<u>AN EUROPEAN UNION INCO-COPERNICUS NETWORK</u>

Sponsored by the Commission of the European Union
Project No: PL97 - 8058

TITLE:
Towards Ecologically Friendly Machining - "Ecofrim"

ADMINISTRATIVE COORDINATOR:
University of Bradford , UK - Prof A S Wronski

TECHNICAL COORDINATOR:
Pramet Šumperk, Czech Republic - P Peltan

PARTNERS:
VTT Manufacturing Technology, Espoo, Finland
SHM (Superhard materials), Šumperk, Czech Republic
Czech Technical University, Prague, Czech Republic
University of Limerick, Ireland
Institute of Metal Cutting (IOS), Krakow, Poland
Tekniker, Eibar, Spain,
Slovak Technical University, Trnava, Slovakia
Paramo, Pardubice, Czech Republic
University of Miskolc, Hungary

NETWORK PROCEEDINGS

"Technical solutions to decrease consumption of cutting fluids"

The First Seminar Workshop: Sobotin - Sumperk, Czech Republic
October 8 - 10, 1998
Organised by Pramet, Sumperk, Czech Republic

Edited by Pramet Sumperk

Ecofrim, an European Union INCO-COPERNICUS Network, has begun in October 1998 and will last till September 2001. Ecofrim is a acronym for “Towards ecologically friendly machining”.

Proceedings you are holding now in your hands, are based on First International Seminar of Ecofrim organised by Pramet Šumperk, Czech Republic. This workshop meeting was held in Sobotin castle near Šumperk during October 7 - 10, 1998.

All themes presented here are joint by a common topic expressed by title:

“Technical solutions to decrease consumption of cutting fluids”.

The individual papers were prepared by Ecofrim partners and submitted for subsequent publication using DTP. Papers were delivered to editors either by e-mail communication or on diskettes. Editors and Publisher are not responsible for the content and / or any deviation from oral presentations which the papers are based on.

We are grateful to prof A S Wronski for his overal assistance during and before Sobotin meeting and to ing Peter Beneš, managing director of Pramet for his support, interest and welcoming all partners. We also wish to remind the help of all member of organising committee and active attitude of the participants. The scientific atmosphere in Sobotin was nice and our thanks go to all involved.

Editors

(P.Remes, P.Peltan, T.Pieczonka)

......the environment is not something which can be ignored by business. The issue continues to grow in importance and widen in its ramifications. Failure to take appropriate action can be costly. Failure to incorporate the environment into business corporate strategy has ceased to be a choice. The effective use of a bona fide environment represents a potentially significant competitive advantage.

John Corrigan,
Irish Trade Board

List of participants

- **University of Bradford** .... Prof A.S. Wronski
- **University of Limerick** .... Dr G. Higgins
- **University of Miskolc** .... Dr I. Raisz
  Dr S. Bedo
- **Czech Technical University** .... Prof J. Madl
  Doc J. Sanovec
- **Slovak Technical University** .... Dr J. Peterka
  Dipl-Ing Stefanek
- **VTT Manufacturing Technology Espoo** .... Mr M. Saynatjoki
  Ms H. Tonteri
- **Tekniker Eibar** .... Mr J. Perez
- **IOS Krakow** .... Dr K. Musialek
  Mrs I. Pofelska-Filip
- **Paramo Pardubice** .... Dipl-Ing R. Lux
- **SHM Šumperk** .... RNDr P. Holubar
  RNDr M. Sima
- **Pramet Šumperk** .... Dipl-Ing P. Benes
  Dipl-Ing P. Peltan
  Dr T. Pieczonka
  Dipl-Ing J. Jandera
  Mgr D. Ficnarova
  Dr N. Ahmad
  Dipl-Ing M. Kotrly
  Mr P. Klapetek

Index of scientific papers

PREFACE

The overal objective of the Ecofrim (European Union Inco-Copernicus NETWORK, Sponsored by the Commission of the European Union) is to catch and keep the attention of industrialists concerning continued use of conventional cutting fluids in machining and to encourage remedial action to the benefit of the machine tool operators and the environment.

Ecofrim Network deals with reuse, recycling and disposal of existing cutting fluids, alternative fluids and dry machining. Participation of industrialists not in the Network is encouraged. All Ecofrim activities are aimed to the better living conditions and to preserve the nature for the future.

Network enables the exchange of experience and the newest scientific informations among engineers, operators, cutting fluid producers and other involved people working in EU and CCE countries.

International cooperation within Ecofrim can be considered also as an effective tool of the European integration in the field of the ecology. Environmental legislation of CCE countries ought to change to match main aspects of EU requirements. Ecofrim seminars organised by partners can be a significant contribution to this matters.

We hope that the readers of this Proceedings volume can discover here many themes useful in many respects of ecology.

P. Peltan

Chairman of the organising committee,
Pramet Šumperk

CUTTING FLUIDS - PROPERTIES REQUIRED FOR THEIR FUNCTION IN MACHINING

Matti Säynätjoki
VTT Manufacturing Technology
P.O.Box 1702
FIN-02044 VTT, Finland

Introduction

Cutting fluids are used in metal machining operations for increasing production rates. The main reasons for this increase are reduced tool costs, better quality of production and the possibility of using more effective production parameters. Suitable cutting fluids provide cost savings mainly due to longer tool life-times that reduce the number of tool-replacement operations. The better condition of the tools also increases the quality of products because tool wear and sudden tool failures often cause problems in the dimensions and surface finish of the work-pieces. The other mechanism affecting the quality of the products is the direct control of the workpiece surface temperature, which helps to maintain the high dimensional accuracy and good surface quality [1].

Function of the cutting fluids

The cutting fluids mainly affect the cutting process by forming a lubricating film in the contact zone between the tool and the workpiece and in the zone between the tool and the chip. Another equally important effect derives from the cooling of the tool and the workpiece.

These two main effects of the cutting fluids are present in all cutting processes, but their criticality for the overall result depends strongly on the nature of the cutting process. Especially cutting speed has proved to be an important factor determining the main mechanism. Cooling is important at high cutting speeds (above 60 m/min) for the reduction of the temperature of the chip-tool contact and thereby to reduce the crater wear of the tool which is temperature sensitive. Lubrication is the main affecting mechanism at low cutting speeds (below 15 m/min) and it works mainly by reducing chip compression, built-up edge formation, cutting forces and power consumption. [2,3]

When different cutting processes and workpiece materials are located in the map of cutting speeds and the mechanisms of cutting fluid action, one can say that cooling is generally important in the case of turning of easier materials, such as carbon steels or aluminium alloys, while lubrication is critical especially in the tapping of stainless steel or other strongly adhering materials.

The lubrication mechanism between the chip and the tool rake face has long been a continuous issue for discussion. A considerable effect of cutting fluid can be easily observed, but it is difficult to explain how the lubricant can get into the contact area between the chip and tool - which follows immediately after the virgin chip surface has been produced. One explanation is based on a contact length approach, which does not require fluid access to the chip interface [3,4]. According to this theory, intimate contact and full adhesion exist between chip material and tool, but the cutting fluid prevents further growth of the adhesion area with the result of reduced contact length between the chip and the tool compared to dry cutting. Friction force is also reduced because the apparent area of contact is almost the same as the real contact area.

Besides the action of the cutting fluid in the tool contact zones, it has also an important role, which is directly related to cutting process, in many cases in removing the chips from the cutting area as well as in binding and removing other dust-like and solid contamination produced in the cutting process.chined. Again the prevention of the microbial growth in the fluid has a crucial importance in this matter, because microbial corrosion is one important corrosion mechanism. In addition to this, it is beneficial if the fluid can protect the workpieces from undesired attacks from the environment. Cutting fluids should not be aggressive for the paints, glues or elastomers or other polymeric materials that are also important materials of the components of machine tools.

Fluid properties for cutting

The main affecting mechanisms of the cutting fluids may often be difficult to fulfil sufficiently with one general purpose fluid, because cooling and lubrication lay very different demands on the fluids.

Cooling capacity of the fluid is mainly dependent on the heat energy that is possible to remove from the tool and workpiece by the chips, surrounding and fluid. Fluids proportion of this depends of its capability to restore heat energy and to transport it away from the area where it has been created. Heat restoring capacity is dominated by the specific heat capacity of the fluid, which describes how much energy is needed to warm up a certain volume of fluid. Naturally it is beneficial to have as high a specific heat capacity as possible. Thus, water is a good liquid from this point of view. The other factor affecting the cooling is the heat transport. This is strongly dependent on the volume of the fluid in the cutting zone. The factors determining the fluid volume fed in the cutting process are the volumetric flow produced by the feeding pump and by direction of the fluid flow.

Lubricating characteristics of the cutting fluids are dominated by similar factors as the lubricating characteristics of other lubricants. The most important is the fluid's tendency to form a film separating two surfaces having relative motion between them. The film formation is mainly related to the chemical nature of the fluid, which dominates the chemical reactions between the fluid and the surfaces. The formation of these reaction layers has often a crucial importance in the tribological performance of materials. Many hydrocarbon chains, that are the base of the oils, have good characteristics that produce reaction layers on the metallic surfaces. The lubricating capability of the base oil is often improved by additives that improve film formation, especially in extremely demanding conditions.

Because of the functional characteristics of a general use cutting fluid differ very much from one operation to another, a combination of lubricating oil and cooling water produced as an oil-water emulsion has found to be a practical selection for a cutting fluid in many cases. This kind of emulsion contains over 90% of its volume water and the rest is concentrate that contains the lubricating oil, emulsifier, keeping oil as drops in water, and other additives that improve the fluid's lubricating and other properties.

Other properties

Because of the nature of their use, cutting fluids are always a part of the working environment. Thus they must fulfil health and occupational requirements general laid on industrial chemicals. The main possible endangering routes of the working personnel are breathing of fluid mist in the air and skin irritation, because of fluid residuals on the machined workpieces. Cutting fluids should not be toxic or harmful for the personnel or the environment. [5,6]

The requirement for non-toxicity may in some cases be in contradiction to another desired property of cutting fluids, namely long operational life time. This is mainly due to one important additive type, biocides, which prevent the bacterial growth in the fluid and can be classified as poisonous compounds. On the other hand the bacterial growth itself is harmful also for the working environment, because it spoils the quality of the air and may also have other unhealthy consequences [5,6].

