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IOT BASED INFORMATION SYSTEM FOR CLEAN MANUFACTURING

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Abstract. *Cutting fluids (CF) are crucial part of the cutting process. CF are used because they improve tool life, surface quality, and productivity. CF, on the other hand, have negative effects on human health and the environment, necessitating a reduction in their use. This paper discusses different types of CF, mineral and vegetable, as well as their negative impacts on the environment and humans. The use of CF could be reduced, and cleaner production achieved while maintaining the required processing quality and productivity by monitoring and analyzing the cutting process. This paper proposes a smart information system model that includes collecting, filtering, and storing data from temperature and flow sensors in order to optimize the use of CF. The proposed system represents a basic starting point for optimizing the use of CF. The information gathered as a result of system implementation is required for further analysis and processing. The collected data are required to determine the relationship between process parameters and sensor data, allowing the development of a model to optimize the use of CF. This information system would be built on the Internet of Things and cloud services in line with Industry 4.0.*

Key words: *Cutting fluids (CF), Environment, Manufacturing Engineering, Internet of Things (IoT), Information System*

1. INTRODUCTION

Throughout history, industrialization has been a major contributor to pollution and disregard of the environmental issues, resulting in an unsustainable production model [1]. The concept of the smart factory has been promoted by the Fourth Industrial Revolution (4IR), also known as Industry 4.0. There are several terms for the smart factory due to a lack of consensus on common nomenclature, such as, intelligent factory, factory of the future, cloud-based factory and digital factory. The entire shift in the way of manufacturing is currently being led by smart factories [2]. The 4IR technologies are required for resource optimization to achieve economic, environmental, and social sustainability [3].

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With the latest advances in information and communication technology (ICT), Industry 4.0 has enabled a transition from traditional to advanced manufacturing processes [4]. The 4IR was defined as, “networks of manufacturing resources (manufacturing machinery, robots, conveyor and warehousing systems, and production facilities) that are autonomous, capable of controlling themselves in response to different situations, self-configuring, knowledge-based, sensor-equipped and spatially dispersed and they incorporate the relevant planning and management systems” [5]. The sensors provide the data and connectivity that form the basis of the "factory of the future". It was determined that the factories of the future will be data-rich environments [6].

To protect resources, reduce energy consumption, waste and toxic emissions (thus achieve cleaner and more sustainable production), optimized technological improvements and process planning are required [7]. The 4IR deployment is given the highest priority because it can boost productivity, but a bigger emphasis must be placed on cleaner production [8]. The 4IR must strive for a sustainable and cleaner production system. In order to achieve cleaner manufacturing and lessen the influence on the environment, the smart factory model is essential [9].

Cutting fluid (coolants and lubricants) has been used in engineering manufacturing for hundreds of years, and it plays an important role in part processing efficiency and surface quality [10]. CF can be categorized according to their phase, composition, source, and application method. They can, however, be broadly classified into four major categories, as illustrated in Fig. 1.

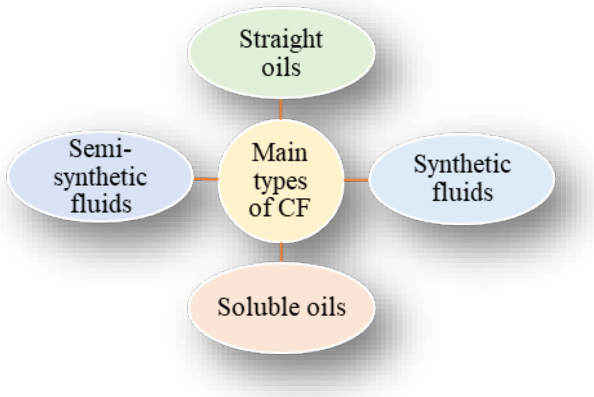

Fig. 1 Main categories of CF

CF are essential to the cutting process. CF provide advantages such as increased tool life, dimensional accuracy, and a good surface finish, all of which contribute to high production rates. CF management that is organized and regulated is one of the starting points for establishing a quality system and ensuring the humane aspect of quality aimed at environmental protection [11]. This is because, at the same time, CF have a negative impact on human health and the environment, necessitating a reduction in their use. Positive and negative effects of CF are shown in Fig. 2.

