observed and from that which method is effectively suitable for treatment of different MCFs were selected. Three metal cutting fluids were used to evaluate the comparison by different methods: *Synthetic cutting fluid (water-in-oil), Semi-synthetic cutting fluid(oil-in-water), Mineral oils*, all the MCF's collected in the emulsified form. The technologies used for recovery of waste oil is *Electrocoagulation* and *Fenton's process* for removal of COD. The physicochemical properties of these new cutting fluids were close to the ones of the initial ones, except the viscosity values which increased.**

***Keywords-Metal Cutting Fluid (MCF's), Electrolytes, Emulsion breakdown, Fenton's process, Electrocoagulation, Recovery & Reuse, Chemical Oxygen Demand (COD).***

## I. INTRODUCTION

**Metal Cutting Fluids** are the type of fluids used in the metal processing industry, stamping, drilling, cutting any many other processes. With increase in manufacturing industries, the is demand in growing for low cost, high productivity and good product quality. Good Productivity is inherently associated with high cutting speed, feed rate and depth of cut, which lead to large amount of heat and raise in temperature at cutting zone. The main functions of cutting fluids are cooling, lubrication, removing chips and metals from the tool/work piece interface, flushing, prevention of corrosion.

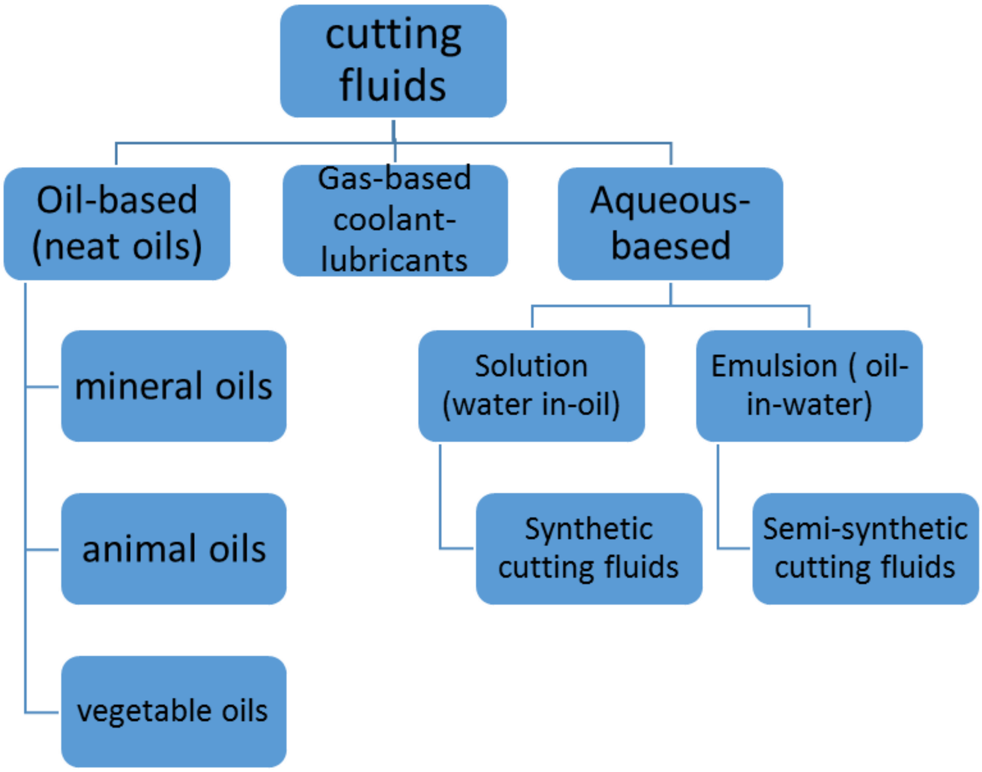
Cutting fluids are used in machine shops to improve the life and function of cutting tools. They act as a key factor in the machine shop productivity and the production of good quality machine parts. The attention is mainly concentrated on improving of working conditions, reducing the health danger for machine operators, and application of new manufacturing procedures, material and technologies. There are now several types of metal cutting fluids available in the market, the most common of which are used broadly categorized as cutting oils or water-miscible fluids, water miscible fluids, including soluble oils, synthetics, and semi-synthetics, are now used in approximately 80 to 90 percent of all applications.