Long life-time is important mainly from the economic point of view, because every time when the fluid is changed, the machine tool or machine tools in the case of centralized fluid system are out of operation and produce nothing. In addition, also the fluid concentrate costs, cleaning agent costs and the disposal costs for both the cutting fluid and cleaning media must be taken into account. Another important economic effect of the fluid life-time is the fluid's effect on the product quality. The longer a cutting fluid remains with its composition equal to the unused fluid, the longer probably it also retains its properties, which helps to keep also the production quality at a sufficient level. [5,6]

Another factor concerning the quality of the final products is the corrosion of the surfaces. It is clear that the cutting fluid must not cause corrosion of the tools, machine tools or materials that are machined. Again the prevention of the microbial growth in the fluid has a crucial importance in this matter, because microbial corrosion is one important corrosion mechanism. In addition to this, it is beneficial if the fluid can protect the workpieces from undesired attacks from the environment. Cutting fluids should not be aggressive for the paints, glues or elastomers or other polymeric materials that are also important materials of the components of machine tools.

Conclusions

Cutting fluids have a critical role in the productivity and economics of many metal machining processes.

In many cases the properties that are not directly connected to the performance in cutting may be critical for fluid selection because the properties affecting the working environment and product quality outside the cutting point.

Cutting fluids must fulfil requirements that often conflict with each other. Thus it is important to be able to compare new fluid candidates with the existing, in order to find fluids that both perform well in production and are ecologically and economically favourable.

References:

[1] Trent E. M., Metal cutting. Butterworths, London & Boston 1977, 203 p.
[2] Tipins V., Cutting tool wear. Wear Control Handbook, ASME, New York 1980, pp. 891-930.
[3] DeChiffre L., Metal cutting - mechanics and applications. Dr thesis, The Technical University of Denmark, Lyngby, Denmark 1990, 102p.
[4] DeChiffre L., Mechanics of metal cutting and cutting fluid action. Int. J. Mach. Tool Des. Res. 17(1977) 225-234.
[5] Bartz, W. J., Lubricants and environment, 1995.
[6] Hewstone, R. K., Environmental health aspects of lubricant additives. The Science of the Total Environment, 159, pp. 243-254.

GENERAL COMMENTS ON ECOLOGICAL AND DRY MACHINING

Ahmad Nasir
Pramet a.s., Uničovská 2, 787 53 Šumperk
Czech Republic

Term *Ecological* has to present the tendency towards harmonisation of production technologies with an accent on ecological aspect and green legislation. Machining (cutting) processes form a narrow segment in general manufacturing technological processes. Access towards the ecological balance means a novel task for managers, designers and process engineers, which is connected not only to the development and launching the new superior technologies but also by applying the present ones with productivity point of view.

From ecological point of view, within the cutting process, existence (application) of cutting fluids is of key importance. There is a close connection between ecological requirements and economical background as for as concerning technological compact of cutting fluids on environment. It is obvious here, that abstaining of cutting fluids seems to be costly, but the only way from the future perspective. In Czech Republic, where engineering industry is passing through deep quality reforms, the task approves to be more complicated due to different technological state. Next hindrance is of economical character of the individual subjects. It is necessary to achieve the goal through different approaches, in other words to apply the most economical way to get most ecological solution. Meanwhile it should be taken into account that introducing the basic ecological aspects to the technological processes including metalworking is one of the conditions to be fulfilled for joining the exclusive club of European Union (EU) Countries by the beginning of the third Millennium.

Basic characteristics of the cutting medium

Appropriate cutting medium enables to elevate the cutting efficiency and tool life, likewise acts favouring the generation of new surfaces (parts), specially in connection with their surface topography. From characteristic point of view, the cutting medium is mainly structured as presented in tab. 1.

DIVISION OF CUTTING MEDIUMS		
Group	**Sub-group 1**	**Sub-group 2**
Gaseous	**• Air** **• Inert gas** **• Fog**	
Liquids	**• Water solutions** **• Emulsions**	• Without EP additives • With EP additives • Special • Semi-synthetic • Synthetic
Liquids	**• Oils**	• Oils • Minerals • Cutting • Cutting with EP additives • Concentrates of high-pressure additives • Synthetic liquids
Solid lubricants		

Tab. 1 Generic division of existing cutting mediums

Within the technological practice, application of cutting fluids play a key role. That is why, some of the general consequences and practical evidences would be directed to the sub-group *emulsions*.

Requirement set on cutting fluids

The main motive for the development of cutting fluids and their application were requirements defined by the own technological process. These could be formulated as follows:

- *Cooling effect* - Heat removal from the place of its generation and its redistribution into tool, workpiece, chip and environment. Cooling effect depends not only upon structure and properties of the fluid but also other characteristics like quantity, speed and type of flowing, temperature, and point of application, etc.

- *Lubricating effect* - This is the elimination of conditions generating mechanism of dry friction between contact surfaces. As a result, there minimises the wear rate at the contact surfaces. For the formation of an effective lubricating layer on the rake and clearance surfaces, it is necessary to secure the penetration of the fluid with a high pressure. Under specific cutting conditions, there is applied absorption and suction effect.

- *Cutting effect* - It is explained by so-called Rebinder effect. Cutting fluid penetrates into micro cracks on the machined surface and hence enables easier formation of chips.

- *Anti built-up-edge effect* – In fact removing or stabilising the built-up-edge results into its positive safety effect. It is primary to prevent breakage of the non-stable part of built-up-edge, mainly at lower speeds and temperatures.

- *Cleaning effect* - It is required that the cutting fluid would remove the chips from the area of their formation and keeps the technological area clean.

- *Protection effect* - Beside the direct effect on cutting process, there is required also anti-corrosion effect on the workpiece and the tool.

Of course no cutting fluid fulfils the all requirements perfectly. Any how it is indispensable to fulfil certain packet of requirements, those secure the productive cutting process with expected quality characteristics. It means there should be defined specific priorities for certain application fields. From this point of view, the fluids can be divided into *wide application* or *narrow application* ones applied at specific operations. In fig. 1 there are exposed requirements of specific machining operations from the cooling and lubricating effect point of view.

To the technological requirements resulted from the essence of the cutting process are added others, those cannot be neglected. First of all, cutting fluids should be thrifty to humans from dermatology or lungs point of view. Further condition is operational stability and long term durability and finally ecological and economical liquidation of the remains. Control of fluids should be easiest and secure.

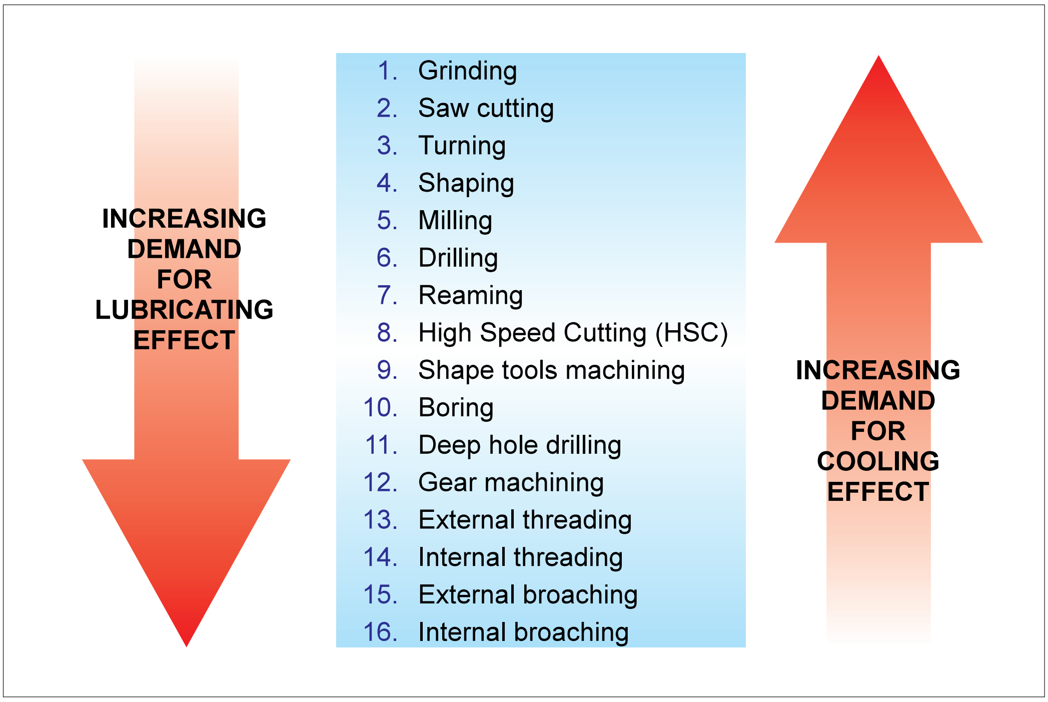


Fig. 1 Succession of machining operations from the cooling and lubricating requirement point of view

Current tools of ecological cutting processes

Higher degree of harmony with ecological requirements can be acquired through gradual steps or considerable one (by investing). Its realisation and speed will effect mainly technological preparation of the company, specific manufacturing programme and its capital equipment. At this moment, there can be characterised following approaches reducing ecological impact affected by cutting fluids in machining.

- **New cutting fluids** with higher application properties and lower risks from pollution point of view within the processor at liquidation. In sub-group *emulsions* there is gradual transition from petroleum based products to semi-synthetic or synthetic products. In case of oils, one of the way is application of vegetable based oils or for higher performances can be applied synthetic polyglycol based fluids.

- **System MQL** (Minimum Quantity Liquid) directs on minimisation of the applied cutting fluid in form of a soft mixture.

- **Attendance and monitoring the cutting fluids** and process. Development and implementation method securing the long term stability of the fluid quality. Changes could be controlled by sophisticated diagnostic and record systems. Higher type of monitoring system includes controlling and evaluation of surrounding equipment's.

- **Dry machining** represents procedures, those exclude the influence of cutting fluids from the process. The philosophy is discussed in a separate paragraph.

- **Introducing certification** including ecological to the manufacturing and development organisations.

Said approaches are not the only possible ones. But certainly, their application and following will highlight transition to EURO standards in the phase of compatible legislation and practices of the EU countries. To further elements of ecologisation can be added systematic education in the field, new liquidation methods and improving new cutting fluids or their appropriate application with respect to the technology and conditions.

Dry machining

The concept was accepted in the beginning of cutting process and practically is applied up-today while milling on conventional machine tools. Technological development of NC machining centres led into higher use of cutting fluids even in interrupt machining. Recently there are introduced so called high pressure emulsion cooling enabling even higher operation performances.