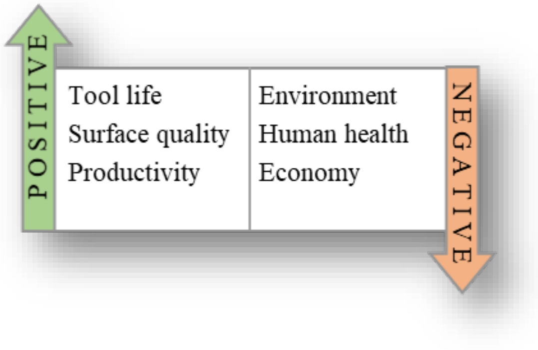

Fig. 2 Positive and negative effects of CF

The Internet of Things (IoT) has ushered in a new era by enabling ubiquitous and exponential connectivity of billions of devices and access to them from any location at any time [12]. IoT-based sensors can be regarded as a solution for efficient manufacturing process monitoring and management [13]. There are numerous "smart sensors" available today that can collect data during the cutting process. By processing and analyzing data collected from cutting process temperature sensors and CF flow sensors, the use of CF can be optimized.

Cooling and lubrication are the primary functions of CF. The primary objectives are to reduce friction between the tool and the material being machined while also dissipating any heat generated. The amount and flow of CF are directly related to the processing temperature [14].

The cutting fluid also serves to flush any chips or swarf away from the cutting zone. The secondary functions of CF include extending tool life, increasing productivity, improving surface quality, preventing corrosion, and cleaning tools and workpieces.

Fig.3 shows the primary and secondary functions of CF.

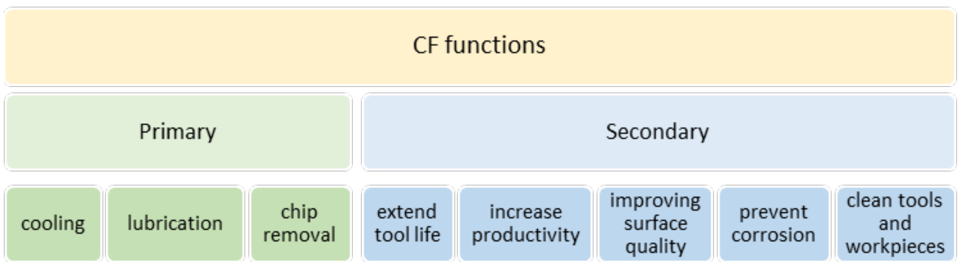

Fig. 3 Primary and secondary functions of CF

The main concern about CF lies in their chemical composition. Anti-corrosives, anti-foaming agents, and biocides are added components that are hazardous to machine operators and the environment. Additives are added to achieve the required physicochemical characteristics, i.e. improved functional properties of CF, as shown in Fig. 4 [11].

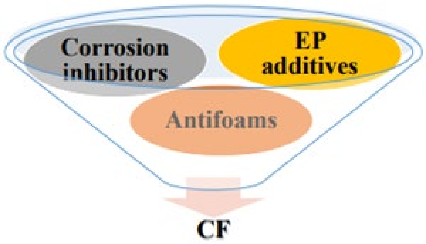

Fig. 4 CF additives

After application, cutting fluids carry away small particles such as wheel grains, machined chips, and other impurities. As a result of contamination, all cutting fluid must be replaced and disposed of at some point. However, this treatment and disposal is frequently done incorrectly, causing environmental damage [15].

To regulate improper CF treatment and disposal, the EU enacted legal requirements for the use of all types of CF in manufacturing, as well as their treatment and disposal [16]. Regulation compliance and limiting the values of CF use are insufficient. The global use of CF is estimated to be 2.2 billion liters, with 54% used in the cutting process, indicating that the machine industry is the primary polluter of the environment [17]. Therefore, the use of cutting fluids must be reduced in order to protect the environment.

The optimal amount of CF is the smallest amount that should be used at specific process parameters in order to meet quality requirements while maintaining productivity. To achieve zero (or at least reduced) levels of pollution and toxicity, careful consideration should be given to the type of CF used and process analysis [11]. Inappropriate application of CF poses a significant problem. The appropriate CF is chosen based on the machining process, workpiece, and tool material. Aside from the use of degraded CF and CF that is unsuitable for the requirements of the metalworking process, the most serious issue with CF application is the use of excessive quantities. The optimal amount of CF is chosen with the following factors in mind: tool condition, tool type and shape, machine conditions, and specific processing parameters (depth of cut, cutting speed) [11].

Based on the previous, MQL methods are used to reduce the amount of CF used during a cutting process. The amount of CF spent by using MQL is about 2 - 8 ml/min, which is less than a normal (classical) lubrication, which consumes about 12l CF/min [18]. Furthermore, in terms of environmental aspects when selecting CF, there is an increasing tendency to use vegetable oils due to their ability to be degradable [19]. This paper discusses the different types of CF, mineral and vegetable, as well as their negative impacts on the environment and humans.

Also, the possibility of using sensors to control the flow of CF and the possibility of applying IoT is presented. A model of a smart information system of the cutting process can be established by monitoring process parameters and analyzing data obtained from sensors. This paper aims to use IoT in the control of CF flow during CNC machining.