Although straight cutting oils are less popular than they were in the past, they are still the fluid of choice for certain metal-working applications. Cutting fluids can be divided into two categories **i) water-based fluids –including straight oils and soluble oils, ii) oil-based fluids –including synthetic and semi-synthetics.** When used in machine processes, these emulsions lose its properties and effectiveness due to the thermal degradation and contamination. The replacement of these emulsions is responsible for the production of oily wastewaters.

Residual fluids have high concentration of carcinogenic potential due to presence of products derived from degradation of additives, polycyclic aromatic hydrocarbon (PHA), nitrosamines among others. The other substances which are formed due to degradation of cutting fluid are foreign bodies and microorganisms. It is essential to treat the cutting fluid wastewaters before its disposal in environment considering the risk presented and the presence of strict environmental regulations.

The Metal Cutting Fluid is not modified with its use, making possible to recycle it several times by replacing the missing additives. Considering the poor biodegradability of the recovered oil phase, recycling is the best alternative to address these threatening residues. The reuse of the recovered oil phase in new cutting fluids prevents its disposal or burning and reduces the extraction of nonrenewable resources for the production of new ones.

**2. Classification of cutting fluids :**




**2.1 Oil-based cutting fluids**

An oil based lubricant (neat oils) is derived from mineral, animal, vegetable, and synthetic oils. Mineral oils (petroleum based) are the major type due to their desirable lubricating characteristics. These cutting fluids usually contain some additives oil enhance their applications. For instance, the characteristics of naphthenic mineral oils and paraffinic mineral oils are usually enhanced through the addition of fatty lubricants, extreme pressure additives, odorants, thickness modifiers, and polar additives. **Mineral-based** are used to lubricate the tool-chip interface and consequently minimize the friction and friction induced heat at the cutting zone.
As a result, low cutting forces are required to reduce the crater wear on the tool rake face. Besides, it is useful in lubricating the moving part of the machining tool, as it prevents corrosion on the machined surface and machine tool.
The advantage of neat oil lubricants are that are excellent in lubrication, anti-seizure, and corrosion resistance. However, their main disadvantage is the high flammability as they are
good in lubrication but poor when machining in higher load and temperatures, resulting in mist and smoke.
Hence, neat oil lubricants are used principally for low-speed operations where temperature rise is not significant. Chemical additives such as sulphur, chlorine, and phosphorous are always added in neat oil lubricant to form thin solid salt layer on the hot and clean metal surfaces. This extreme pressure film reduces the friction between chip and tool in metal cutting effectively.

**2.2 Synthetic Cutting Fluids**

Synthetic cutting fluid which is made of chemical with additives and diluted in water, is free from mineral oil. They tend to have a clear, watery appearance, while dye may be added to make a clear green or yellow liquid. Synthetic cutting fluid forms transparent solutions and provides good visibility of cutting operation. The addition of organic and inorganic chemical solutions in synthetics cutting fluid provides water softening, corrosion resistance, lubrication, reduction of surface tension and blending. Synthetic cutting fluid is a good coolant but it provides insufficient lubrication compared to other cutting fluids due to lack of oiliness. As, a result, they are particularly used for low force operations where cooling is a primary requirement.

**2.3 Semi-Synthetic Cutting Fluids**

Semi-synthetic fluids are chemical emulsion, which contain mineral oil diluted in water with some additives to reduce the size of oil particles making it more effective lubricant. The only difference between synthetic and semi-synthetic fluids is that there is no oil present in synthetic cutting fluid.
Semi-synthetic fluids contain mineral oils of concentration varying between 10% and 50%, providing more lubrication than synthetic oils. Both the synthetic and semi-synthetic fluids show good cooling property as they have a low corrosion rate with low vulnerability for bacteria growth, lead to a decrease in irritation to the skin and odors.

**3.0 Advantage and Disadvantages of cutting fluid type**

| Type of cutting fluid | Advantages | Disadvantages |
|---|---|---|
| **Straight oil** | Excellent lubricity and rust control | Low cooling, fire hazard, create mist or smoke, limited to low-speed and heavy cutting operations |
| **Soluble oils** | Good lubricity and cooling | Rust control problems, bacterial growth, evaporation losses |
| **Semi synthetics** | Good cooling, rust control and microbial control | Foam easily, stability is affected by water hardness, and easily contaminated by other machine fluids |
| **Synthetics** | Excellent cooling, microbial control, non-flammable, non-smoking, good corrosion control, reduced misting and foaming problems | Poor lubricity and easily contaminated by other machine fluids |