Gradual come back of *Dry machining* philosophy came into existence just due to pragmatic reasons:

- Legislation has forced manufacturers, mainly in EU countries, to behave ecologically friendly, which led into higher prices of the products. It is basically legal reaction against requirements "continuous development ", which is of global character.

- Cost share of cutting fluids is about 15% out of whole costs to machine a part. As for as concerning field like automobile industry (see fig. 2). It could be affected too by lobby of heat resistant tool makers like ceramics.

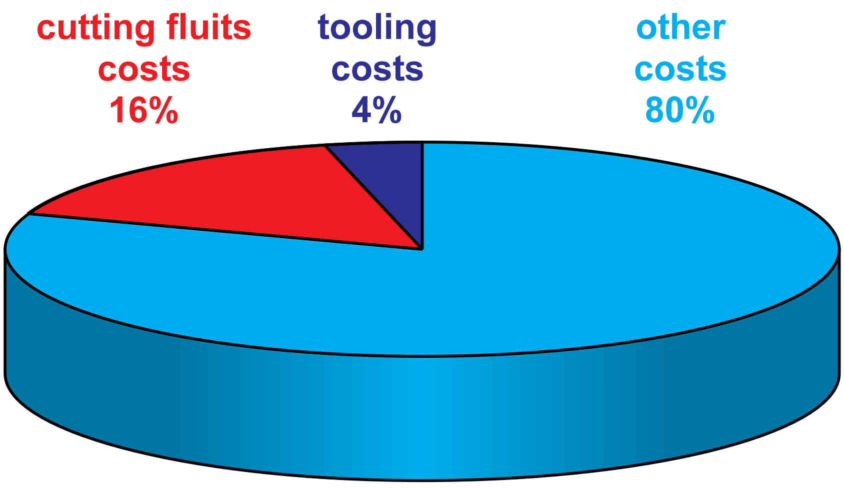


Fig. 2 Cost share for machining the pert in automobile industry (source: Daimler Benz)

It is possible to apply this simple philosophy without decreasing the level of current productivity, which is set to be as starting from dry machining point of view. Which is acceptable according to current knowledge in the field, but under certain presumptions. This paper aims to verify mainly technological presumptions having in mind legal, ecological and social dimensions. Only their fulfilment means solution of the whole complex and interconnected problems:

- **Elevation of stability of current tool materials to higher temperatures** Means to prepare chemically, structurally and technologically new material systems with stability limiting to 1200 to 1300 °C. Industrial application of these materials is expected in first half of 21st century. Among current material systems PVD coated Cermets are referred to be acceptable for dry machining (see fig. 3 [2]).

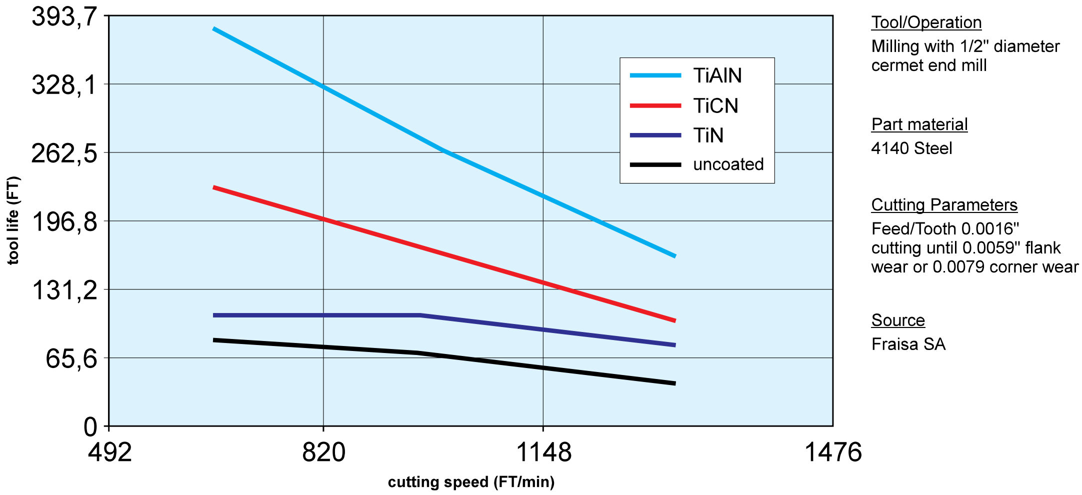


Fig. 3 Taylor's relation for PVD coated Cermets for milling operations without cooling

Decreasing the energetical demands of the cutting process affecting the heat emerging sources There comes into mind application of significant positive geometry's in new material grades. It seams to be easier from for consumption. Without the application of new materials high positive geometry's would not be enough effective.

- **Application of non-cutting principles of parts production** Unfortunately much of current non-cutting manufacturing technologies cannot be applied without the use of lubricants. Certain exceptions are laser, water stream and electroerosive machining technologies where are applied certain technological fluids.

- **Suggesting new ecological inert gas or solid medium applying in conditions of minimum depth of cut** It is a very important area machining with increasing share due to the near-net shape technology.

- **Replenishing machining tools with new controlling and regulating systems** These enable controlling and directing higher heat impacts in the process of dry machining.

It is obvious from the discussed problems that actual technological situations are not as simple as they seems to be, due to the long term, complicated and investment reasons. It would be easier to monitor the issue from the legal, technological development and social aspects point of view. There is essential an international (global) co-operation and knowledge exchange with in ECOFRIM like projects.

References :

[1] ARNOLD, D.B.: Cutting Tools into the Early 21st Century. Proc. "Second International Conf. and Ex.", GAMI, Atlanta, USA, March 1996.
[2] BALZERS Tool Coating, Inc. : Use of Thin Film Wear Resistance Coating Cutting Tools. Proc. "Second International Conf. and Ex." GAMI, Atlanta, USA, March 1996.
[3] MING-SHOW WONG – SPROUL, W. D. – BARNETT, S. A. – CHUNG, Y. W.: Development of Hard and Superhard Coatings for Cutting Tool Applications. Proc. "Second International Conf. and Ex.", GAMI, Atlanta, USA, March 1996.

CONSUMPTION OF CUTTING FLUIDS AND RESULTING ENVIRONMENTAL TRENDS

Madl J.
Faculty of Mechanical Engineering, Czech Technical University, Prague, Czech Republic

Key words : machining, environment, cutting fluids, consumption, environmental trends

Introduction

In manufacturing technology auxiliary technological fluids are applied. These fluids are mostly used in material removal processes (cutting fluids are applied). The consumption of cutting fluids is enormous. There are many economical and environmental problems in the use, maintenance and disposal of traditional cutting fluids. World-wide environmental trends call for changes in manufacturing technology. Cutting fluids represent one of the main environmental problems in production.

1. Consumption of cutting fluids

Cutting fluids are an important component of the machining process. They influence economic and quantitative results. It has been known for many years that certain fluids may improve the machining process. In some cases proper cutting fluids may increase economical removal rate from 50 to 100 %, sometimes even more. In fact, some machining operations are impossible to accomplish without cutting fluids.

Cutting fluids are the most important environmental factor in manufacturing. There is a large range of cutting fluids in use. Reduction or substitution of traditional environmental non-friendly cutting fluids by new environmental ones is one of the main tasks of current manufacturing technology. There is a considerable consumption of cutting fluids in manufacturing. For example Fig. 1 shows the consumption of fluids in Germany in 1994.

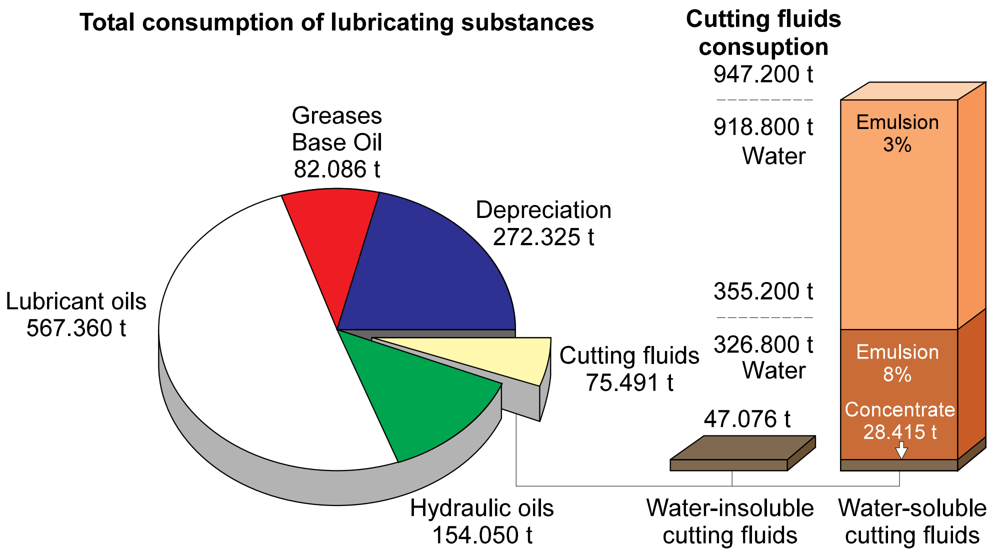


Fig. 1. Consumption of fluids in Germany in 1994.

2. Requirements on cutting fluids

The primary objective of machining operations is to produce a workpiece within some tolerance of dimensional accuracy and surface finish and at minimal cost.

Cutting fluids should primarily provide good cooling and lubrication, but there are a number of other effects that assist in achieving the good results. Machining process can by improved by:

- increasing tool life
- improving the surface finish
- reducing deformation in chip formation
- reducing cutting forces and power consumption
- reducing distortion due to temperature rise in the workpiece
- facilitating removal of chips
- preventing formation of a built-up edge
- minimising minimum chip thickness
- influencing or reducing residual stresses on the workpiece surface
- influencing or reducing work hardening on the workpiece surface

There are a number of other requirements, including environmental, which must be taken into account when applying a cutting fluid. The cutting fluid:

- must not produce unpleasant side effects like allergic reactions and smells
- must not foam in applying with high pressure equipment
- must not cause corrosion of the workpiece
- must not affect the coating on the machine tool
- must not corrode machine tool components and seals on the machine tool
- must not cling or stick causing chips and particles to become attached
- should be able to dissolve leakage oil without its performance deteriorating

It is difficult to find the proper cutting fluid for the above mentioned effects and requirements. Some additives may by used to improve their properties. Especially for low cutting speeds extreme-pressure (E.P.) additives are used.

