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IS EDM THE BEST AVAILABLE CLEAN TECHNOLOGY?

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ABSTRACT: The benefits of EDM are considerable, and it is often appropriate to EDM instead of using conventional manufacturing processes. EDM is presently known as the best available technology (BAT) to solve various problems in machine construction. This paper attempts to provide some answers to the question - is EDM a clean technology? Working methodology consisted in processing literature data and data obtained from author's experimental research on the environmental impact of EDM. In conclusion, there are several issues to be solved before EDM can be considered a clean technology. The article also suggests solutions for these problems.
KEY WORDS: EDM technology, environmental impact, clean technology.

7 INTRODUCTION

The improvement of the environmental impact of machine tools is enforced by European environmental legislation. As a consequence, the reduction of energy, resources end noise demands is an essential key to improve the environmental performance of industrial manufacturing processes. Most applications and studies have focused on products — particularly product design, and, to a lesser extent, communication of environmental performance of processes.

In general, manufacturing operations are most often viewed as the set of processes employed to operate on discrete parts. Generally these processes utilize mechanical, thermal, and chemical means to change some characteristic(s) of an input component to produce a final component — an output. In addition to the processed part, operations have a number of other outputs or by-products that essentially represent manufacturing process waste streams. In [1] suggest that traditional machining operations can be represented via an input-output form, such as shown in figure 1

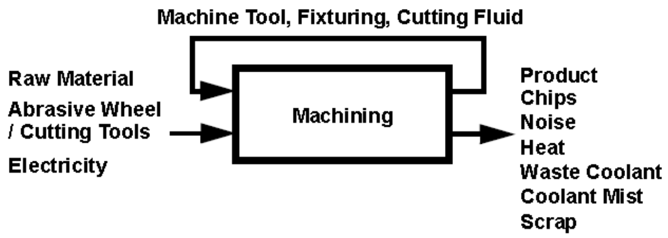

Figure 1. Input-Output Diagram of a Traditional Machining Process

Figure 1 depicts an input-output relationship for a traditional machining operation. As is evident from the figure, there are a number of outputs from the process, in addition to the desired product.

Recently, the role of cutting fluids in machining operations has received increased attention because of environmental and industrial hygiene concerns [1, 2, 3, 4]. Fluid splashing, spillage, and chip carry-off can lead to inadvertent contamination of groundwater with the fluid as well as metal fines. Treatment of used fluids prior to the introduction into wastewater streams is not totally effective and also represents a significant and increasing cost.

The industrial hygiene community is also directing ever more attention to cutting fluid exposure because of the negative health effects due to skin contact and fluid mist inhalation.

Recent studies [5, 6, 7] have shown that mist concentrations, as well as the number of super and submicron particles, can be manipulated by changing machining conditions. The use of life-cycle approaches to study processes, and, in particular, EDM processes, is less mature.

The main types of risk assessment and environmental emissions are based on: assessments of health and environmental assessments.

The risk assessment and emissions based on assessments of health is the most important risk assessments. Recent developments took into account labor protection, the international limit thresholds to determine safe exposure to various chemicals, for certain periods of time. For example, the World Health Organization standards have been developed to levels acceptable concentrations of pollutants in the atmosphere and indicative limit to maintain human health and environmental health, for different parameters.

The risk assessment based on environmental assessments of emissions into the environment is the latest and most dynamic in terms of development, the risk assessments. These ratings compare the expected concentrations of pollutants in the environment with toxic thresholds estimated in order to assess the security of emissions. Ecological risk assessment methodologies developed for comparing eco-toxicological human or environmental risks associated with an event occurring using different sophisticated instruments with a number of scoring systems.

However, some applications for reduction of environmental impact are relevant to EDM as the following paragraphs illustrates.

8 EMISSIONS INTO THE ENVIRONMENT OF EDM PROCESSES

Today research on EDM aims at a more application oriented field rather than searching for a unified EDM model. There were a number of problems when mathematical modeling of the EDM process was initiated. The gap pollution, the hydrodynamic and thermodynamic behavior of the working fluid were difficult to model.

