

REVIEW

Metal Swarf and Cutting Fluid Waste Management in Metal Processing Industry

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ABSTRACT

Metal swarf is unavoidable material in metal processing industry, also metal swarf treatment lead to cost savings by metal waste reduction and removing the cutting fluid waste, that cause to increasing process stability and metal value. It is interested that in how to recycle metal swarf especially when swarf surrounded by cutting fluid, is considered because these waste are classified as hazardous waste. The aim of the study is to increase the process efficiency and environmental performance by metal waste reduction at source which are the first step of the waste hierarchy. The results of the experiments showed that 3391 tons of metal swarf coated with cutting fluids which contained 2.29% cutting fluid be produced annually. It has been found that if the total amount of cutting fluid on the swarf surface be reduced to less than 1% leads to a significant mass reduction in the amount of hazardous waste. In this research, it was considered, 107,922 USD profit at the end of first year and 205,278 USD at the end of second year would be obtained by reducing the cutting fluid content from 2.29% to 0.8% with using cutting fluid that surrounded metal swarf separation equipment in manufacturing location.

1.Introduction

Metalworking fluids are performed as multiple functions in the metal processes. All metal-working fluids are prepared within a specific concentration range, also these limits are considered and

suggested by the manufacturer for ideal performance. Genarally the fluids are defined, as independent from the metal manufacturing process, and usually metal working fluids (MWFs) are defined in the coolant, lubricant, grinding oil and cutting fluid process. Cutting fluid

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waste residues destroy electronic components during the process and the inside of the machine cabinet be created unpleasant brown layer. The companies realize that must be changed their thinking considerably, the most return out of their machine tools are swarf and cutting fluid. Metalworking fluids consist of 1 to 2 percent of the total cost of the part being produced, and impact on the whole of overall manufacturing costs about 95 percent^[1]. In this research new approaches and innovative techniques have been adopted. These approaches are^[2] examined under the heading of environmental process as end-of-pipe and waste minimizing technologies^[3]. Collecting and classifying waste according to legal regulations and technical conditions need to be managed differently, as an appropriate recovery, storage and disposal facilities, also lead to national waste management plans or plans for increasing hazardous waste reduction efficiency. It is important, the correct identification of the wastes to establish a reliable inventory in the preparation of national waste management plans be considered. Waste reduction at the source increases the company's environmental performance and reduces waste management costs. In the scope of this research, eco-efficiency in an Organized Industrial Plant (OIP) in the framework of the Cleaner Production practices are investigated. The concept of sustainability is becoming more important among different organizations and stakeholders in the world. The IPPC (Totalitarian / Integrated Pollution Prevention and Control), Directive of the European Union (EU), Sustainable Industrial Policy (SCP / SIP) in 2008, and regulations on waste prevention and reduction, issues such as natural resource efficiency has been the basic principles of industrial growth. Eco-efficiency is based on the principle of using a high-yielding production technology and administrative tools with less natural resource and decrease energy consumption and waste generation. The concepts of sustainability and efficiency have been changed in coordination with the total quality concept. KAIZEN, 5S, TPM etc. Production models; by the aim of improving the relationship between environmental production and to make the sustainable structure, have been considered. The introduction of waste reduction practices in the industry can lead to a reduction in the total amount of hazardous waste produced as a whole. Waste minimization techniques depend on factors such as cost of raw materials, cost of energy, cost of disposal, and value of recovered materials^[4]. With this characteristic, it is not only environmental concerns but also many other areas have been considered such as conservation of natural resources, industrial efficiency and economic development. In the production process, the "natural resource and energy consumption" are controlled

by a holistic approach to minimize hazardous waste and emission. This approach is defined as pollution control or (end-of-pipe). The World Business Council for Sustainable Development defines waste minimization as a goal to reduce productivity. One of the reasons for increasing environmental problems is the high cost of investments based on end-of-pipe approach to environmental protection^[5]. In addition, increased environmental awareness over the last 20-30 years has led to consumers in developed countries to prefer products and processes that are less harmful to the environment^[6]. Each year, a plenty of metal swarf waste is produced from the industries. These solid waste, mixed with cutting fluids, and cause to some difficulties to recycle. Metal swarf wastes recycling enhance the economic benefits and decrease the negative environmental impact of manufacturing. Metal swarf waste from the industries is a considerably environmental and economic concern. It has been found during the experiments that the separation efficiency can be significant and stable as long as the process performance^[7]. The original car engine part generating facilities in operation, was established at the beginning of the 1970s in Turkey. Today, the Bursa location of the plant is one of the biggest production points in the world. In particular, the implementation of tools such as the 16,949 Automotive Quality Management System by main suppliers and sub-contractors accelerated in this process. Waste reduction is becoming an important process in the field of environmental engineering. Furthermore, the final disposal may cause long-term environmental damage. Suggested method has a wide range of benefits for the industry because it increases energy efficiency by reducing waste production.