The major group of E.P. fluids in practical use are traditional mineral oils with added sulphides and chlorides. Sulphides can be added to oils in the form of chemical compounds that do not decompose until they reach high temperatures. It is usual to blend sulphurized and chlorinated oils. The two elements are active at different temperatures. The cutting fluid is active over a wide range of cutting speeds.

In the extreme-pressure fluids group there are also chemical compounds such as carbon tetrachloride. Theses are mostly toxic and are of limited practical use.By far the most common of all cutting fluids in use are the oil-in-water emulsions. These are used primarily as coolants. Some emulsions can contain chloride or sulphide additives to provide some friction-reducing properties.

Some cutting fluids are basically water with small proportion of inorganic additives for rust prevention. They include additives such as amines, nitrite and others.

Used cutting oils and oil emulsions must not be released into the public sewage system. Emulsions are treated so that water and oil are separated. The oil that is separated is strongly contaminated by the additives. Waste disposal is not simple and is usually expensive.

3. Production costs related to cutting fluid consumption

Costs related to cutting fluids in production process may by very high. Figs 2 and 3 show two different examples of cutting fluids costs. In case of central device cutting fluids costs are 7-17% of production costs. They are higher than tool costs (2-4%), see Fig.2. It should also be noted that, as shown in Fig. 3, costs associated with cutting fluids may differ within a given group of individual machine tools.

It is obvious that costs structure may differ in different machining processes.

4. Environmental trends in manufacturing related to cutting fluids

Traditional cutting fluid are based upon a mineral oil and may contain (oil emulsion as well) non-environmental components. Substitution of these cutting fluids is difficult. But there are still alternative environmental cutting fluids on the market. Substitution of traditional cutting fluids is not the only way to environmental machining. The main environmental trends in machining processes are as follows.

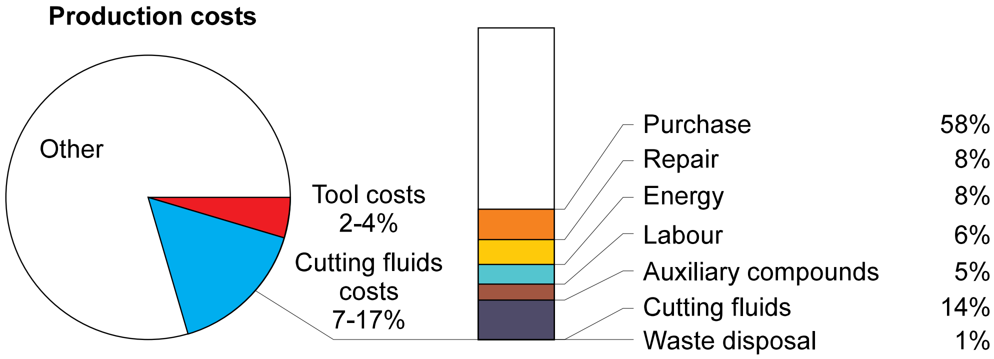


Fig.2. Cutting fluids costs in case of central cutting fluid device
(Mercedes-Benz, Volkswagen)

Dry machining

In dry machining we try to eliminate the use of cutting fluids, reduce the costs for their maintenance, filtering and recycling, and eliminate their purchase cost. One of the main effects of cutting fluids is cooling, so in dry machining cooling becomes a problem. Cooling may increase tool life (decrease tool wear), facilitate chip formation, reduce residual stresses etc. But dry machining may have positive effect as well. For example, it may prevent thermal shock in intermittent cutting, or in machining with ceramic cutting tools.

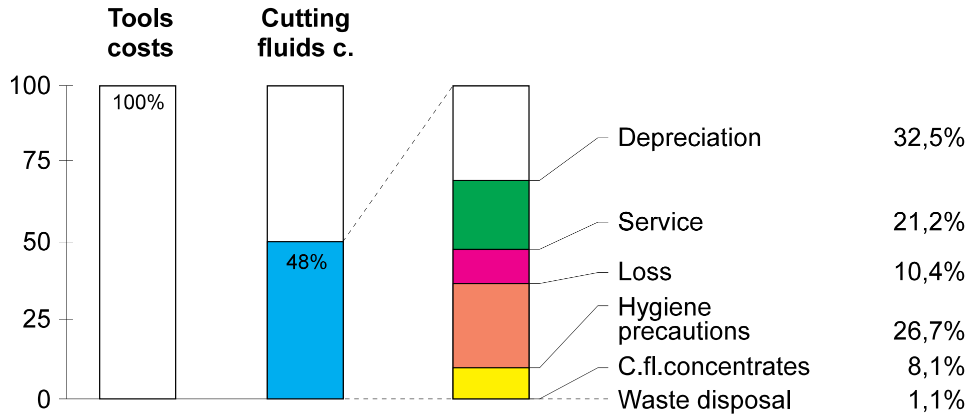


Fig.3. Cutting fluids costs in case of machining within a group of individual machine tools (Lauscher)

Cutting fluid reduction

Many machining processes are impossible to accomplish without a cutting fluid. In grinding for example considerable amount of heat is generated in the cutting process. To prevent structural damage the cooling effect is very important. Besides of the usually difficult elimination of cutting fluids, quasi dry machining is applied, leaving a reduced amount of cutting fluid for lubrication and reduction of friction forces acting between the cutting and machined materials. The volume of cutting fluids has been reduced up to sixty thousand times. Special devices for low quantity of cutting fluid application are shown in Fig.4.

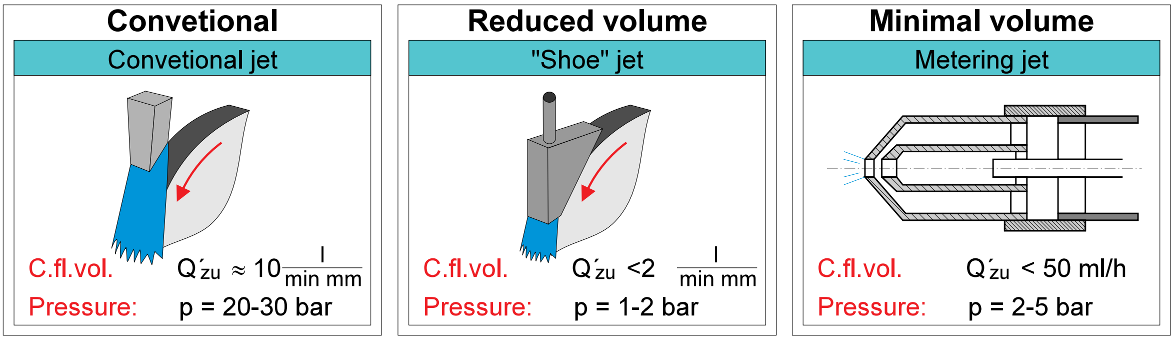


Fig.4. Special devices for use with low quantity of cutting fluid application.
(Source: Aachener Werkzeugmaschinen Kolloquium 1966)

Cutting fluids substitution

Traditional cutting oil base is mineral oil. Both mineral cutting oils and cutting emulsions as well may contain unhealthy substances (e. g. sulphides and chlorides). For that reasons new environmental cutting fluids are produced (e. g. rape base cutting oil). For example cutting fluids free of sulphur and chlorine, and cutting fluids based on vegetable oil

Multifunctional oils

Multifunctional oils may be used as cutting fluids (e. g. hydraulic oil and lubricating oil of machine tools). To design these oils is not simple and will depend upon future research.

Cutting fluids generating little emissions

Emissions are generated on the workpiece or the cutting tool (due to high peripheral velocity, high temperature of the workpiece, cutting tool and chip). New fluids are therefore applied, e. g. esters, which minimize these emissions.

Substitution of cutting oils for cutting emulsions

Cutting fluids based on mineral oil present special environmental problems. Waste disposal is difficult and expensive. For that reason one of the environmental trends is substitution of cutting oils by cutting emulsions.

Technological processes substitution

Some of processes may be accomplished by non-traditional means. For instance, grinding may be replaced by fine turning with ceramics, diamond and CBN. CBN is the second material after diamond in hardness but, by comparison with diamond, it keeps its hardness up to much higher temperatures (as high as 2000 Celsius), surpassing the melting temperature of steels. CBN also has much higher resistance against mechanical and thermal shock.

So called hard machining means cutting of very hard materials (e. g. hardened steels) by tools with a definite shape of the cutting edge. This process replaces grinding.

5. Conclusion

Consumption of miner oil based cutting fluids is enormous. Environmental world-wide trends in manufacturing technology must be considered not only in the context of solving individual technological problems, but they ought to be considered as a strategy of the enterprise for the future.

INFLUENCE OF LUBRICANTS ON THE SHEET METAL FORMING PROCESS

Jan Šanovec, Petr Kábrt, Karel Cajthaml
Division of Forming, Casing and Welding
Dept. of Manufacturing Technology, Faculty of Mechanical Engineering,
Czech Technical University, Technická 4, 166 07 Praha 6
Czech Republic

Key words: lubricant, deep drawing, draw bead, detail

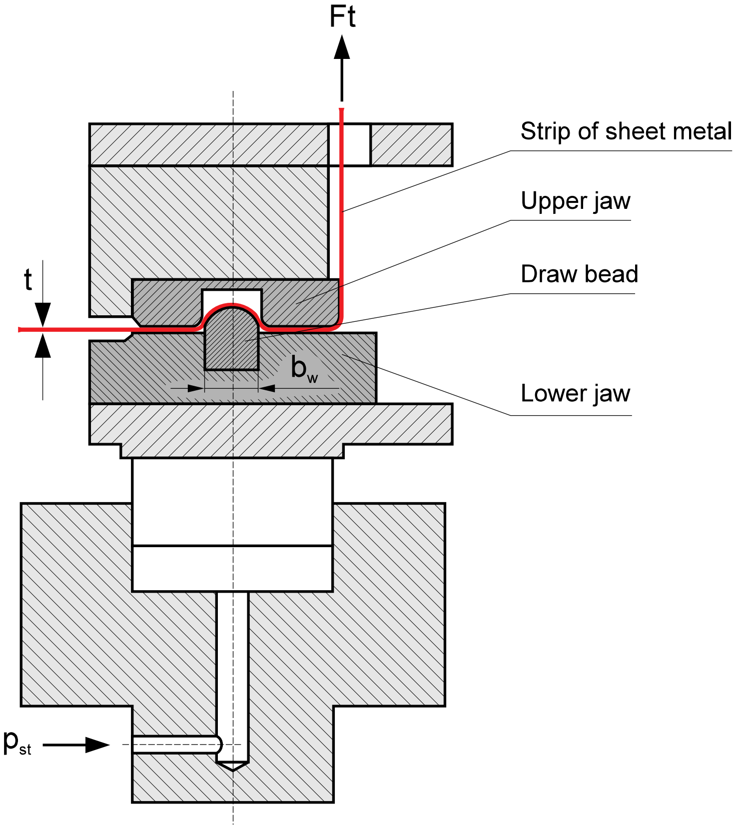
In the process of deep drawn stamping, many different types of lubricants are used. They have to be choosen individually for each technological detail, because there are several factors which may affect the interaction between lubricant and details. The lubricants are strained as much in the deep drawing process as are the drawn shell and instrument surfaces. Lubricants are also subject to chemical stress. Since they must be reliable, they should be choosen as carefully as the tool material. So the engineer needs an extensive knowledge of lubricant properties and their working conditions.