2. CHARACTERISTICS AND ENVIRONMENTAL ASPECTS OF CUTTING FLUIDS

Cutting fluids (CF) are widely used and today are an indispensable part of different machine operations. As the cutting operations have become staider, the formulation of cutting fluid has become more complex in order to meet operation requests and environmental aspects. Based on the previous, CF can be classified into three types: oil-based (neat oils), water-soluble fluids and gas-based [20].

2.1 Oil – based cutting fluids

The term neat or straight CF refers to oils based on mineral, animal, or vegetable oil that do not mix with water [20,21]. Straight CF can have an oily and waterless appearance.

Mineral oils, whose composition is based on petroleum derivatives, are frequently used due to their favorable lubricating properties. Vegetable oils include jojoba, palm, sunflower, and other oils [22]. These lubricating oils also contain various additives such as fatty lubricants, extreme pressure additives, thickness modifiers, fragrances and polar additives in order to improve their characteristics [23]. These oils are only used for cutting operations at low temperatures and speeds [20].

The benefits of using this type of oil include improved lubrication, less clogging, and corrosion resistance. However, the main disadvantage of these oils is their flammability and low cooling capacity (Table 1). Chemical additives, such as sulfur, chlorine and phosphorus, are always added to these oils to form a thin layer of film on metal surfaces. This addition of additives is one of the extreme pressure additives and the role is to reduce the friction between the chip and the tool when cutting metal [24].

2.2. Water-soluble fluids

Soluble or emulsified oils are a suspension of non-dissolvable oil droplets in water. For this type of fluid, the oil is mixed with an emulsifier to improve the emulsion stability.

Emulsified oils (soluble oils), chemical (synthetic) fluids, and semi-chemical (semisynthetic) fluids are the three types of water-soluble fluids [20]. The basic components of emulsified oils are mineral or vegetable base oil, emulsifier and additives [21]. During metal processing, soluble oil is mixed with an emulsifier, usually in a ratio of 1:20 – 1:30. The role of the emulsifier is to disperse the oil in water to form a stable emulsion. The presence of water in the emulsion contributes to cooling, while the presence of oil reduces oxidation. Such emulsions are used at high speeds and low pressures where temperature increases significantly [20]. As advantages of using emulsified oils, it can be stated that there is no danger of fire and a lower rate of oil fogging, lower costs because water is used for dilution and lower temperature, which enables higher processing speeds. The disadvantages of emulsified oils are the development of bacteria and fungi due to the presence of water (Table 1). The presence of bacteria in the emulsion results in the separation of the emulsion. In addition, bacteria growth can lead to corrosion and poor lubricating properties [25]. The development of bacteria can be prevented by using various biocides, but this has a negative impact on the operator [20].

Synthetic CF is made from chemicals that have been diluted in water with additives. They have a clear watery appearance, almost transparent. Synthetic CF has excellent cooling, good corrosion and microbial control, and is used for low force operations due to insufficient lubrication, which is a disadvantage [24].

Semi-synthetic CF are chemical emulsions, which contain mineral oil diluted in water with some additives. The main reason for dissolving in water is to reduce the size of oil droplets which make the CF a more effective lubricant. They have translucent appearance. The benefits of semi-synthetic CF include good cooling and rust control, as well as microbial control. The main disadvantage is easy contamination with other machine fluids and foam (Table 1) [23].

2.3. Gas-based cutting fluid

Gas-based CF refers to refrigerants that are gaseous at room temperature and are eco-friendly lubricants. This type of lubricant must be in the form of a gas or a coolant under pressure when used. Gas-based CF are air, nitrogen, argon helium and carbon dioxide. Since gaseous lubricants are considered inert gas, they have a high corrosion resistance that prevents oxidation of tools and treated surfaces [20].

Table 1 Characteristics of CF [21,26,27]

Type of CF → **Characteristics ↓**	**Straight oils**	**Soluble oils**	**Semi - synthetics**	**Synthetics**
Appearance	Oily, waterless	Milky color, aqueous	Translucent	Transparent aqueous
Use	Heavy-duty material, corrosion inhibition	Coolant and lubrication, corrosion inhibition	Coolant and less lubrication than for aqueous oils	Excellent coolant, minimal lubrication
Advantages	Excellent lubricity and rust control	Good lubricity and cooling	Good cooling, rust control and microbial control	Excellent cooling, microbial control, non-flammable, nonsmoking, good corrosion control, reduced misting and foaming properties
Disadvantages	Low cooling, fire hazard, create mist or smoke, limited to low-speed and heavy cutting operations	Rust control problems, bacterial growth, evaporation losses	Foam easily, stability is affected by water hardness, and easily contaminated by other machine fluids	Poor lubricity and easily contaminated by other machine fluids

2.4. Vegetable oils

Vegetable oils are special type of so-called pure oils. Vegetable oils are triglycerides or fatty acids that are composed of chains of carbon atoms, mainly 14-22 atoms. Vegetable oils with this triglyceride structure provide good CF characteristics. Long chains of fatty acids make it possible to create high-strength films in contact with metal surfaces, which reduces the effect of friction and wear. Vegetable oils are not used in their pure, natural form. Instead, various techniques and additives are used to increase their efficacy and efficiency [21]. Vegetable oils can be categorized into several groups based on the source or the use (end use). The most widely used vegetable oils include palm, sunflower, etc. [22].