2. Waste Reduction Concept

The majority of organizations aim at sustainable development in terms of green concepts and the evaluation of green performance is one of the important parameters^[8]. In pollution control, emissions and waste are monitored, removed by pollution control equipment, and little change is observed in existing production processes^[9]. These technologies are similar examples for reducing the wastes generated at the end of processes such as filters installed in chimneys or other methods^[10]. Waste reduction is directly associated with environmental impacts and economic performance^[11]. The concept of "cleaner (sustainable) production" is defined by the United Nations Environment Program (UNEP) as the continuous application of an integrated environmental strategy to increase efficiency and reduce risks.

According to the definition of waste management and usage activities;

- 1) Reducing material usage and energy consumption for efficient production processes, is considerable by avoiding hazardous waste.
- 2) Reducing the adverse effects of products throughout the life cycle from handling of material to the final disposal stage.
- 3) For services, environmental concerns are integrated into the design and service phases^[12].

Reasons that push factories to become eco-friendly can be summarized as:

- 1) Environmental actions and the growing pressure of public opinion,
- 1) Increase in legal regulations,
- 2) Increases in costs,
- 3) Increase in technological risks and accidents,
- 4) Increased social responsibility
- 5) Gaining social reputation and respectability,
- 6) Implementation of Environmental Management Systems,
- 7) Increase in Total Quality Management practices,
- 8) Increased voluntary organizations that protect the environment,
- 9) The aim of sustainable development^[13].
- 10) Reuse and recycling facilities^[14]
- 11) Less waste and contamination.

3. Materials and Methods

3.1 Research Methodology and Analysis Framework Creation

In this study, qualitative research design (approach) was used. Research data; field survey, analytical measures for the product/wastes, was investigated by face-to-face interviews and evaluation of the data from a statistical point of view. General information about the company was obtained and investigations have been made in the production departments of the workplace under the supervision of the environmental officer. Field observations were conducted periodically in two periods of three months to understand production processes and determine waste generation points. Afterwards, a questionnaire was prepared about the subjects that are required to obtain detailed information about environmentally sensitive production activities. Raw materials, product range, yield loss and environmental impact parameters were determined by continuous measurement method. Improvement proposals have been tried to be developed about the identified priority issues. Numerical data were obtained by using the Sartorius Entris® 623I-IS precision balance in all units in the production and weight-based measurements at each stage from the raw material input to the final product recovery. The cutting fluid which is used in the processing technol-

ogy was separated from the swarf then they are weighed and measured. During the Product Flow, the first priority in the waste hierarchy was examined in the waste management practices carried out in an original equipment (OE) producing facility in the automotive industry within the framework of research and development studies to reduce waste in sources. Purpose of the study; is increasing the production efficiency, creation of economic incentives for the sustainable development of the plant and improvement of the environmental performance. This study contributes to the development and integration of environmental and economic objectives with successful applications. The concept of sustainable development and social justice is combined with economic production^[15]. Turkish legislation and the environmental criteria of the European Union, reduce the pollutant discharge and increasing the efficiency of raw material consumption and efficient energy use^[16]. Separation of wastes at the source will result with less energy and material use and less hazardous waste generation. Scope of work, gravimetric analysis of raw material product (Sartorius Entris® 623I-IS 'Internal Calibration' 620 Gr / 1 mg Precision Scale), mass balance profile of the components entering and exiting the system, determination of actual losses and leaks, waste generation per crop, interpreted by SPSS 22.0 statistic program.

In the automotive industries, cutting fluids and metal swarf which are produced during the metal process. After processes the metal swarf which is covered by cutting fluids discharged to the swarf-conveyor, then this mixed waste should be separated to the metal swarf and cutting fluid. Cutting fluids and metal swarf are the main problem during the transportation and treatment process. Particularly the recycling and disposal of fluids and metal swarf can resolve the environmental pollution problems and cost reduction is considered. The production plant aims to make safety, environmental and cost efficient plant by using high-tech production equipment. In accordance with the confidentiality agreement signed with the company.