Which lubricant to use? This is not an easy question to answer. There are many methods for evaluating lubricant qualities. Each methods give different results, and each has advantages and disadvantages. Let me tell you something about our method.

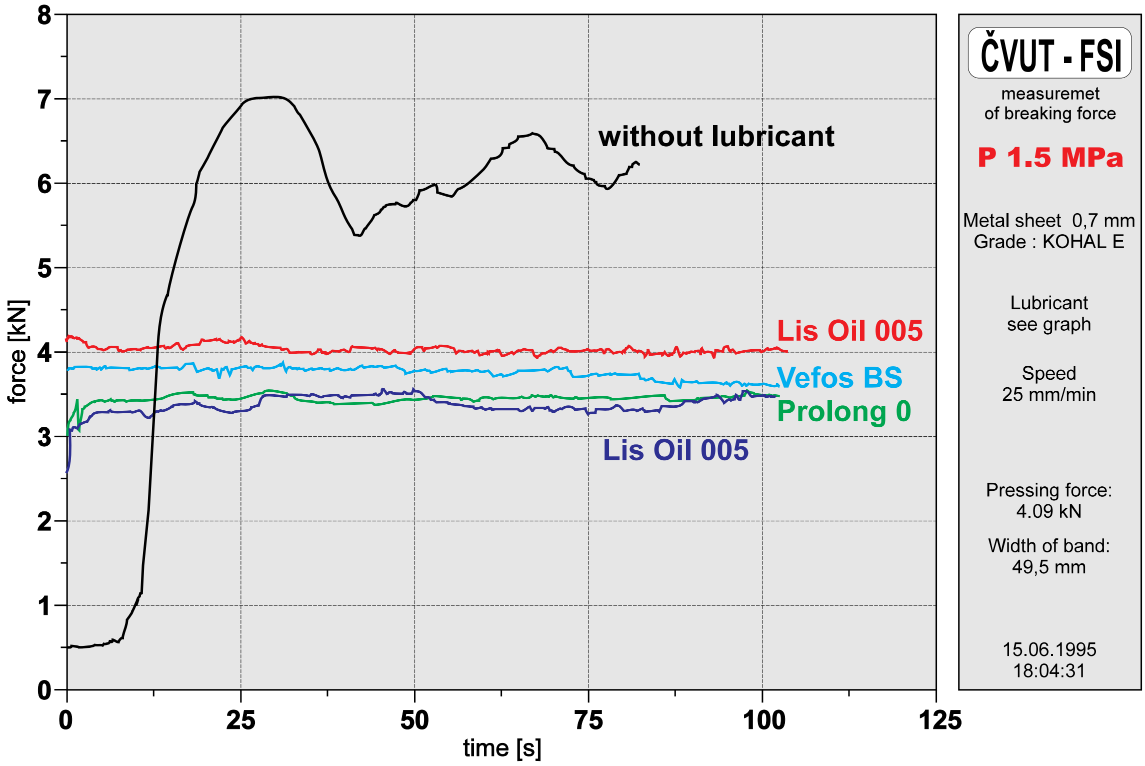
The following lubricants were choosen for testing:

Vefos BS, Prolong 0, Lis Oil 005 and Lis Oil 006. All are products of the firm Triga.

We also made measurements of drawing without any lubricant and measurements of drawing with a polyethylene sheet. All measurements were made using a device which was especially designed for this purpose. A simple jig was developed to measure brake force between flat and profiled dies, Fig.1. Later a new jig was designed to measure brake force with two draw beads [1], [3]. In this later device, centres of the draw beads are at distance 16,3 mm from each other. Braking was induced by an additional hydraulic device equipped with a pressure guage.



Sheet-steel strips were gradually drawn and bent between a movable jaw and a fixed jaw. The sheet-steel strip was finally bent 90°. The end of the sheet-steel strip was fixed in a special collet. The steel collet was fixed to a tearing machine. Measuring itself was acomplished on a ZDM tearing machine. Nevertheless this method was not entirely successful. So all final data was taken using this new method. With the new method, drawing force was measured using a tube with tensometers. All data were entered into a PC which was then used to produce the graphs (Fig.2). Measured results are drawing forces for different lubricants and for different holding forces. The metal sheet position during the measurement was also scanned. Initial conditions were the same for every measurement : Sheet metal Kohal E was used. Its thickness was 0,7 mm and its width was 49,5 mm. Drawing speed was 25 mm.min^{-1}. Following facts were determined by these experiments. Practical results you can see on Fig.2.



It is clear from this analysis that the tested lubricant giving the least friction was Lis Oil 006 (except polyethylen sheet - which was only for one value of holding force). For all holding forces tested lubricant Lis Oil 006 consistently gives lower friction. However, with these other holding forces, the order of other tested lubricant changes. This effect can be caused by the fact, that drawing takes place under extreme conditions friction. Between planes there is a very thin critical layer of lubricant (approx. 0,1 mm). The intermolecular forces influence the layer. So that it isn't controlled by hydraulic laws.

It should be noted, that before we choose a lubricant for deep drawing we must test many lubricants. The tests must be done under practical manufacturing conditions.

References :

[1] Žák, O.: Metodika zjišťování mazacích účinků na bázi ropných a neropných mazadel, diplomová práce ČVUT, 1990.
[2] Lange, K., Gräbener, Th.: Projekt BMFT Förderung Tribologie, 1980-1983, 235-271.
[3] Doege, E., Witthüser, P., Grahnert, R.: Projekt BMFT Förderung Tribologie, 1978-1981, 551-575.

CUTTING FLUIDS DISPOSAL AND SOME POSSIBILITIES OF THE NEUTRALIZATION OF USED CUTTING FLUIDS PRODUCED ON A BASE OF THE MINERAL OIL

K. Musialek, W. Polowski, I. Pofelska-Filip
Instytut Obróbki Skrawaniem, Kraków, Poland

Abstract

State-of-the art of the cutting fluid disposal problem is presented. Some methods of disposal of coolant wastes are described. Special attention is paid to the Rotresel neutralization method, which is as a reasonably cheap one-step disposal process that may be especially useful for small and medium enterprises (SMEs).

Key words: cutting fluid, disposal, neutralization, coolant, waste

1. Introduction.

The problem of utilization and neutralization of cutting fluids becomes more and more important due to the continued increase in the use of cutting fluids and pollution of the environment. All the EU countries have very strict ecological legislation. All companies, large and small, must obey it. To meet all the necessary requirements they must incur all necessary costs. The costs of disposal of the cutting fluids at 700 ECU / ton in Germany is 4 times higher than the cutting tool costs [1]. Such expenditure is not considered economically realistic by CCE countries where even the existing legislation is not strictly enforced by SMEs. This must be changed before CCE countries can enter EU. It is estimated that some millions of cubic meters of cutting fluids a year are used in Poland and quite a lot of used cutting fluids are drained and let into the natural water. Such large amounts of used cutting fluids are very dangerous to the natural environment. They pollute underground and superficial water by hydrocarbons that do not decompose and are a risk for biological life and health of the population, especially in industrial regions. To help the situation in CCE countries, a new, relatively cheap method of fluid treatment and disposal should be developed and applied. Existing methods of treatment cost up to 400 ECU / ton [1] and a method developed by IOS, which is substantially cheaper (some 100 ECU / ton), is now being tested.

Used oil-based fluids are to some extent collected and regenerated, but the majority of used cutting fluids presumably is disposed as trade wastes. They are severely contaminated by metallic fines, because they are usually exploited for a long time and they keep a lot of suspended solids e.g. metallic fines, rust and abrasive particles.

It should be mentioned that 1m^3 of the oil emulsion of 5% dissipation causes degradation of about 50,000 m^3 of water, making this water unsuitable for consumption. At the same time some

1000 m^3 of water are polluted up to the allowable oil contents in the trade wastes (50g/m^3), according to the relevant administrative regulations. Oil-based emulsions used only in automotive industry are able to devastate 40% of the water in Polish rivers. Due to Environmental Protection Agency (EPA) and Occupational Safety and Health Administration (OSHA) - laws regulating coolant and lubricant manufacturing were enacted in the USA [2]. Manufacturers today must look at the whole process, worker health and safety issues, the application, age and the requirements of the equipment, metallurgy of the workpiece, environmental concerns, and the treatability of the wastes generated [3]. New generation of fluids is operator and environment safe and meets to-day‘s productivity demands. New soluble - oil formulations also contain EPA - approved odour - counteractants that provide virtually unlimited sump life. Advanced soluble oils do not corrode ferrous steels and cast irons, nor do they stain brass, copper and other nonferrous materials. This permits the same coolant to be used plantwide for all types of operations and metals [2, 3]. Properly maintained, users can recycle modern soluble oils almost indefinitely. The only trade - waste cost incurred is from tramp oil, which should be removed frequently. Disposal of cutting fluids depends on the fluid type. It was believed that in the case of the high quality synthetic fluids after contaminants were removed, fluids could be safely dumped into most sanitary sewer systems. Later the opinion was presented that synthetic coolants are far more difficult to dispose [4]. Synthetics are composed largely of water - soluble organic materials that do not respond to conventional waste - treatment methods. After processing, these organics leave high biological oxygen demand (BOD)/ chemical oxygen demand (COD) levels in the effluent that can be subject to heavy surcharges imposed by local sewage treatments facilities [4]. Nevertheless of all improvements, oil-based emulsions have to be replaced with fresh ones after certain time because their functional properties deteriorate as a result of the ageing process, reproduction and growth of microorganisms (bacteria, fungi, yeasts). But oil based emulsion cannot be disposed unless properly treated. When disposing of spent coolant in the USA, users are advised to work closely with the coolant supplier and EPA to assure that all requirements are met [2-5].