2.4.1 Technical characteristics

To use oils, it is necessary to know their technical properties, which show the advantages and disadvantages as well as where a specific type of oil can be used. The most important characteristics to consider when selecting an oil are density, viscosity, viscosity index, soapy number, pour point, and flash point. The characteristics of vegetable oils are shown in Table 2.

Table 2 Characteristics of vegetable oils [Adopted from 22]

Characteristic → / Type of Oil ↓	**Density (g/mL)**	**Kinematic Viscosity (mm²/sec)**	**Viscosity Index**	**Saponification Value**	**Pour point (◦C)**	**Flash Point (◦C)**
Coconut oil	0.915	27.9	155	250 - 264	20	240
Palm oil	0.910	41.9	189	196 - 209	12	304
Sunflower oil	0.890	38.2	205	186 – 194	-15	272
Castor oil	0.970	249.8	85	170 - 185	-31	260
Groundnut oil	0.914	36.84	144	184 - 195	3	336
Olive oil	0.912	43.2	-	183 - 190	-9	315
Mustard oil	0.967	63.40	105 - 159	125.6	-18	310
Jojoba oil	0.849	21.8	242	91.6	9	295

Based on the data shown in Table 2, one can notice that vegetable oils are characterized by a high viscosity index, from 85 in Castor oil to 242 in Jojoba oil. Such a high viscosity index indicates that there will be less change in viscosity compared to the change in temperature, which during the metalworking process provides a more stable lubricity in the operating temperature range [28]. Vegetable oils have a wide range of kinematic viscosity, ranging from 21.8 to 249.8, which is very close to the values of synthetic oils. This feature indicates that it is possible to provide superior lubrication without compromising the cooling capabilities. Also, as shown in Table 2, some oil plants have low pour temperatures (thinning) up to -18°C, allowing these oils to be used at low temperatures without compromising their lubricating properties.

High flash temperature is another positive characteristic of a vegetable oil. The flash temperatures range from 240°C to 315°C, as shown in Table 2. This feature enables them to be used in metal processing in high-temperature operations. The next feature that results from this characteristic is fire and smoke reduction. Vegetable oils have high boiling point and molecular weight, which slows evaporation and fog formation [29]. The density of vegetable oils is comparable to mineral and synthetic.

2.5. Environmental aspects of CF use

The chemical structure of CF changes when it is used several times during the cutting process. These changes have an impact on the environment, the quality of metal processing and efficiency. Disposal of used lubricants is expensive, so the focus is on the application of biodegradable lubricants. Aspects observed in environmentally friendly CF are biodegradability and toxicity [21].

Biodegradability takes place under the action of microorganisms. Biodegradability is used to determine ecological compatibility. Vegetable oils have a high percentage of biodegradability, ranging from 70 to 100%, which is an important factor to consider when selecting oils. The mineral oils are slightly susceptible to biodegradability (about 20%), which is their disadvantage [19].

Toxicity is an important characteristic because various gases, vapors, and particles are released during operation, which can be harmful to the environment and humans. Although mineral lubricants have good technical properties, they have negative impact on the environment and humans from an ecological standpoint. Skin irritation, aerosol release, and other issues can occur when using mineral lubricants [22]. There is also the problem of soil, water and air pollution. On the other hand, the technical characteristics of vegetable oils contribute to the reduction of negative effects. Thus, the high boiling point of vegetable oils reduces the amount of fog that is formed during metal processing, which directly contributes to better working conditions. Also, the high flash point of vegetable oils contributes to the reduction of steam and the possibility of fire. These two characteristics of vegetable oils give them an advantage over mineral oils, which are characterized by high toxicity.

When comparing the characteristics of mineral and vegetable oils, it can be stated that mineral oils have a preference in terms of availability and technical characteristics, but vegetable oils can also meet the technical requirements. Mineral oils, on the other hand, are lacking in terms of the effects they have on the environment and humans, whereas vegetable oils meet the ecological requirements. Thus, when selecting a lubricant, the focus should be on the use of herbal lubricants.