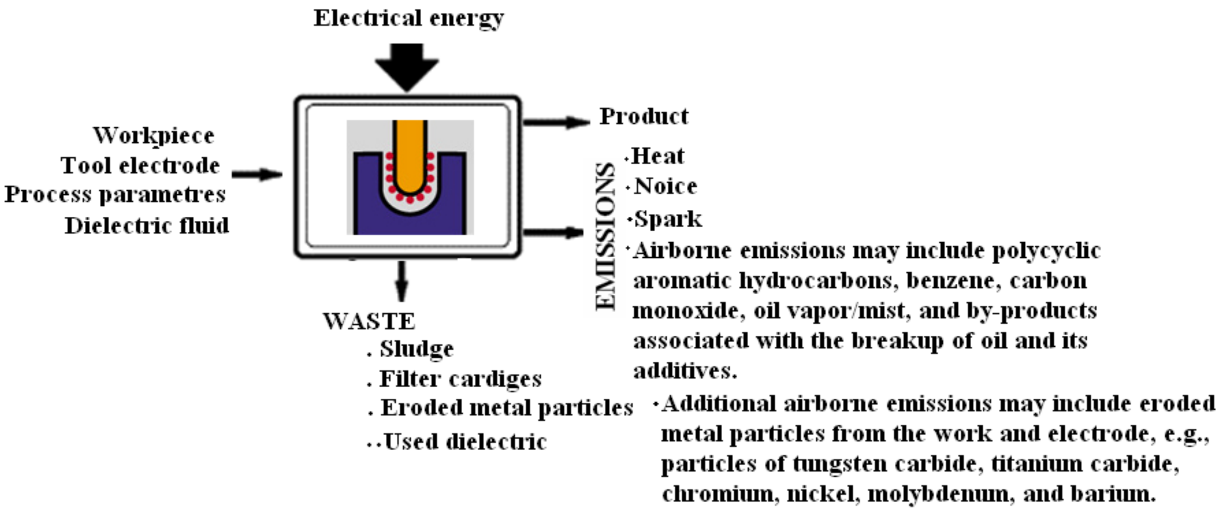

Figure 2. Input-Output Diagram of a EDM Process

Getting a model with practical technological results was impossible. This inability, along with the high demand from the market led to a more pragmatic application oriented research into the EDM process.

In EDM, a negatively charged tool and a positively charged workpiece are brought close to one another while submerged in a dielectric fluid (at low voltages, the fluid acts as an insulator).

The voltage difference between the tool and work is increased until the dielectric fluid ionizes and a spark jumps across the tool - work gap; once the spark is produced, the dielectric fluid de-ionizes and is once again an effective insulator. The cycle repeats at a rate of 200 to 500,000 Hz, and the energy supplied by the sparks may produce local temperatures in the work of 12,000°C — a temperature high enough to vaporize the work material.

The EDM processes produce waste in solid, liquid, gas, and aerosol form (figure 2). For example, the solid waste is in the form of sludge and used filters, inclusive eroded particles. EDM also produces considerable amounts of pollutant waste including quantities of heavy metal sludge (metal oxides and hydroxides). These waste components can be toxic, hazardous, corrosive, or carcinogenic.

Tonshoff et al. (2006) report that if a mineral oil is used for EDM, airborne emissions may include polycyclic aromatic hydrocarbons, benzene, carbon monoxide, oil vapor/mist, and by-products associated with the breakup of oil and it's additives. Additional airborne waste may include eroded metal particles from the work and electrode, e.g., particles of tungsten carbide, titanium carbide, chromium, nickel, molybdenum, and barium.

Used dielectric fluid may contain measurable amounts of iron, lead, chromium, vanadium, carbon black, zinc, copper, cadmium, tungsten, nickel, cobalt, titanium, and molybdenum.

The amount of residue generated is approximately 100 to 300 cubic centimeters for every cubic centimeter of removed material [5].

