CUTTING FLUIDS EVALUATION BASED ON OCCUPATIONAL HEALTH AND ENVIRONMENTAL HAZARDS

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Abstract. The selection of cutting fluids in metal machining process is often observed to be a multi-criteria decision-making problem with conflicting and diverse objectives. Traditionally, the cooling and lubricating performance of a cutting fluid has been evaluated. But increasing environmental consciousness in society can be thought of as a basis for the improvement of the health and environmental performance of machining. This contribution presents a current state of the development of computer software for the cutting fluids evaluation, based on occupational health and environmental hazards associated with their use. As a part of existing CAPP software it will serve as an aid in cutting fluids decision-making for machine shop engineers in machining process planning. The system requirements and the principal structure of the developed software tool are described. Also a case study is presented to show the effectiveness of the software.

Keywords: cutting fluids, process planning, computer software.

Introduction

Traditional approaches to cutting fluid selection are based on functional requirements and cost performance. Due to the increasing number of laws and directives governing industrial safety and environmental protection, the use of cutting fluids is putting intense economic pressure on manufacturing companies because cutting fluid is an important source of health and environmental risks. Health impacts associated with exposure to cutting fluids range from irritation of the skin, lungs, eyes, nose and throat to more severe conditions such as dermatitis, acne, asthma, hypersensitivity pneumonitis, irritation of the upper respiratory tract, and a variety of cancers. Health and environmental impacts of cutting fluids are discussed in [1-5], and others. Another big problem is associated with cutting fluids disposal [6-8]. Cutting fluids disposal can impact the environment due to hazardous metal carry-off, hazardous chemical constituents, oxygen depletion, oil content and nutrient loading. Therefore, optimal selection of cutting fluids based on health and environmental risks is an effective path to reduce occupational diseases of employees and minimize the environmental pollution, which will improve also the costs.

The traditional selection of a cutting fluid is mostly based on the type of machining operation, material being machined, cutting tool material and machining conditions. Innovative methodologies for decision support in the cutting fluids selection process must consider the environmental, health and safety characteristics, too. While some of these characteristics are available from the Material Safety Data Sheet (MSDS), this information is far from comprehensive and also is often only qualitative. Once a database of cutting fluids and their characteristics have been established, decision makers are still left with a problem: what the difference between two cutting fluids is. The database of cutting fluids and their properties is not enough. A method to group these media into categories on the base of similarity of their properties is also needed [9].

The development of computer software called "CFSystem", designed for the optimization of cutting fluids selection with regard to human and environmental hazards, is presented in this contribution.

Computer software design

Computer software CFSystem is designed to run in Windows XP/Vista/7, so the minimum hardware requirements are determined by these operating systems. In addition, Microsoft .NET Framework 2.0 and DAO 3.7+ have to be installed. The software can be installed by following the installation steps in *Setup.exe*.

The principal structure of CFSystem has been created by these three modules (Fig. 1.):

- database module,
- user interface module,
- process optimization module.

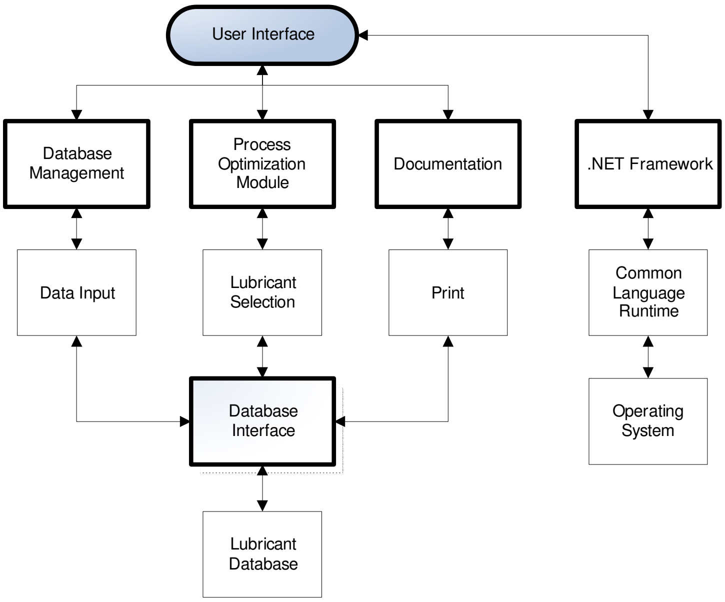

Fig. 1. **Structure of the CFSystem**

The data included in sections of MSDS (Material Safety Data Sheet) will serve as the input data for the development of a cutting fluid/lubricant database created using Microsoft Access.