3. IoT Sensors in Manufacturing

The development of sensor technology and wireless communication has led to easier detecting, measuring and gathering real world information and transferring them to end users [30]. IoT technology in the industrial sector (Industrial Internet of Things-IIoT) is tightly connected with the 4IR. IoT is growing and improving, allowing Computer Numerical Control (CNC) processing to become more profitable and useful. For measuring and optimization of industrial processes various sensors, wireless networks, large amount of data and analytics are used.

The use of IoT in cutting processes has an impact on reducing consumption, optimizing processes and producing higher-quality products, all while considering and adhering to environmental protection and the creation of cleaner production. With the help of IoT it becomes easier to manage the entire manufacturing process. As it connects and digitizes our factories, IoT represents a revolution in many manufacturing practices. The two main objectives of IoT are increase of productivity and cost savings. Constant monitoring of the process allows for timely response, resulting in maximum productivity. However, those aren't the only benefits that speak to the value of using IoT in industry. The most significant advantages of IoT in cutting processes are product quality control, preventive maintenance, and automated operation [31].

Based on the previous, it can be said that the IoT is an advanced system for automatization and analytics that makes use of a network of smart devices such as IoT sensors. IoT sensors can detect defects in tools and materials as well as errors in the cutting process, and remote monitoring of both the machines and the products can be done in real time. By monitoring a superior transparency, increased control and performance of the cutting process is achieved. The sensors optimize and automate the CNC machine by continuously monitoring the cutting process and warning of any problems or deviations. Sensors are required for data acquisition. The necessary changes are made based on sensor feedback to solve the problem or improve the cutting process itself. IoT is strongly linked to information gathering for a sustainable production [32]. Cutting process costs, preventing workplace injuries, and reducing negative environmental effects are all benefits of IoT cutting process automation. This paper focuses on reducing negative effects of CF on the environment with the help of IoT sensors. Sensors are very important as they represent the essence of every IoT system due to collecting crucial data. They're notable for their ability to convert information obtained from the outside world into data for analysis. Therefore, sensors can be defined as pieces of hardware that detect changes in the environment (Fig. 5).

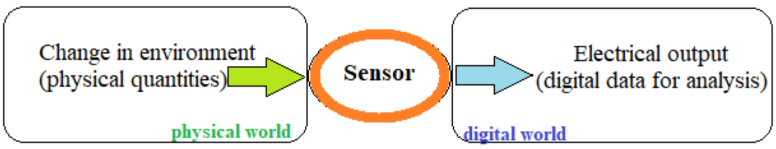

Fig. 5 Sensor block diagram

The sensors detect specific physical phenomena, which are then converted from analog to digital data. So, they're the pieces of an IoT ecosystem that bridge the digital world to the physical world. Data is digitized and sent to data collection systems to be processed and analyzed [33]. Because of this, sensors have become ubiquitous in factories and entire production ecosystems [34]. The information from analyzed data is returned to the physical world. This is a data flow cycle (Fig. 6).

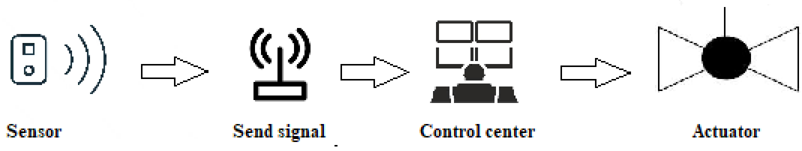

Fig. 6 Data flow from sensor to actuator

This most often implies sending orders to actuators to perform some actions, thus achieving a complete system of control and management [35]. Sending data to data collection systems from sensors can be achieved via wireless connection, allowing easy access and control from a remote location. Monitoring and measuring very simple parameters in the cutting process can extend the life of tools and other components, increase productivity, reduce downtime while optimizing the use of CF, which can have positive outcome on reducing environmental pollution and other negative effects of CF.

3.1. Cutting temperature and CF flow sensors

From a practical standpoint, investigating, measuring, and understanding the cutting temperature distribution within the tool and workpiece is crucial. The heat generation depends on the tool and workpiece materials, cutting speed, feed rate, depth of cut, tool geometry and CF. The generated heat has an impact on productivity, surface quality, machining accuracy, and other process output characteristics. The hardness of the material decreases as heat is transferred to the tool, resulting in gradual plastic deformation of the cutting blades, loss of the tool's cutting ability, and blunting. The temperature monitoring techniques found in the literature fall into two main categories: contact (or conductive) and non-conduct (or radiative) techniques [36]. Sensors can work on the principle of natural, semi-artificial or artificial thermocouple, calorimetric, non-contact, etc. Cutting temperature measurement methods are shown in Fig. 7.