Researchers are beginning only now to highlight this type of information. Given the vast number of manufacturing unit operations, much work remains to be performed in terms of describing the energy usage and waste stream character and quantity. Along with process improvement, emphasis is placed on creating new processes and modifying existing processes to be more environmentally benign.

All these require knowledge about manufacturing process waste streams and energy. These waste streams may be in various states and employ different transport mechanisms to reach a variety of receptors. The down-stream effects of the waste streams are quite varied.

9 THE ENVIRONMENTAL IMPACT OF EDM PROCESS

An environmental impact assessment must be rigorous, interdisciplinary and cover as much as possible, all the possibilities. Any environmental impact assessment involves four phases: scoping, inventory, setting conditions and the evaluation itself. The first phase defines the scope of the project. The second phase is a cataloging sensitive areas, including areas that are influenced by socio-economic project. The third phase is the process of estimating the impact of alternatives considered. The last phase made interpretation of the first three.

In the previous section, the by-products of several different classes of manufacturing processes were examined. It was noted that many of these waste streams had environmental, health, and/or safety consequences. The energy efficiency of a few of the operations was noted. Attention now turns to identifying actions that may be employed to improve the EDM performance of these manufacturing operations.

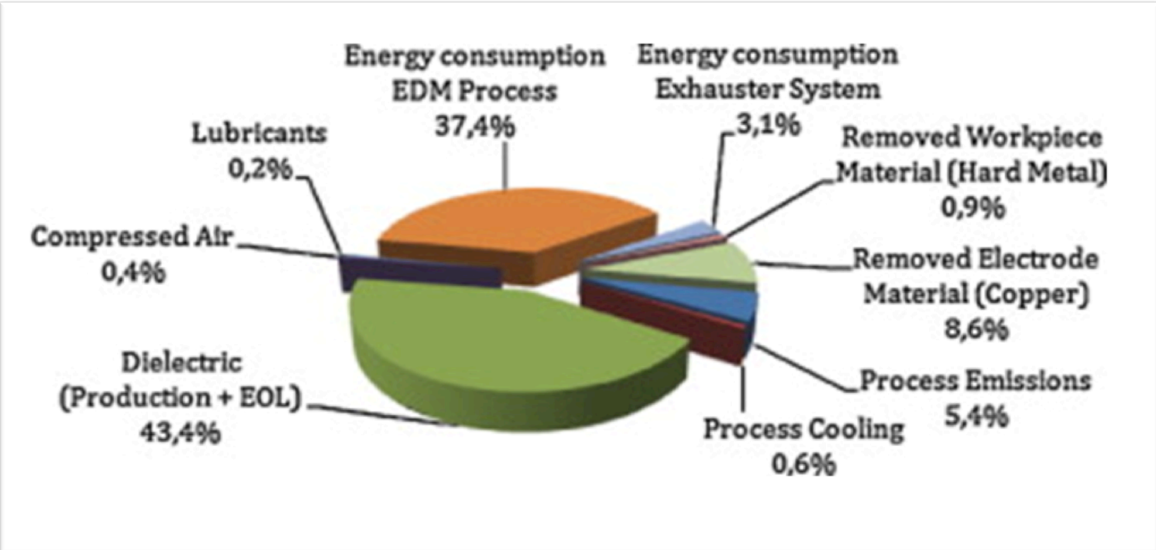

Figure 3.Distribution of the environmental impact during 1 h of EDM roughing

In figure 3 depicts a distribution of the environmental impact during 1 h of EDM roughing. It can be seen that the largest environmental impact was dielectric (Production + EOL 43%), and electricity consumed in the EDM process (37%) [7].

With regard to energy efficiency of an EDM process, things are worse. To determine the efficiency of primary and secondary energy use for an EDM process, the following efficiencies in the energy conversion are assumed:

- Crude oil to fuel oil is 90% (0.90);
- Fuel oil to electricity is 40% (0.40);
- Electricity transmission and distributions are 90% (0.90);
- Conversion of electrical energy into thermal energy of the EDM process is 35% (0.35).