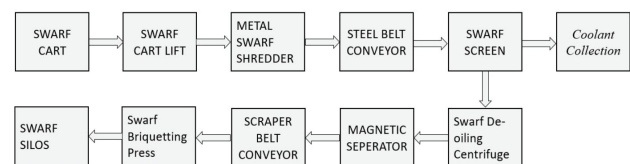


Figure1. Schematic Diagram of Process Steps^[17]

4. Results

4.1 Waste Management

Specially the recycling and disposal of fluids and metal swarf is dangerous. Oil-based cutting fluids and metal

swarf affect on living and working environment. Waste Management is applied to solve waste problems in relation to production processes^[18]. It is one of the most analytical and quantitative methods for achieving sustainable development^[19]. Environmental concerns are focused on the firm's performance, and therefore, lean manufacturing techniques are often applied^[20]. In accordance with the principles of waste reduction, the cutting fluids and swarf quantities in the production flow in the OE plant were measured separately for each process, and the findings obtained were shared and some improvement suggestions were made in terms of the main production processes and waste management.

4.1.1 Determination of Changes in Product and Cutting Fluid Mass

It is emphasized that these changes and productivity-oriented activities, which are aimed at the development of the production sector. In the study, gravimetric analyzes were made on the product and cutting fluid mass. The amount of cutting fluid per part was calculated by measuring the weights of the component which is coated by cutting fluid. The amount of swarf, weight of the raw material and the weight of product after the process were measured. As a result of the evaluation studies, 74% of the company's waste swarf is pre-formed and the first turning operation of the part that has been realized as A (Rough Turning) section. It was observed that 9% of the remaining part was from the second (B), and 17% was from the C (Milling) section (Figure 2).

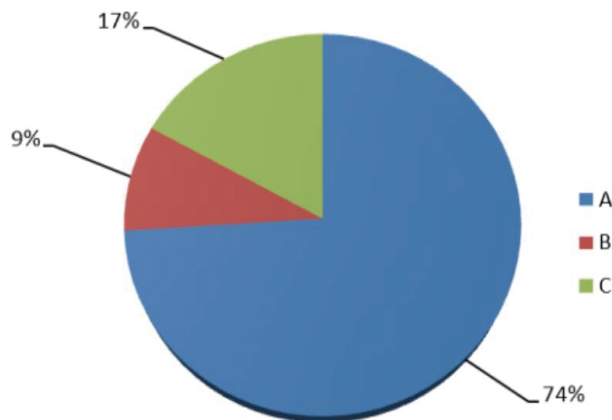


Figure 2. Percentage of Waste Disposal in the Whole Process

From the beginning to the end of the production process, total of $24,875 \pm 1,123$ gr waste cutting fluid carried per product. It was seen that 91% of the cutting fluid waste carried on the product was from part A, 1% was from B and 8% was from C section (Figure 3).

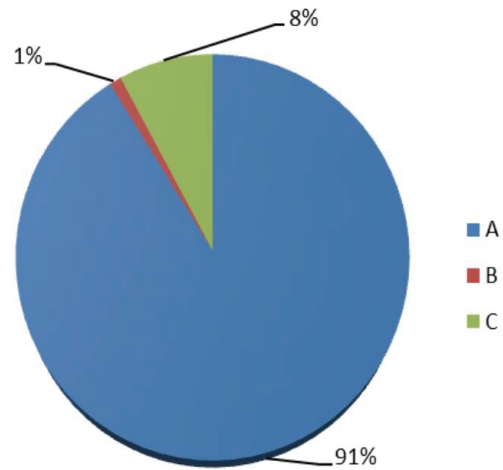


Figure 3. Percentage display of the amount of waste cutting fluid carried on the process product

5. Discussion

As you can see in the figure below, the process of production in the industry is carried out in two selective method. In the first method(a) the swarf and surface cutting fluid waste after treatment(filtration or adding chemical), the cutting fluid is returned for reuse to the system. High efficiency filtration leads to increase the fluid life. previously, the high cost of filtration sheet and equipment was frustrating factor. Now the high cost of metalworking fluids and the fluid disposal, cause to implementing the coolant filtration.

But in the second one(b) the mixed of swarf and cutting fluid be separated by equipment in the manufactory, then the cutting fluid waste send to licensed firms to elimination and swarf be sold as separately.