The sensors quickly detect poor conditions of the cutting process and early intervention can prevent the associated costs caused by waste parts or increased tool wear, excessive use of CF and so on. Flow and temperature measuring sensors can optimize the use of CF, thus reducing their negative impact. Since the cooling effect is closely related to the flow rate, monitoring of this parameter is crucial for the optimal use of CF. Thermal stability control is essential in industrial machining processes for achieving the desired quality of the machined product while also protecting the cutting tool. Optimized use of CF is the key to efficient processing and good quality of the final product. This is especially important in serial production, where the cutting machine's feed rate is constantly optimized to achieve the highest output rate in relation to efficiency. Increasing number of sensors are based on digital technology. Large number of fluid flow sensors have more than affordable prices and are compatible with many chemical agents. The fluid flow meter measures the amount of CF used for cooling and lubrication of tools. The flow sensor can work on different principles like floating bodies, magnetic field, calorimetric principle, thermodynamic principle, Hall-effect, etc. The sensor can be installed at different positions.

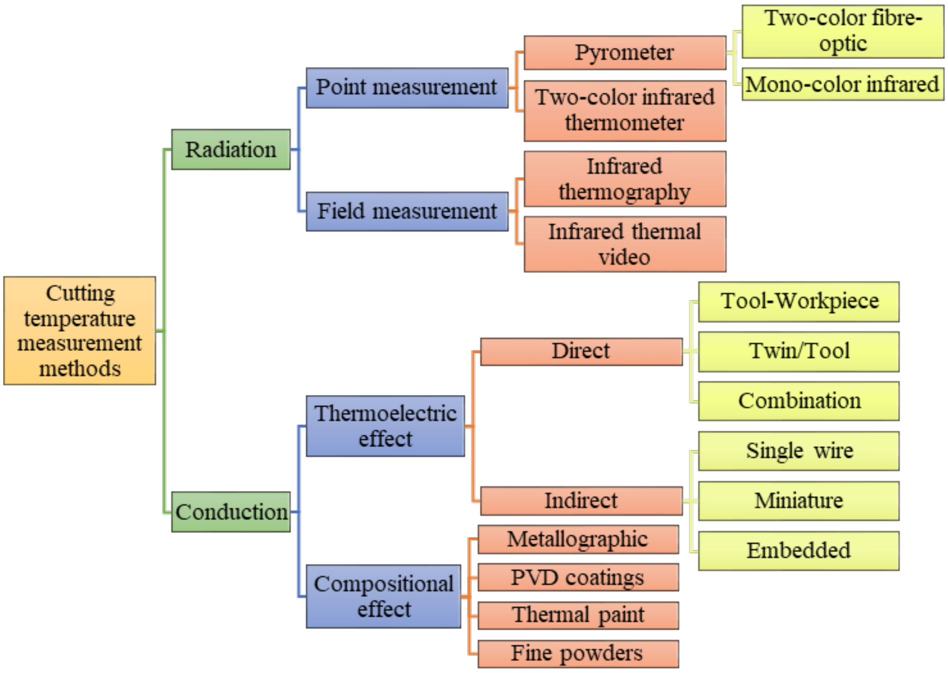

Fig. 7 Cutting temperature measurement methods [37, 38]

To avoid damage to the workpiece, cutting tools, and machines, the supply of CF must be constantly monitored [39]. There are precise sensors with alarms built in that get activated if they detect a deviation in the set parameters for active CF flow. The flow rate and volume of liquid that has passed through a pipe can be checked and controlled as needed using a flow sensor with a microcontroller. Flow sensors provide the information needed to control CF in order to prevent the overheating and damage of a workpiece and tool during machining. The flow sensor can be linked to an LCD where it can display the amount of fluid passing through the valve.

Based on the previous, a conclusion can be drawn that sensors for measuring temperature and CF flow are a crucial part of the information system which will be presented in this paper.

4. Information System

This smart information system model for clean manufacturing is based on the optimized CF on a CNC machine. There are four main stages in the development of this smart information system model. Fig. 8 shows the main stages of data flow from collection to model development [40].

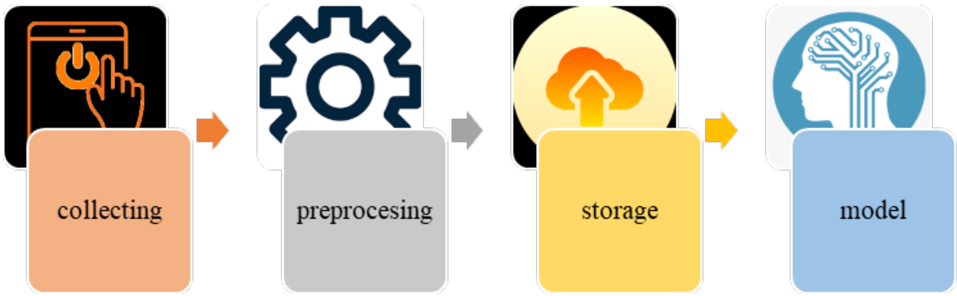

Fig. 8 Main data flow stages [40]

The first step is to collect the necessary data. To develop a model that will optimize the use of CF, data from two sources must be collected. The first source is the control unit, from which data on the cutting process parameters are obtained (cutting speed, feed rate, depth of cut). Cutting speed and feed rate can be measured or taken from predefined values according to the form or catalog recommendations. The second source is a sensor system. A CF flow sensor and an industrial temperature measurement sensor comprise the sensor system. The sensor system in the cutting process environment is shown in Fig. 9.