The overall efficiency for the primary energy source is the product of all the individual conversion efficiencies:

Overall Efficiency = (0.90)(0.40)(0.90)(0.35) = (0.1134) or 11.34%.

When compared to traditional machining processes, non-traditional operations are much less energy efficient.

However, the evolution of the EDM was due to powerful generators, new tool electrodes, better mechanical concepts and improved machine intelligence. Over the years the speed of EDM has gone up 20 times, machining costs have decreased by at least 30% over the years. Surface finish has improved by a factor of 15, while discharge current has gone up more than 10 times higher [5].

The advent of the rectangular pulse generator in EDM has resulted in improved metal removal rates (MRR) and reduced electrode wear compared to the performance of the former relaxation-type generator. It is a fact that the problem of electrode wear persists and that it is particularly important during finishing operations. During finishing operations higher MRR, though preferable, is not very important. Accuracy is the key factor. As a solution to the tool wear problem, besides parameter selection, non-rectangular current pulses, comb current, and other types of current pulses have been applied successfully.

10 SUMMARY AND CONCLUSIONS

Summarizing our findings, at this stage of study, the following basic options on EDM environmental improvements can be discussed.

At the moment all companies organizations are forced to make an assessment of the environmental impact of economic activities and projects within their jurisdiction.

The environmental impact assessment is to quantify the effects of human activity on the environment, human health and safety and property of any kind.

There are gaps in standardization of machine tools specifically regarding the eco-design process, marking/ labeling of materials/ components (e.g. identification of hazardous substances), power consumption measurements (machines and modules), power modes, power management, consumption of lubricants and of compressed air and process waste generation measurement including yield losses.

There are no data available regarding the environmental performance and related savings potentials of EDM machine tools considering the multitude of design options identified and subject to assessment.

Study results show, that energy efficiency – despite some outstanding initiatives - is not very important in the marketing of the EDM machine tool manufacturers. Recent survey results [8, 9, 10, 11, 12] and stakeholder feedback show that "energy efficiency" – despite some outstanding initiatives - is only recently becoming important in the marketing of the machine tool manufacturers. The important facts are price, cutting speed and innovative equipment. Although machine tools users' interests regarding energy efficiency aspects is growing, technical features and performance criteria still dominate.

Implementation obstacles regarding new energy efficient solutions on the users' side can be observed. For most EDM machine tool users, the price-profitability relation and therefore the amortization time of such solutions, as well as limited financial resources, are some of these barriers.

Retrofitting and refurbishment of machine tools after a certain time in use is very common and reported to take place typically a couple of times throughout the lifetime of a machine tool.

Although there are some machine tools which are claimed to be environmentally friendly or eco-efficient, it is rather not possible to define a complete machine tool as Best Available Technology (BAT) or Best Not yet Available Technologies (BNAT), as this could only refer to a very specific configuration and application scenario. The BAT / BNAT for machine tools are the result of BAT / BNAT at the components level. Therefore, individual measures are described below.

The reduction of environmental impact of manufacturing processes demands accurate knowledge about the existing material and energy flows as well as the origins of associated environmental impact.

In addition to known standards in industry [13, 14, 15], there is no agreement for environmental impact evaluation of EDM processes.

For EDM machine tool type, because they are not subjected to high stresses during the processing, regarding the environmental relevancy, fields of optimization are given in the manufacturing phase (e.g. substitution of materials with alternatives such as metal foam).

The operational phase of the EDM machine tool type can be optimized with respect to the choice of electrode tool and the most suitable working parameters.

Although Best Available Technology is not yet described, there are improvement potentials which will become available in the future. This goes together with the innovative spirit of the sector and it will have enormous impact on the cutting of energy consumption.

In this paper a concept to visualize the specific environmental attributes of the EDM process has been proposed, but given the typically long lifetime of the machinery considered, any implemented measure is projected to produce significant overall savings results only over the medium to long-term.

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