Compared with other European Union countries, the UK was slow to adopt environmentally - friendly practices, but the situation has recently improved. The costs of coolant disposal in the UK are on average 10p per litre - and 2.5 million gallons of water based cutting fluids are disposed every month. This coolant disposal price is significantly lower than for Germany and Scandinavia, where 40p per litre is common, because their regulations are more stringent [6]. Spent coolant comprises a large percentage of most plants’ trade waste, so every metalworking facility’s goal today is to have zero trade waste taken away. There is a real need for coolants’ recycling being the essential point of coolant management (CM) programmes that are very different in case of SMEs and large companies [3-5].

Neutralization (final treatment to make fluid neutral to the environment) and utilization costs of the used oil-based emulsions are increasing permanently also in CCE countries because the environment law regulations become more severe and also due to development of manufacturing processes. Some simple methods of coolants’ neutralization are described below including Rotresel method worked out at IOS [7,8].

2. Used cutting fluid disposal techniques

There are two simple methods of purification treatment of the used oil-based cutting fluids:

a) First method consists in cleaning of used fluid by filtration, setting (sedimentation) or centrifugation or either by a combination of all these processes. After removing the solid state impurities, the fluid is ready for recycling (reuse). The fluid should be mixed with the fresh oil emulsion in proportion 1:2, before it is reused. Such a cleaned oil should not be mixed with liquid oil of different type, because of the possibility of the antagonistic action of their components.

b) Second method is based on heating the liquid oil at a temperature of 80^{o}C for 30 minutes. Besides the segregation of solids the significant neutralization of microorganisms present in the oil takes place. The oil after neutralization can be used again, even without additions of fresh oil, but its exploitation time will be shorter in comparison to the fresh oil coolant.

Utilization of the used water-soluble and emulsion cutting fluids is a very difficult problem. Frequently used cutting fluids are not collected and are removed simply to sewage systems without any neutralization. This is a very dangerous situation in respect of municipal wastes and biological life of the natural waters and soil.

Neutralization of the used water-soluble and emulsion cutting fluids.

To protect the environment the neutralization of used cutting fluids should be performed without any exception. Neutralization consists in separating the oils and harmful chemical compounds – components of the fluid or products of the decomposition from the water. Methods of the oil phase separation from the water phase of the emulsion cutting fluids are presented in Table 1. The methods of the used cutting fluids neutralization in the end users' plants are given in Table 2.

Method	**Range of application**
Settling (sedimentation)	Oils separation when their contents is above 500 mg/l
Mechanical	Separation of alien oils
Chemical	Emulsion breaking-up to clean waste water
Coagulation	Colloid impurities separation during cleaning waste water
Flotation	Emulsion phases separation
Electrochemical	Separation of stable emulsions in oil, to obtain technical water and oil phase suitable for regeneration
Sorptive	Emulsion separation to obtain cleaned water
Membrane	Emulsion phases separation to obtain water and oil possible for use
Thermic	Emulsion separation to obtain cleaned water and oil phase that can be utilized

Table 1. Methods of separation of emulsion cutting fluids.

Several novel methods of emulsion breaking-up have been developed recently.

At the Institute of Metal Cutting the electrostatic-electrolytic method of the used oil emulsions breaking-up was developed and RESEL and ROTRESEL units were designed and made (Fig. 1). In this method droplets that are ionized in electrostatic field, are deposited on the electrode surface. Due to absorption and coagulation processes, the oil phase lighter than water is formed. This oil is saturated with gases (oxygen and hydrogen) so it flows-out on the liquid surface, separating from the water phase. Oil phase contains a certain amount of dispersed water ("inverse emulsion") that depends on the kind of emulsion and a degree of contamination with macro- and micro-chips (metallic fines) coming from the cutting process. In connection with the above it would be advisable to pre-filer the used emulsion.

Utilized product	**Possible application**	**Carrying out the utilization**
Oil (liquid oil, alien oils, oil obtained after emulsion separation)	Fuel	Addition to liquid fuel and to coal
	Technological lubricants (e.g. in metal working process)	Separation of water and solid state impurities and additions to the clean oils
	Conservation of mettles	Separation of solid state impurities and water putting in thickeners and additions (e.g. graphite, MoS_2)
	Basic component of polish-ing pastes	
Emulsions	Quenching liquids	Separation of solid state impurities and water, putting in additions
Emulsion and water diluted cutting fluids	Cleaning (washing) solutions	Separation of solid state impurities and composition control
Residues of cutting fluids (slimes)	Components of grinding paste	Cleaning granulometric sorting, putting in thicking substance and softeners
	Material used in Powder Metallurgy	Cleaning granulometric sorting, addi-tions of metal powders, pressing and sintering

Table 2. Utilization of used cutting fluids at the end-user plant.

Several novel methods of breaking-up of emulsions have been developed recently.

At the Institute of Metal Cutting the electrostatic-electrolytic method of breaking-up of the used oil emulsions was developed and RESEL and ROTRESEL units were designed and made (Fig. 1). In this method droplets that are ionized in electrostatic field, are deposited on the electrode surface. Due to absorption and coagulation processes, a lighter than water oil phase is formed. This oil is saturated with gases (oxygen and hydrogen), so it flows-out on the liquid surface, separating from the water phase. The oil phase contains a certain amount of dispersed water (“inverse emulsion”) that depends on the kind of emulsion and a degree of contamination with macro- and micro-chips (metallic fines) coming from the cutting process. In connection with the above, it would be advisable to pre-filter the used emulsion.

Water phase coming from the broken-up emulsion may be run out to the sewage or undergo further cleaning if it is necessary because of any special contamination (e.g. heavy metals). Oil phase goes through filters. After it is dried, it can be either burnt or used. To break-up $1m^3$ of emulsion some 20-25 kWh of electric energy is needed. Total cost of breaking-up the emulsion using ROTRESEL unit averages 12 – 15 ECU per $1m^3$ of neutralized machine tool cutting fluid.

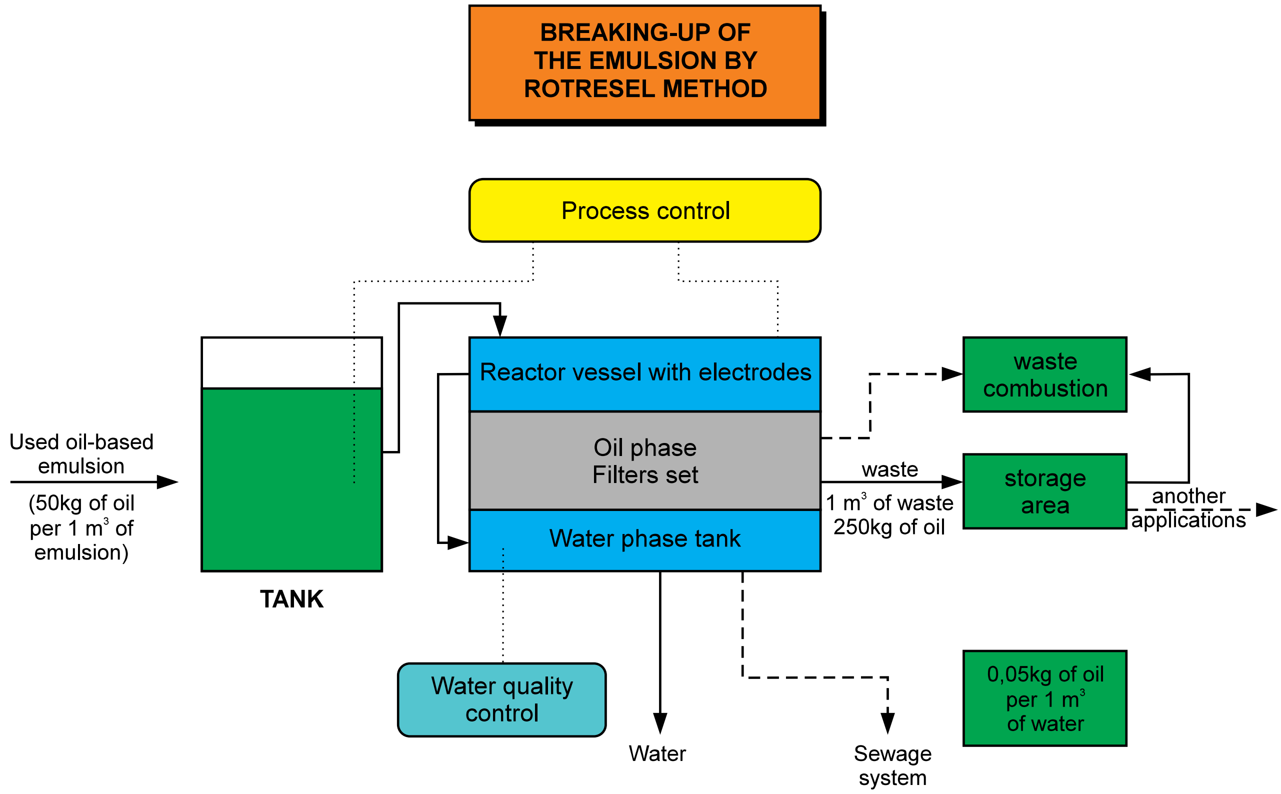


Fig. 1 Block diagram of the ROTRESEL unit

Characteristic features of the ROTRESEL method

ROTRESEL method is an ecological technology in comparison with chemical methods using strong basic or acidic compounds and also with physical-mechanical methods being more energy consuming processes. As the result of the ROTRESEL process a reasonably clean water is obtained, acceptable for sewage, and substrate containing the oil phase and residues of the electrolysis process of high calorific value. This substrate can be processed into briquettes (patent fuel). ROTRESEL method is a cheap method of neutralization and its efficiency depends on the ratio of emulsion use.