**4.0 Application of cutting fluids**

| Type of oil | Appearance | Use | Dilution |
|---|---|---|---|
| **Neat/Straight Oils** | Oily, wastes | Heavy-duty Material, corrosion Inhibition | Not Required |
| **Soluble/ Emulsifiable Oils** | Milky colour, aqueous | Coolant and lubrication, corrosion inhibition | Yes,2-3% |
| **Semi-synthetic Oils, soluble** | Translucent | Coolant and Less Lubrication Than for Aqueous Oils | Yes,1-3% |
| **Synthetic Oils** | Transparent | Excellent Coolant, minimal Lubrication | Yes,1-5% |

**5.0 Emulsion Breakdown by using Electrolytes:**

An **electrolyte** is a substance that produces an electrically conducting solution when dissolved in a polar solvent, such as water. The dissolved electrolyte separates into cations and anions, which disperse uniformly through the solvent. If an electrical potential (voltage) is applied to such a solution, the cations of the solution would be drawn to the electrode that has an abundance of electrons, while the anions would be drawn to the electrode that has a deficit of electrons.

5.1 **List of some electrolytes:**

| **Electrolytes** | **Chemical formula** |
|---|---|
| Sodium chloride | NaCl |
| Copper sulphate | CuSO4 |
| Potassium chloride | KCl |
| Magnesium nitrate | $Mg(No_3)_2$ |
| Calcium chlorice | $CaCl_2$ |
| Lithium chloride | LiCl |
| Potassium carbonate | $K_2CO_3$ |
| Calcium carbonate | $CaCO_3$ |
| Sodium bicarbonate | $NaHCO_3$ |
| Ammonium acetate | $NH_4C_2H_{3O}2$ |
| Silver nitrate | $AgNO_3$ |
| Ferric chloride | $FeCl_3$ |
| Sodium nitrate | $NaNO_3$ |

The electrolytes which are used in the literature for breakdown of oily wastewater are NaCl, $CaCl_2$, $H_2SO_4$, $CuSO_4$, etc.

**5.2 Experimental process:**

In the experiment the apparatus used are:
1.emulsion, 2. glass electrode, 3. electrolyte solution, 4. stirrer, 5. geared motor, 6. level controller, 7. solenoid valve, 8. neon-sign transformer, 9. slid ax, 10. brass plate, 11. cylinder of acrylic resin (9 cm).
Emulsion phase was thoroughly mixed with the stirrer of acrylic resin which was set near the center of the vessel about 1 cm from the tip of glass electrode.

In this technique Electrolyte is used for the breakdown of waste by cutting fluid emulsion, by which reusing of recovered oil phase to develop new cutting fluids. The aqueous effluent observed after oil phase removal was characterized by turbidity, oil and grease content, pH, and presence of anions and cations. Additives were added to the recovered oil phase to obtain new cutting fluids. The physicochemical properties of these new cutting fluids were close to the ones of the initial ones, except for the viscosity values which increases.

To promote destabilization of cutting fluid emulsion, specific amount of aqueous solution of electrolyte were added with constant stirring for different time and at observed temperature is carried out. After stirring solution is allowed to settle for certain time. The breakdown of the emulsion is evaluated considering the concentration of electrolytes, temperature, time, and oil phase separation.

The aqueous phase obtained after emulsion breakdown was analyzed considering: turbidity, oil and grease content, pH, and presence of cations and anions. Turbidity is measured by using turbid meter. An infraclass TOG/TPH Analyzer was used to determine the oil-in water concentration. The pH was obtained by using pH meter. Anions were assessed by ions chromatography analysis. The recovered oil is analyzed considering the density, total acid number, viscosity, flash point and corrosiveness.

**6.0 Fenton's Process:**

Fenton's process is a solution of hydrogen peroxide and iron catalyst that is used to oxidize contaminants or wastewaters. Fenton's process can be used to destroy organic compounds such as trichloroethylene (TCE) and tetra-chloro ethylene (PCE).

$$(1)\ Fe^{2+} + H2O2 \rightarrow Fe^{3+} + OH\cdot + OH^{-}$$

$$(2)\ Fe^{3+} + H2O2 \rightarrow Fe^{2+} + OOH\cdot + H^{+}$$

- Ferrous Iron (II) is oxidized by hydrogen peroxide to ferric iron (III), a hydroxyl radical and a hydroxyl anion. Iron(III) is then reduced back to iron(II), a peroxide radical and a proton by Fenton's reagent is a powerful, non-selective oxidant.