The structure of the database is given by these tables:

- identification of manufacturer – name and location of company,
- identification of product/cutting fluid – name,
- identification of health hazards – health hazard symbols and R-phrases,
- toxicological information (acute toxicity – oral, dermal, inhalation; subacute (subchronic) toxicity; chronic toxicity – mutagenicity, carcinogenicity, toxicity for reproduction),
- identification of environmental hazards – environmental hazard symbol and R-phrases,
- ecotoxicological information (aquatic toxicity, biodegradability, bioaccumulation).

The user interface module is user-friendly and is made by the form of windows. It is designed to control the operation of the whole software, for data input, editing and deleting as well as for reporting the results. The user can log into the software by entering the user name and password to view the list of cutting fluids, manufacturers, symbols, R-phrases and toxicological information. The software can be extended in further development and new data may be added any time.

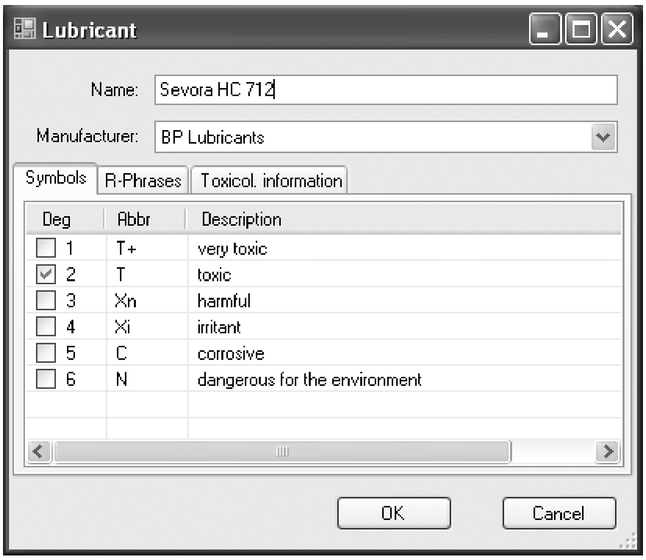

Fig. 2. **Data Input Form**

In the Data Input Form may be added: the name of a cutting fluid/lubricant, its manufacturer, the health and environmental hazard symbols (degree, abbreviation and description), R-phrases and eco/toxicological information (e.g., toxic in contact with skin, irritant to eyes, harmful to aquatic organisms, etc.). Saving of the added data is automatic.

The process optimization module is the main part of the software. The principle of this module is to compare the health and environmental properties of the given cutting fluid, which are represented by R-phrases, with the properties of a reference cutting fluid (it has the maximum number of R-phrases and represents the worst health variant).

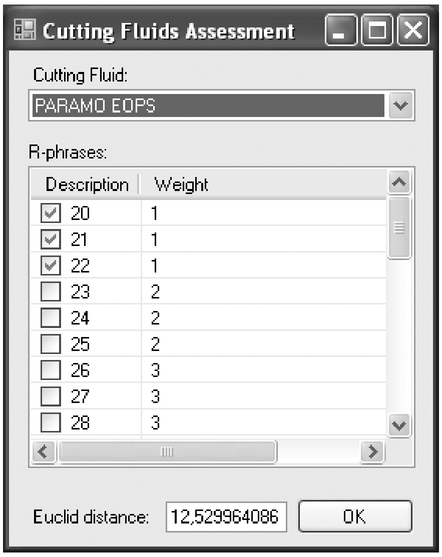

Fig. 3. **Cutting Fluids Health/Environmental Assessment Form**

Similarity is defined in terms of a distance metric, most often the Euclid distance (d_E) or relatives of the Euclid distance. The similarity index between the cutting fluids is defined as follows:

$$d_{E(x,y)} = \sqrt{\sum_{i=1}^{n} g_i (x_i - y_i)^2} \qquad (1)$$

where g_i – weighting factor of the i-th cutting fluid property;
x_i, y_i – values of the i-th cutting fluid property.