5.1 Waste Management Efficiencies

In the metal working industry, the direct swarf has a negative impact on the environment. Due to the presence of swarf values in the markets, these metal waste are sold to licensed recycling companies. However, if the cutting fluid in the substance contains more than 1% of the dangerous specifications, these materials may be sold to licensed waste disposal companies or hazardous waste recycling companies at lower prices, and this is an important financial loss for the company. According to the principle of reducing the waste at the source, de-oiling process from the swarf was prioritized. As a result of observations in the scope of the study, the mixed collection of cutting fluid waste and metal swarf in the same container was determined as the main problem of swarf management. In the waste storage area, it is determined that the centrifugal unit is designed to gain only mineral waste cutting fluid, but for

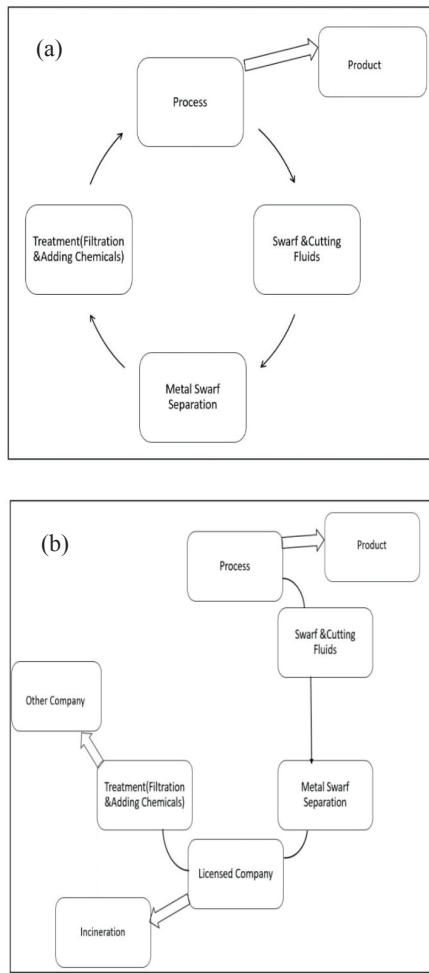


Figure 4. Cutting Fluid Removal Process Methods Schematic Diagram

the waste metal recovery, briquetting system is needed.

75% space saving in storage and ease of transportation,

Easier management of the final waste product,

It is proposed that the last product can be sold to licensed enterprises with higher prices.

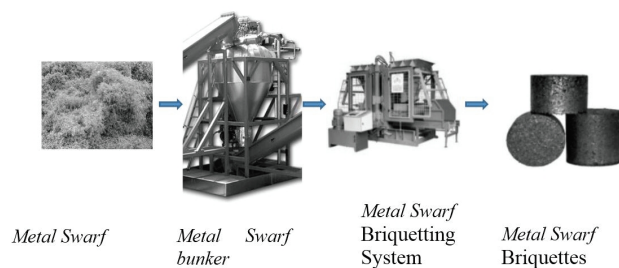


Figure 5. Sample of recycle unit for metal swarf coated by cutting fluid

5.1.1 Cutting Fluid Leaks and Spills

As a result of the observations, it was determined that

most of the occupational health / safety and environmental problems at the factory were caused by different types cutting fluids adhere to metal swarf used in metal processing. For the removal of this nonconformity, it has been proposed to increase machine equipment maintenance, and to create systems that target recycling to avoid oil spills (Figure 5).



Figure 6. Cutting fluid leaks at the bottom of the machines

5.1.2 Metal swarf and Cutting Fluid Separation by Briquetting Unit

This system main compress cylinder compresses the metal swarf into a smaller briquettes. The briquette system is beneficial for automotive and metal processing industries when they have a low volume of space that it is useful to store metal swarf waste, also this means that amount of metal swarf waste production in the company. Recommended metal swarf and cutting fluid separation by briquetting unit:

Cutting fluid Separation Centrifuge

Metal swarf Breaker

Briquetting Press

Screw Conveyor

Steel Belt Conveyor

Metal swarf shells

Cutting fluid Collection System

The swarf receptacle must be available

In this way, it is possible that the waste metal swarf in dangerous class will enter into a recyclable waste character.

5.1.3 Cutting Fluid

Cutting fluids be used in metal cutting process for the last 200 years. In the beginning, cutting fluids have been used in brushing to lubricate and cooling the machine tool.