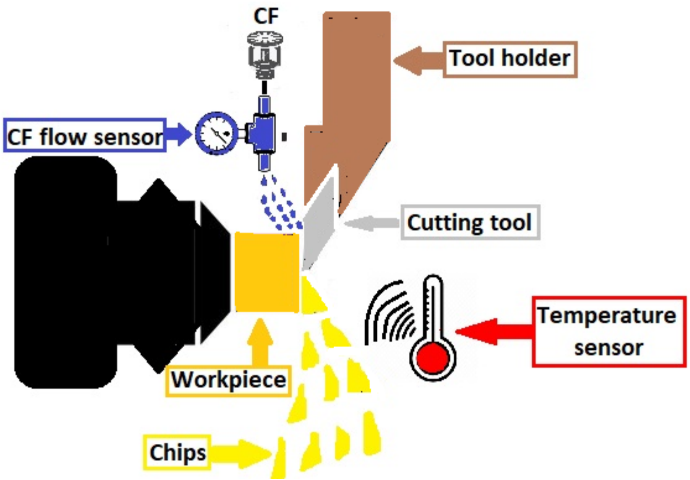

Fig. 9 Sensor system in cutting process environment

Flow and temperature sensors work in conjunction to reduce the CF use. Because the cutting process's temperature and the flow of the cutting fluid are inextricably linked (depend on each other), the process temperature must be within certain limits. The CF flow maintains the cutting process temperature. If the temperature rises above the upper limit or falls below the lower limit, the system adjusts the CF flow to increase or decrease cooling. The sensor's connection can be wired or wireless via Bluetooth, GSM, or Wi-Fi. IoT sensors use protocols like ZigBee, BLE, Wi-Fi, Modbus, Z-Wave, BACnet, RFID, NFC, LoRa and 5G to send data [41].