This is a very efficient method. The results of laboratory tests proved that its output is 50-100l/h at energy consumption of 10-20 kWh per $1m^3$. Laboratory testresults indicate that the ROTRESEL method can be applied for neutralization of other used cutting fluids, like semisynthetics and synthetics and oil emulsions with microadditives, that are very difficult for neutralization (e.g. in case of physical methods).

a) EMUCONTROL method

The EMUCONTROL method was developed in Germany. In this method special organic substances neutralizing the electric charges of emulsion surface-active particles are added to the emulsion. The process is controlled by a microprocessor. Due to this process 98% of oil is removed from the used emulsion. The removed oil phase is subject to further treatment (dehydration process). The water phase obtained in the neutralization process is sufficiently clean to be disposed directly to a sewage or subject to the next step of the cleaning process (e.g. ultrafiltration, flocculation, adsorption). The EMUCONTROL method is used in the first stage of the cutting emulsion neutralization process. To break-up one cubic metre of oil emulsion one kilo of organic flocculent substance is necessary with the cost of 16-20 ECU. The price of the equipment is about 20 000 ECU.

b) FLOCCULENT method

At the small factories (workshops) where small amounts of cutting fluids are used, a simplified flocculent method can be applied. Special organic compounds (flocculents) are usually added to the emulsion causing its separation to oil and neutral water phase (pH = 6.5 - 9). Using commercial P3 – Ferrolin flocculent, made by Henkel, the oil concentration can be reduced from 1000 mg per litre to 10 mg per litre. The process based on the flocculent method is cheaper (some 30 %) than the conventional process of breaking – up emulsions with the use of coagulating agents.

4. Summary

1. The situation regarding disposal of used cutting fluids in the USA, EU and CCE countries is presented.
2. Some methods of neutralization of the used cutting fluids are described.
3. It seems that the activity within the ECOFRIM Project should go towards: detailed classification of neutralization and disposal methods, estimation of the costs connected with the ecological aspects of cutting fluids, agreement upon identification of the most ecological fluids .
4. The aim of the activity in the field of cutting fluids is the mineral oil – based, semisynthetic and synthetic fluids improvement.

References:

[1] EU Concerted Action Contract No. ERBIC15 CT98 0810: "Towards Ecologically Friendly Machining (ECOFRIM)", Technical Annex.
[2] T. L. Hause: Cut. Tool Eng., 41 (1989), 98.
[3] J. V. Owen: Manufact. Eng., 120 (1998), 92.
[4] W. A. Sluhan: American Machinist, 137 (1993), 53.
[5] J. F. Davisson: Tooling & Production, 60 (1995), 45.
[6] C. Granger: Machinery & Prod. Eng., 152 (1994), 20.
[7] W Polowski: International Conference: Analysis and Utilization of Oily Wastes AUZO '96 Proc., 1 (1996)
[8] W Polowski, K. Musia³ek, Prace IOS, Seria Referaty, 433 (1998), 4

DRY MACHINING

Mojmir Jilek, SHM Ltd. Sumperk, Czech republic

Hard wear resistant coatings are solution for dry cutting without reduction of tool life. CVD and PVD wear resistant coatings are two general possibilities of this solution.

CVD

The CVD wear resistant coatings have enhanced cutting performance of cemented carbide indexable cutting tools almost for 30 years. This type of coatings grows at the temperature approx. 1000 ^{o}C. Surface decarburation of the cemented carbide substrate is caused by diffusion in this case by diffusion of nitrides and carbides of transition metals (usually TiN and TiC). By this way affected cemented carbide has on the one side quite higher surface hardness (especially in tzhe high temperature) but on the other side is more brittle. So substrate with CVD layer has higher resistance against edge plastic deformation. This is an advantage especially in the case of high cutting speed.

PVD

During PVD layer growth the coating temperature does not exceed 600^{O}C. This low temperature does not influence on the surface of cemented carbide. The PVD coated inserts have higher resistance against mechanical strokes but quite lower crater wear resistance. PVD layer is created under unbalanced conditions due to the low coating temperature and ion bombardment during layer growing. The lower layer grain size and high residual internal layer stress cause higher PVD layer hardness in comparison to the same type of CVD layer. It is clear that cemented carbide indexable cutting tools with CVD layer are suitable for applications in quite different cutting fields than PVD.

SHM - R&D and Production

SHM cooperates very closely with Pramet. SHM prepares PVD coatings with a new quality on indexable cutting inserts made from cemented carbide which are produced by Pramet. SHM´s standard coating TiAlSiN has hardness 35 - 40 GPa ($HV_{plast\ 70\ mN}$) with good chemical and thermal stability.

SHM´s aim is to prepare superhard layers (HV hardness above 50 GPa) with good quality and thermal and chemical stability on the own equipment with reasonable productivity.

The main goals:

- to produce good coatings which can help to replace griding of hard material (above 60 HRC) by cutting.
- to produce good coatings suitable for high speed cutting
- to produce good coatings suitable for dry machining

There are three main ideas of the solution of superhard coatings :

1. layers based on nanocrystalline composites - present time SHM produces one PVD coating - TiAlSiN. This coating reaches very high hardness with good stability. Addition of Si mainly influences on the grain size. The grain size of this coating is approx. several nm and on the other side the size of conventional TiAlN coatings is approx. several hunderd nm. When the grain size reaches size between 3 - 5 nm the thermal and chemical stability rapidly raises. That is why TiAlSiN layer can be used as a wear resistant coating suitable for dry machining. The influence of Si content in the coatings and its optimization is under present development.

2. multilayers - combination of nanocrystalline composite and multilayer - it is the main idea. Present state of multilayer based on TiAlSiN is almost at the production beginning. Cutting tests made in cooperation with Pramet show that this multilayer is suitable for both high speed and dry machining. Hardness is approx. 50 GPa.

3. layers based on cBN - everybody knows that thermal and chemical stability of cBN is very good. Hard films based on amorphous or cBN could reach the hardness value of diamond. The hardness of Ti -B-N films developed at SHM reached the level 60 GPa (HV) with Young modulus 550 GPa. The adhesion of these films is realy good. Next development is aimed on the higher content of B-N bonds in the layer.

Type of coating	Composition
nanocrystalline composites	TiN-Si_3N_4 ; TiAlSiN
multilayers and superlattices	TiN-NbN ; TiAlN-TiN ; TiAlN-Al_2O_3 ; TiN-AlN
nanocrystalline multilayers	TiAlSiN
coatings based on B-N	cBN ;Ti-B-N; TiN-BN

Table 1 – A list of the most interesting wear resistant coatings

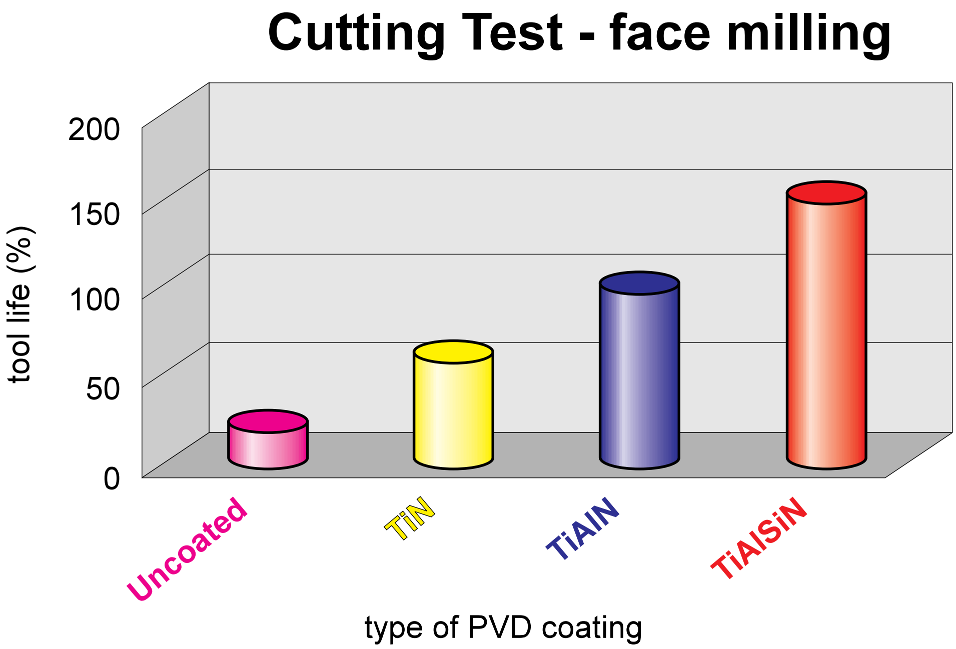


Fig 1 - Cutting test

ALTERNATIVES TOWARDS AN ECOLOGICAL MACHINING:

Joseba Perez
Fundacion Tekniker, Eibar, Spain

(depending on cutting operations, cutting conditions, workpiece material, and cutting tool)

- **TOTAL ELIMINATION OF CUTTING FLUIDS**
  - PVD coated tools
  - Pressurised air or gas

  (bearing in mind the chip evacuation and the heat not eliminated by the cutting fluid)

- **PARTIAL ELIMINATION OF CUTTING FLUIDS**
  - PVD coated tools
  - MQL systems (with not toxic biodegradable cooling lubricants)

  (bearing in mind possible misty problems, generation of fog)

- **WITHOUT ELIMINATION OF COOLING LUBRICANTS**
  - Increasing the service life of conventional mineral-base cutting fluids (with better systems of maintenance and control)
  - Replacement by environmental friendly cutting fluids (not toxic biodegradable cooling lubricants)

Fundación TEKNIKER
Research Centre

DIRECT REPLACEMENT BY ENVIRONMENTAL FRIENDLY CUTTING FLUIDS:

CONSIDERATIONS:

- ✓ TO BEAR IN MIND THAT THE REST OF THE LUBRICATION SYSTEMS OF THE MACHINE-TOOL IN POSSIBLE CONTACT WITH THE CUTTING FLUID INCLUDE ALSO ECOLOGICAL LUBRICANTS.

- ✓ THE COMPATIBILITY OF THE ECOLOGICAL CUTTING FLUID WITH THE ELEMENTS OF THE MACHINE-TOOL IN CONTACT (SEALS, PAINTS...).

- ✓ STUDY THE LIFE IN SERVICE OF THIS ECOLOGICAL CUTTING FLUIDS (BIODETERIORATION).

Fundación TEKNIKER
Research Centre

TEKNIKER'S PROJECTS IN THIS FIELD:

In Tekniker, The Materials Department has been working in the last four years on more ecological manufacturing in different projects:

- ***"Development of an automatic control system to minimize the use of cutting fluids"***
  Minimising the environmental impact of cutting fluids through the increase of their lifetime using a correct selection, control and maintenance (Cooperation project partially funded by the Basque Government).