There are different types of cutting fluids which are categorized as cutting fluid and they can be found in the market broadly. Cutting fluid plays a significant role in metal process and has an effective impact on shop productivity, tool life and work quality. Waste management has been complex and expensive operation. Environmental

responsibilities are the main factors in waste disposal. Many companies and regulatory agencies operate and pay cost for environmental cleanups and poor waste disposal practices.

Cutting fluid management provides following means:^[21]

- It is environmental friendly manner;
- Efficient productivity with less costs;
- Increased competition
- Environmental protection increase
- Manufacturing high quality products
- Healty and safety ambient creation

Swarf is the major type of waste produced by fabricating process then it can be sold back to metal swarf dealers at a fraction of the original purchase cost and might be contaminated by fluids .

Machining operation life through recycling method such as filtering can be extended which leads to remove the cutting fluid swarf, also it depends on the size of the particles and the type of cutting fluid^[22].

5.1.4 Metal Swarf Shipping Tools

Transportation vehicles used for collecting swarf waste from different machines, leaks at the base of these vehicles in the temporary storage area during the loading and unloading have been identified as a problem affecting the whole operation in terms of occupational safety and environment.

It has been suggested to take action on the repair, maintenance and renewal of these vehicles and to investigate the possibilities of manufacturing with a different design. Although oil-based fluids are susceptible to the problems which are remain at several levels. Figure 7 shows the tools.

5.1.5 Waste Containers



Figure 7. Metal swarf transport vehicles

It has been determined that waste containers are not easily opened and closed in the plant, which contains temporarily stored domestic waste, recyclable waste, and hazardous waste. Figure 8. shows suggestion for one-handed opening and closing waste container covers. It has been determined that planning and improvement work on waste generation and disposal is required.



Figure 8. Waste containers

It is stated that the implementation of the 5S Sort (Seiri), Arrangement (Seiton), Cleaning (Seiso), Standardization (Seiketsu), Discipline (Shitsuke) rule, which is accepted as one of the management models in the enterprises, will contribute to the work of the company. Figure 8 shows an example.

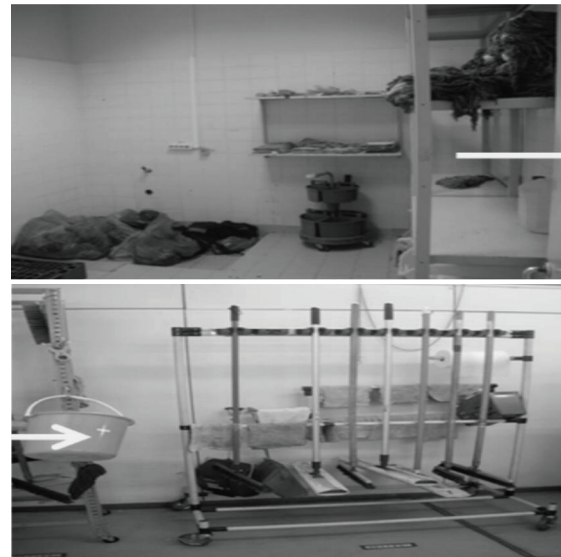


Figure 9. The current state of the plant according to the 5S rule and the situation that should be seen^[23]

In addition, different types of waste disposal and fluid cutting fluid collection containers were directly affected by waste disposal costs. In the examinations, it was observed that there were problems related to the subject, and it was determined that different types of waste thrown into containers which reduce the recycling efficiency and increase the amount of waste. Figure 10 shows examples of this issue.



Table 1. Statistical evaluation of cutting fluid weight, swarf weight and cutting fluid / swarf ratio values by machine types

	Group	N	Ave.	standard deviation	F	P	Mean Difference
Cutting Fluid weight	Turning	96	2.314	1.158	752.24	0	2>1
	milling	96	3.533	2.095			3>1
Swarf Weight	Turning	96	134.55	0.482	1956273.26	0	1>2
	milling	96	114.86	0.482			1>3
Cutting fluid/Swarf Weight	Turning	96	1.719	0.86	17.454	0	3>1
	milling	96	3.076	1.823			5>1