Some of the weighting factors for individual properties are shown in Table 1. The basis for the weights allocation of each R – phrase or their combination takes into account the seriousness of the resultant health/environmental effects. The weights are numbered from 1 to 10.

Table 1

Weighting of individual health/environmental effects

R-phrase	**Weight**
R48/23/24/25	8.6
R39, R40, R45, R62, R63, R64	9.0
R39/23, R39/24, R39/25	9.1
R39/23/24, R39/23/25, R39/24/25	9.2
R39/23/24/25	9.3
R39/26, R39/27, R39/28	9.4
R39/26/27, R39/26/28, R39/27/28	9.5
R39/26/27/28	9.6
R46, R49, R60, R61	10.0

The acute toxicity – oral, dermal, inhalational, describes the adverse effects of a substance which result either from a single exposure or from multiple exposures in a short space of time (usually less than 24 hours). It is less harmful and is ranked with a lower degree. Chronic toxicity is a property of a substance that has toxic effects on a living organism, when that organism is exposed to the substance continuously or repeatedly. The chronic toxicity as mutagenicity, carcinogenicity and toxicity for reproduction are more dangerous for the health of people, therefore are ranked with high numbers.

The Euclid distance indicates how much the given cutting fluid is similar to the reference one. The bigger the index is, the more different the cutting fluids are and the less harmful a cutting fluid to the health of workforce and environment is. If d_E equals zero, it means that the cutting fluids are identical. It is the worst variant.

Results and discussion

A case study is presented to show the effectiveness of the developed software tool. The case study shows how to select a suitable cutting fluid for a specific process among three types of cutting fluids which have approximately equivalent functional and cost performance. The input data for CFSystem derived from MSDS's are summarized in Table 2.

Table 2

Input data for CFSystem (case study)

Fluid	R-phrase	Effect
CF1	R 21	harmful in contact with skin
	R 22	harmful if swallowed
	R 34	causes burns
	R 38	irritating skin
	R 41	risk of serious damage to eyes
	R 52	harmful to aquatic organisms
	R 36/38	irritating to eyes and skin
CF2	R 20	harmful by inhalation
	R 36/38	irritating to eyes and skin
	R 36/37/38	irritating to eyes, respiratory system and skin
CF3	R51/53	toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment
	R 22, R 36/38	harmful if swallowed, irritating to eyes and skin
	R65	harmful: may cause lung damage if swallowed

The comprehensive assessment results are shown in Table 3. The results show that the cutting fluid CF2 achieves the best score with the Euclid distance equal 24.1. Contrariwise, the cutting fluid CF1 has the worst properties from health and environmental hazards point of view.

Table 3

Comprehensive assessment results

Cutting fluid	Euclid distance
CF1	23.7
CF2	24.1
CF3	23.9

Conclusions

Computer-aided process planning systems have been developed to simplify, improve, and provide consistency within the process planning function. One of the many process planning tasks in machining is selection of an optimal cutting fluid. There are a number of attributes by which they may be chosen.

The problem of selecting the most suitable cutting fluid from a bigger group of cutting fluids, which may be better in some respects but worse in others, is a multi-attribute decision problem. It is obvious that the selection has to be governed not only by functional requirements and cost performance but as well health hazards and environmental performance.

This paper has introduced a software tool for cutting fluids evaluation based on health and environmental risks. The tool enables the calculation of the overall score to measure health/environmental performance of a given cutting fluid. The industrial praxis demands engineers that understand tasks of manufacturing process planning and are health and environmentally-conscious.

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