- ***"Substitution of conventional cutting fluids in steel machining"***
  Using a special pressurised air system to substitute the coolant effect of the cutting fluid (Generic project funded by the Basque Government).

- ***"Development of less pollutant cutting technologies"***
  Using coated cutting tools for dry machining operations, minimum quantity lubrication systems (MQL) and environmentally friendly cooling lubricants to avoid pollutant waste disposal (BRITE EURAM project called LEPOCUT).

- ***"Development of environmental friendly machining technologies". Application to Lathes & Machining Modules (MECECO)***
  This project keeps the objectives of the European Project but focused on different materials and operations and on the high speed machining (Cooperation project partially funded by the Basque Government).

Fundación TEKNIKER
Research Centre

CHARACTERISTICS OF THE CUTTING FLUIDS

Jozef Peterka, Michal Stefanek,
Slovak Technical University, Faculty of Materials Science and Technology in Trnava,
Department of Machining and Assembly

***Key words**: cutting fluids, dry machining.*

Introduction

Cutting proces i.e. removing the material from machined part by cutting tool in form leaving chips is surrounding by define environment, usually by air. It is frequent to lead various fluids, gases or saturated steams into cutting area. In general we could say *cutting fluids*.

Each cutting fluid is carrying technological, economical and ecological dimension within.

1. Technological dimension

Main effects of cutting environment resp. cutting fluid on cutting process are:

- lubricating effect,
- cooling effect,
- cleaning effect,
- corrosive effect.

1.1 Lubricating effect of environment

Lubricating effect express itself between contacted bodies during their relative motion:

- by decreasing of friction (outer lubricating effect),
- by alleviating of plastic deformation,
- by increasing of frictioned surface layers brittleness
- by decreasing of internal friction work.

1.2 Cooling effect of environment

Cooling effect express itself by ability to lead away the heat from cutting place i.e. from sources of heat origin (primary area of deformation, friction on cutter face and on cutter flank) and so save cutting wedge against decreasing of cutting characteristic and by this against lost of cutability.

1.3 Cleaning effect of environment

Cleaning effect of environment consist in removing of chips metal and grinding dust from cutting place. Typical example is drilling of deep holes, where the chip is leading from drilled hole by machanical effect of fluid stream.

1.4 Corosive effect of environment

For apprecation of this effect it is necessary to say, that cutting fluids based on water i.e. various sorts of emulsions are causing corrosion of all metal parts which come into contact with them (tables and guideways of machine tools, fixtures, tool holders and tools itself, and so on), but oils are not causing corrosion of steel and cast irons.

If we summarise influences of environment on cutting process, we can say, that they influenced in positive way:

- course of machined material deformation (formatting of chip),
- friction of machined material and formatted chip on cutting wedge,
- leading away of heat from cutting place,
- durability of cutting edge,
- energy consumption,
- quality of machined surface.

2. Economical dimension

Economical dimension of cutting fluids it is necessary to see in their *purchase, use, renewal (regeneration) and disposal*. All these activities in production enterprise keep some financial means for their refundment. These activities we call fluid management and expenses joint to them we call expenses for cutting fluids. Amount of these expenses, resp. how these expenses share on total production expenses is various, and depend mostly on way of their putting:

- one ore more cutting fluids,
- in small quantities (small production enterprises with piece production) or in great quantities (in big gigantic concerns in batch or mass production), technical way of leading of cutting fluid into cutting place (in small volumes - lubricating effect is dominant e.g. by finishing cut, in great volumes - cooling effect is dominant e.g. by roughing cut).

Investigations indicate [1] that the cutting fluid expenses are 7-17% of the total production expenses in the motor industry.

Also the amount of the supplied cutting fluids influences its effect and economical results of the cutting. The Fig.1 [2] shows the dependence of cutting tool life, tool expenses and cutting fluids expenses on the cutting fluid amount. With increasing amount of the supplied cutting fluid is improved the cutting tool life, firstly expressively, later with the bigger amount of cutting fluid is this affect not significant. On the contrary the cutting expenses increase, because cutting fluid expenses are increasing.

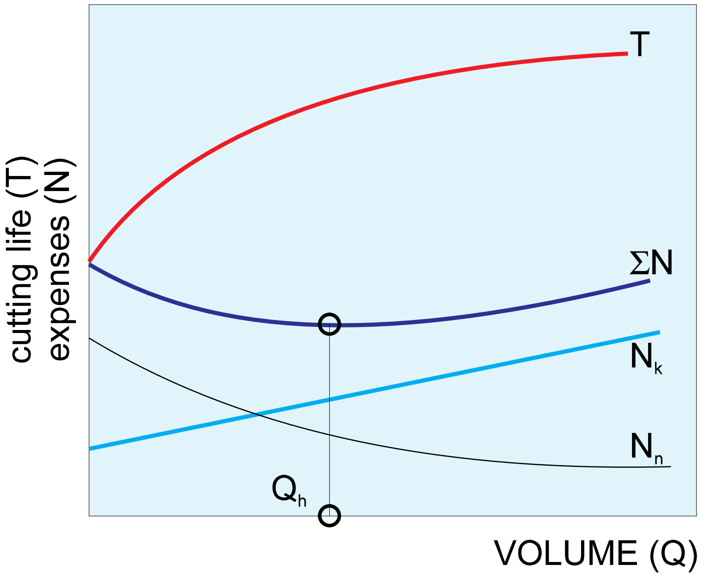


Fig.1 The typical course of the cutting life and the cutting expenses as the dependence from the supplied cutting fluid amount.
T - cutting life, ΣN - cutting expenses, Nk - cutting fluid expenses, Nn - tool expenses,
Qh - economical amount of the supplied cutting fluid

2. Ecological dimension

In general utilising the whatever cutting fluid is related with its chemical nature. It is possible to consider the cutting fluid as the chemical mater. Therefore we must manipulate with it with necessary attention.

We name some negative ecological effects of the cutting fluids. They are negative influenced on:

a) healt state of the worker,

- activate any cutaneous illnesses,
- activate any respiratory illnesses,
- the danger of the injury and so on.

b) **work-bench environment in the workroom**,

- annoying smell,
- jetting and issue the cutting fluid out of the working space of the machine,
- contamination and pollution of the dress and footwear of the worker,
- total liability on the dirty environment and so on.

c) living environment,

- problematical disposal of the applied cutting fluid,
- possibility of the cutting fluid to escape in the local drainage and in the natural environment,
- possibility of the detonation genesis and of the fire genesis and so on.

Conclusion

In the last excellent improvement of the various cutting process characteristics have been achieved by use of the cutting fluids. These cutting fluids contained the harmful toxical chemical components.

The ecological process began at first with defence of the health of cutting machine worker namely with the restriction for use of toxic components in the cutting fluids. Gradually the cutting fluids were developed with the minimal harm effects on the natural environment. Today we know various so called *ecological fluids*, but either these have not the trouble-free ecological use.

Today in the foreground is the request, how to favourable keep effects of the cutting fluids to respect the living environment and to lower the cutting expenses.

From the ecology and economy view the most accommondating stage is to work without use of the cutting fluid. This is significant trend of the development in cutting. It is call - *dry machining*.

There is the important question. ***Is it successful possible to realize the dry machining from technological view?***

We will try to analyse this question late in this project ”Towards friendly machining”.

References:

[1] Mádl, J.: Význam řezných materiálu a ochrany prostředí pro rozvoj technologie obrábění. Medzinárodná vedecko-ped. konf. Význa a uplatnění progr. technologií ve strojírenské výrobě. Sborník prednášek, ISBN 80-214-0914-2, 8.-9. října 1997, Brno, ČR, s.73-76
[2] Buda, J. - Békés, J.: Teoretické základy obrábania kovov. SVTL Bratislava, 1967

DISPOSAL OF CUTTING FLUIDS

S. Bedo, I. Raisz
University of Miskolc, Department of Physical Chemistry, Miskolc, Hungary

The metal-working activity is associated with the application of a large quantity of cutting fluids having high importance in the processes. The presence of cutting fluids makes it possible to form combined effect of cooling and lubrication meanwhile the efficiency and the economic parameters have been improved.

The properties of cutting fluids

The most of the existing cutting fluids are O/W emulsions including natural or synthetic oils and ionic or non-ionic surfaceactive agents. The formation of exhausted fluids is attributed to the irreversible structural changes caused by their aging and decomposition facilitated by different solid, liquid and bacterial pollutants. The polluted cutting fluids are multicomponent stable disperse systems having effect of environmental pollution and health damage. The problem arising from the increasing quantity of waste requires the development of environmentally sound methods for the deteriorated cutting fluids disposal.

Principle of disposal

The disposal of cutting emulsions can be performed by phase separation through destruction of the interfacial layer composed of surfactants and fine solids applying physical, chemical, physico chemical or combined methods. In the following the point of a possible physico chemical method expected to meet EU environmental directives will be presented. One of the most effective phase separations is the change of stable O/W emulsions into unstable suspensions with high tendency of coagulation by the addition of suitable demulsifiers. As a result of the disposal process the oil phase, the surfactant, the fine and coarse solids and other pollutants can be concentrated into small volume of a sludge-phase which would be treated by different appropriate ways. The desired demulsifiers for the formation of unstable suspensions are different clay minerals with modified surface having high ability of electrolyte adsorption surface dissociation and oil adsorption in aqueous medium. The thickness of the electrical double layer of silicate formed at the S/L interface can be influenced by the addition of different cations to promote the tendency of coagulation. The greater the adsorption of cations the smaller the thickness of double layer, the value of z-potential and after all the stability of the disperse system. The order of adsorption is directly proportional to the charge of the ions and the dehydrated ionic radius what is described by the liotropic series of ions:

$Al^{3+} > Ba^{2+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+} > Li^{+}$

Resulting from the previous findings you have to use a complex demulsifier composed of aqueous suspension of a suitable clay mineral activated by addition of electrolyte including given amount of the selected cation. The efficiency of the disposal process can be derived from the results of quality control for the water phase performed by the determination of oil content and COD. At the end of the successful disposal process the water separated can be lead into a receiving water or channel and the solid waste can be stored by landfills or it can be subject to some reasonable treatment, e.g. incineration.

Conclusions:

Problems arising from the increasing volume of waste needs to develope environmentally sound methods for the deteriorated cutting fluids disposal. One of effective phase separations is the change of stable O/W emulsions into unstable suspensions.The efficiency of the disposal process depends on the results of quality control for the water phase performed by the determination of oil content and COD.