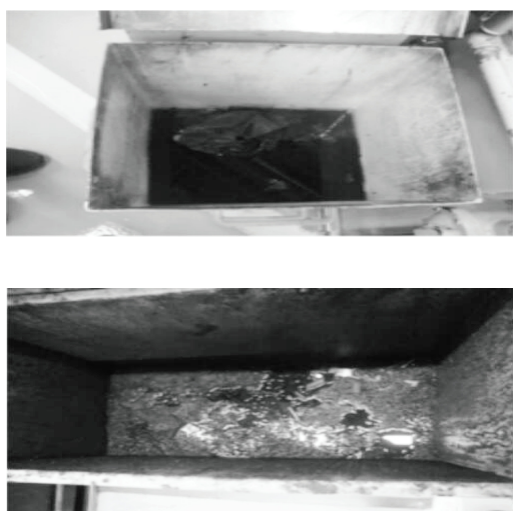


Figure 10. Swarf waste and waste cutting fluid containers

Chemical and water tanks locations and safety rules have been reviewed. Some places where chemical tanks are used in the factory represent a danger to occupational safety.



Figure 11. Representation of chemical and water tanks

5.2 Evaluation of Data and Discussion

The main aim of the study was to determine the waste reduction targets at the source based on the amount of cutting fluid and swarf, also studies were conducted in this direction. Data were analyzed by using SPSS for Windows 22.0 program. Mean, standard deviation was used as descriptive statistical methods in the evaluation of the data.

(One way) Anova test was used to compare quantitative continuous data between more than two indepen-

dent groups. Scheffe test was used as a complementary post-hoc analysis to determine the differences after the Anova test. Pearson correlation analysis was applied to the continuous variables of the study. The findings were evaluated at 95% confidence interval and 5% significance level.

Cutting fluid weight, swarf weight and cutting fluid / swarf ratio during statistical evaluations are given in Table 4.1 according to machine types.

One-way analysis of variance (Anova) was used to determine whether the mean oil weight scores of the machines participating in the study showed a significant difference according to the machine type variable. ($F=752.240$; $p=0<0.05$).

A complementary post-hoc analysis was conducted to determine the sources of differences.

In the next step (Anova) was used to determine whether the mean swarf weight scores of the machines participating during the study showed, according to the machine type variable. ($F=1956273.267$; $p=0<0.05$).

In the same way, the difference between the Cutting fluid and swarf mixed ratio of the machines was statistically significant ($F = 17.454$; $p = 0 < 0.05$). In the experiments, the most significant relationship was determined as turning and milling and average cutting fluid and swarf weights were examined.

Figure 12 shows the results of the measurement for cutting fluid weights, Figure 13 the results of the swarf weights and Figure 14. Cutting fluid / swarf ratio.

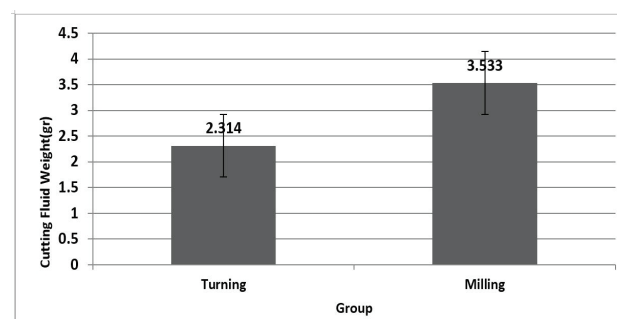


Figure 12. Cutting Fluid Measurement Results

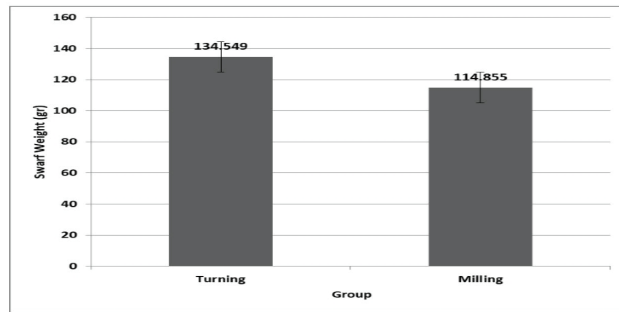


Figure 13. Swarf weights measurement results

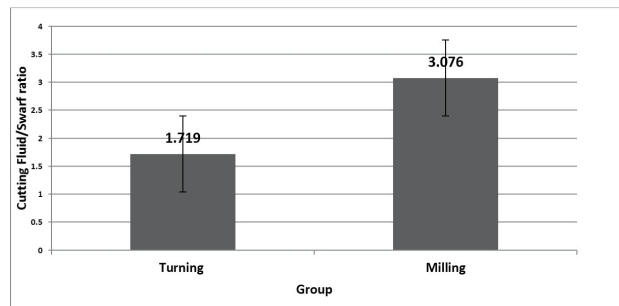


Figure 14. Cutting fluid swarf rate

The amount of cutting fluid remaining in the parts in the machines was evaluated for each process step from the raw metal to the final product. Metal swarf production depends on type of metal process system, so unnecessary parts are cut by using milling and turning devices. Metal swarf volume is approximately 15 to 30 times more than the raw materials generated before process.