- Oxidation of an organic compound by Fenton's reagent is rapid and exothermic (heat- producing) and results in the oxidation of contaminants to primarily carbon dioxide and water.

- Reaction (1) the presence of iron is truly catalytic and two molecules of hydrogen peroxide are converted into two hydroxyl radicals and water. The generated radicals then engage in secondary reactions. Iron (II) sulphate is a typical iron compound in Fenton's reagent. The exact mechanisms are debated (also non-OH· oxidizing mechanisms of organic compounds have been suggested) and, therefore, it may be appropriate to broadly discuss 'Fenton chemistry' rather than a 'Fenton reaction'.

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- Many metals have special oxygen transfer properties which improve the utility of hydrogen peroxide. By far, the most common of these is iron which, when used in the prescribed manner, results in the generation of highly reactive hydroxyl radicals.

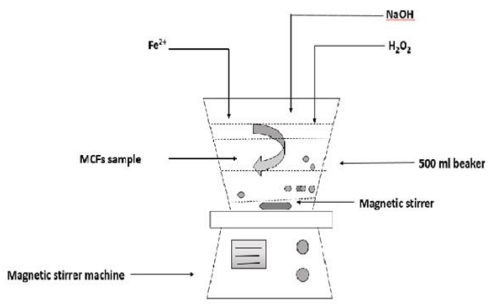
- Today, Fenton's Reagent is used to treat a variety of industrial wastes containing a range of toxic organic compounds. The process may be applied to wastewaters, sludge's, or contaminated soils, with the effects being:

1. Organic pollutant destruction
2. Toxicity reduction
3. Biodegrabality improvement
4. BOD / COD removal
5. Odour and color removal

**6.1 Experimental setup & Procedure:**

- Adjusting the wastewater to pH 3-5;
- Adding the iron catalyst (as a solution of $FeSO_4$); and

- Adding slowly the $H_2O_2$. If the pH is too high, the iron precipitates as Fe $(OH)_3$ and catalytically decomposes the $H_2O_2$ to oxygen -- potentially creating a hazardous situation.
- Reaction rates with Fenton's Reagent are generally limited by the rate of. OH generation (i.e., concentration of iron catalyst) and less so by the specific wastewater being treated. Typical Fe: $H_2O_2$ ratios are 1:5-10 wt/wt, though iron levels < 25-50 mg/L can require excessive reaction times (10-24 hours). This is particularly true where the oxidation products (organic acids) sequester the iron and remove it from the catalytic cycle. Fenton's Reagent is most effective as a pre-treatment tool, where COD's are >500mg/L
- In addition to free radical scavengers, the process is inhibited by (iron) chelants such as phosphates, EDTA, formaldehyde, and citric/oxalic acids. Because of the sensitivity of Fenton's Reagent to different wastewaters, it is recommended that the reaction always be characterized through laboratory treatability tests before proceeding to plant scale.




**Schematic diagram of Fenton's Process**

**7.0 Results**

In the first part of investigations, optimization of Fenton's reaction was carried out for the three types of MCFs like Synthetic, Semi-synthetic and Mineral cutting fluid. Different doses of $H_2O_2$, as well as concentration of $Fe^{2+}$ Ions and pH was reduced from 8-10 to 3-4 and residence time about 30 min.

### 7.1 Results of Lab Scale Experiment

| Types of MCFs | Dose | | Metal Cutting Fluid (COD mg/l) | | COD removal (%) |
|---|---|---|---|---|---|
| | $FeSO_4$ (ml) | $H_2O_2$ (ml) | Raw | After Fenton | |
| | | | | | |
| Synthetic MCFs | 20 | 30 | 72,000 | 23,000 | 68.06% |
| | 30 | 20 | 72,000 | 15,000 | 79.17% |
| | 30 | 30 | 72,000 | 17,000 | 76.39% |
| | | | | | |
| Semi Synthetic MCFs | 20 | 30 | 1,63,968 | 42,000 | 74.39% |
| | 30 | 20 | 1,63,968 | 27,000 | 83.53% |
| | 30 | 30 | 1,63,968 | 35,000 | 78.65% |
| | | | | | |
| Mineral MCFs | 20 | 30 | 61,600 | 31,000 | 49.68% |
| | 30 | 20 | 61,600 | 26,000 | 57.79% |
| | 30 | 30 | 61,600 | 29,000 | 52.92% |

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