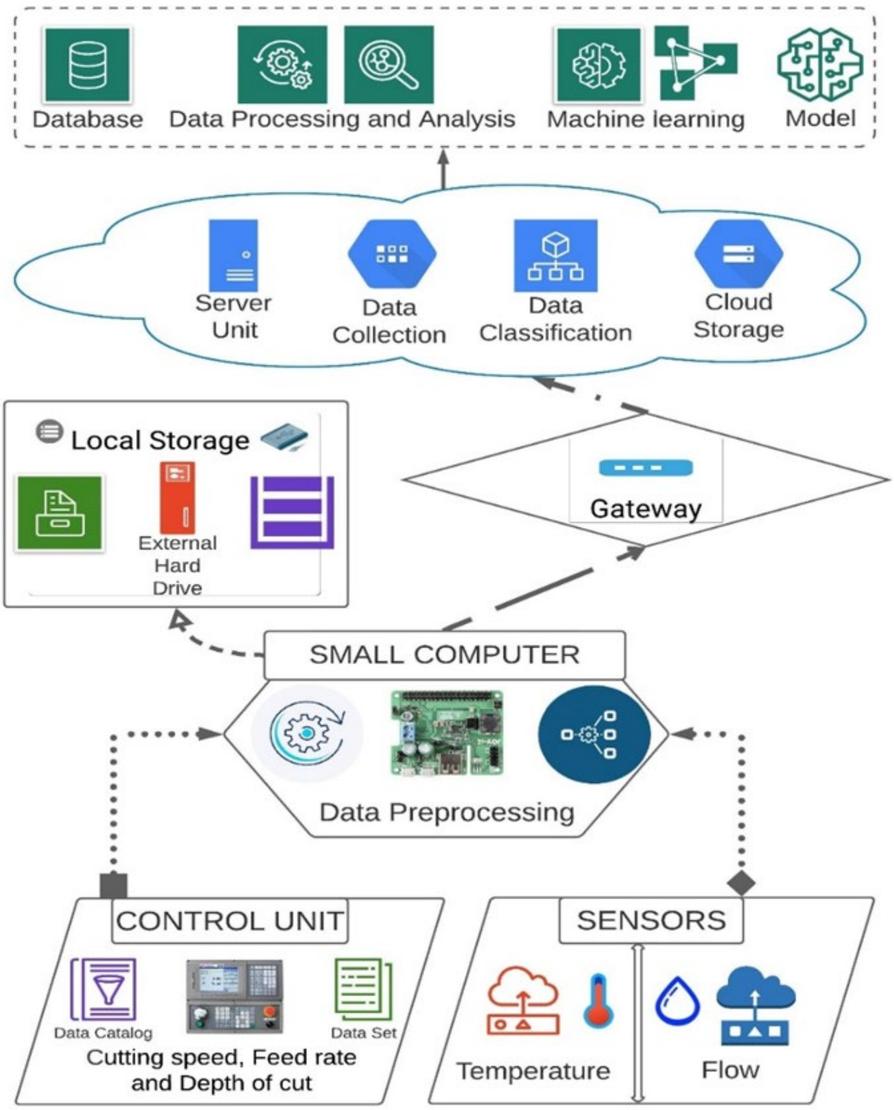

Fig. 10 Scheme of the overall structure of the intelligent information system [40]

The data must pass through a filter (preprocessing), in order to remove unwanted by-product that is not relevant for analysis (noise, short circuit, and downtime). Preprocessing is a very important step (second stage). Sensors are linked to a minicomputer (Raspberry Pi, Banana Pi, or Arduino) that is attached to a CNC machine. IoT sensors can send data to the cloud for storage and processing. Process parameter data can also be sent to a minicomputer or directly to the cloud along with sensor data. For reliability purposes in case of a disconnect issue with the cloud, the data can be stored on a mini computer, that has an external hard drive or memory card. From SD memory card or some other type of external memory after a certain time interval data can be sent to the cloud. As soon as the connection is available again the data is forwarded at preset intervals. By analyzing and processing (machine learning) of the collected data, a correlation is made between the process parameters data and the data obtained from the sensors, which enables creating a model of a sustainable turning process system. This information system structure is applicable in the case of milling. When optimizing the use of CF, the goal is to maintain the required surface quality.

What has to be considered is that the main machine time (Tg) must be within certain limits. The amount of CF would be reduced in this manner without reducing the productivity or compromising production quality. Fig. 10 shows the overall structure of the intelligent information system for optimizing the use of cutting fluid in the cutting process [40]. Depending on the communication protocol, data can be sent directly to the cloud or through an intermediary gateway. The combination of both accesses is possible. The gateway stage can be in charge of pre-processing the previously collected data and preparing for further analysis. Simply put, at this stage data is collected and digitalized.

Data processing can be done on the device-side or the cloud-side. Device-side processing is called Edge computing. Edge system can be in charge of a deeper analysis of the acquired information. Thereby, analysis is done at the "edge of network". With the help of a computer it is possible to avoid the transfer of unprocessed data by cleaning, unification and analyzing the data on the device itself, and forward the refined data. After processing, the data are stored either in a centralized database or on the cloud. Unlike the Edge system, data can be directly stored on the cloud or in data centers where they are further processed and analyzed. Analysis can be performed in real time or subsequently.

For the realization of a quality IoT infrastructure it is possible to use Cloud Computing and Big Data infrastructure. A component of the cloud can be an IoT platform with accompanying applications and services. With certain additional applications it is possible to communicate with the system and exchange messages, perform supervision and control, as well as make decisions thanks to data received in real time. It is possible to include dispatch of commands out of the cloud or gateway device to actuators. Communication with the cloud is realized through protocols such as MQTT, CoAP, AMQP, HTTP, etc. The cloud can include various databases for storing data from sensors such as MySQL, PostgreSQL, SQLite, Cassandra, InfluxDB, MongoDB, CreateDB, RethinkDB, etc.

5. Conclusions

Cutting fluids are a major polluter of the environment in metalworking processes. Therefore, it is very important to reduce the use of CF. Because of the high level of environmental pollution, this is quickly becoming one of the most important goals for all manufacturers. Cleaner production encourages the use of eco-friendly CF, but this is not enough to achieve sustainable production in this regard. IoT is expected to play an increasing role in CNC machining due to the positive impact and benefits it can have on manufacturing processes. IoT sensors are the best solution for measuring and monitoring the cutting process. The crucial element of any optimization model is data collection. The advantages of today's sensors include low cost, small size, reliability, no moving parts, long service life, and efficiency. IoT sensors in the above-described information system described above provide the necessary data on the process temperature and CF flow. After collecting and storing the necessary data, the next step is to analyze it. The relationship between the sensor data and the process parameters creates a model that will be used to optimize the use of CF. Optimizing the use of CF is critical for sustainable production because it can significantly reduce the negative environmental effects. This is the basic way to achieve cleaner production. The proposed IoT system is in line with the most recent developments, 4IR, and the vision of cleaner production and sustainable development. With the help of this IoT information system, manufacturing becomes environmentally friendly.

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