Table 2 shows the correlation between the weight of the swarf and the cutting fluid in the machines.

The relationship between the weight of fluid and swarf were investigated. Cutting fluid increases with increasing swarf in turning machines (2nd step). The positive relationship between the weight of the swarf and the cutting fluid weight in these machines supports the expected result (cutting fluid with swarf). The lack of relationship between the weight of the swarf and the cutting fluid weight

Table 2. Correlation between swarf weight and cutting fluid in machines

	Boyut	Boyut	N	r	p
Turning	Swarf Weight	Cutting Fluid Weight	96	0.204*	0.046
Milling	Swarf Weight	Cutting Fluid Weight	96	0.042	0.686

in the milling machines (step 3) indicates that the amount of swarf is independent of the cutting fluid or the oil is independent of the amount of swarf.

Figure 15 shows the amount of sales of cutting fluid and swarf mixture each month. It is observed that the highest income was in April and September due to waste flake formation. It is considered that waste oil will be disposed of in IZAYDAS.

In Table 4.3 and Figure 16, the first investment required to reduce the cutting fluid in metal swarf to less than 1% of total weight and the data on the earnings to be obtained at the end of the operating cost are presented. Accordingly, due to the first investment and operating costs in the first year, the annual gain is still advantageous compared to the sale of swarf and cutting fluid, so reduction of 1,239,851 USD is obtained. In the 2nd and 3rd years, a gain of 1,337,207 USD can be obtained from the sale of cutting fluid metal.

In this way, it is possible to reduce the amount of metal waste during production process and also to prevent or minimize the amount of oil as a hazardous waste.

6. Conclusion

The automotive sector in Turkey has a significant value as a leading sector. Sustainable production culture is rapidly spreading within the framework of changing standards in the world. In this context, a study was carried out on waste reduction applications in an international enterprise operating in the original equipment (OE) production in

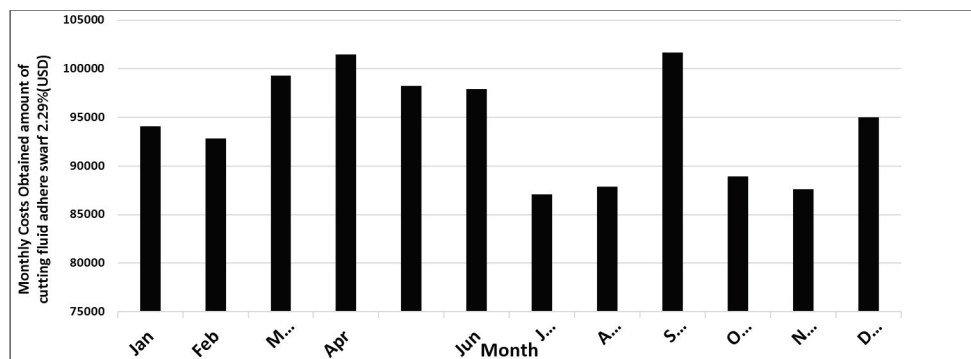


Figure 15. Monthly costs obtained amount of mixture of cutting fluid adhere the swarf 2.29%(USD)

Table 3. Cost analysis for waste management (2014)

Time	Cost factors	USD
1. Year	Device Cost (USD) -First Year	-97,356
	Swarf without cutting fluid cost (USD/Annually)	1,390,839
	operating cost (USD/Annually)	-34,306
	Cutting Fluid Remove cost (USD/Annually)	-19,325
	Profit (USD/Annually)	1,239,851
	Annually difference of Swarf coated cutting fluid Sales Price and Equipment Separated Cutting Fluid and Swarf Sales(USD/Annually)	107,922
2. Year	Swarf without cutting fluid cost (USD/Annually)	1,390,839
	operating cost (USD/Annually)	-34,306
	cutting fluid Remove cost (USD/Annually)	-19,325
	Profit (USD/Annually)	1,337,207
	Annually difference of Oily Swarf Sales Price and Equipment Separated Oil and Swarf Sales (USD/Annually)	205,278
3. Year	Swarf without cutting fluid cost (USD/Annually)	1,390,839
	operating cost (USD/Annually)	-34,306
	cutting fluid Remove cost (USD/Annually)	-19,325
	Profit (USD/Annually)	1,337,207
	Annually difference of Swarf coated cutting fluid Sales Price and Equipment Separated cutting fluid and Swarf Sales (USD/Annually)	205,278

Turkey. According to the findings, it was determined that the amount of cutting fluid waste increased in the process stage due to the amount of metal swarf waste. It has been considered that during the waste management, the swarf covered cutting fluid has been converted into a non-hazardous waste by separating each other in the plant and reducing the mass of the cutting fluid concentration to less than 1% also it is switch to a reduction and recycling-waste method. Recycling methods of metal swarf and cutting fluid lead to generate a profit by converting to reusable products. At the end of the study, it has been considered that the amount of cutting fluid can be reduced to 0.8% and difference of swarf coated cutting fluid waste selling cost and swarf and cutting fluid separated selling cost is about 107,922 USD in the 1st year, and 205,278USD from the second and third years be achieved, also this gain continues every year. In general, it is seen that the separated cutting fluid and metal swarf sales are more profitable than swarf and cutting fluid mixture sales.

It is important to minimize the environmental impacts of the product during or after the process. Understanding the principles of observation, methodical measurement and improvement manners are the basis of these study. In addition, it is important to ensure that the waste reduction activities to be implemented in such enterprises will bring both economic and environmental benefits to the business authorities correctly. This paper recommends that the effect of cutting fluid on processed surface quality, performance and environmental safety should be important factors. Due to the development of relations between metal process efficiency and environmental standard, becomes more important, especially for swarf and cutting fluid of metal working which cause environmental pollution with decreasing the long life and high stable quality requirements. The effect of cutting fluid on metal swarf surface integrity and service performance will be considered in new technologies. After the improvements in this research, the economic gain will be obtained obviously.

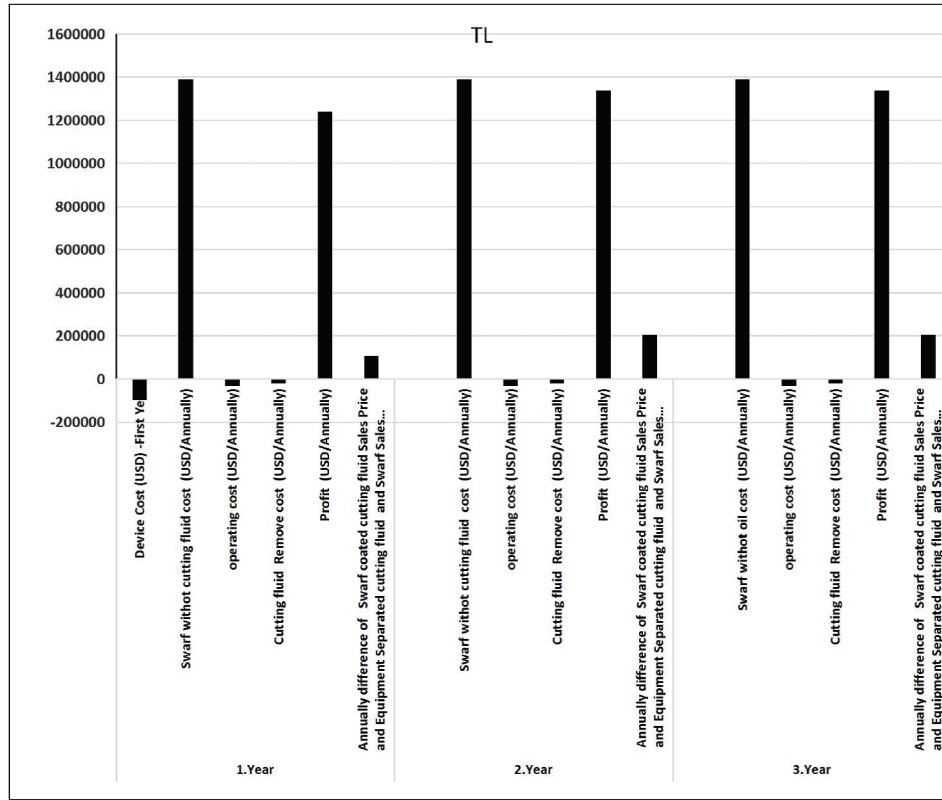


Figure 16. Cost analysis for waste management

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