Design and Development of Small Quantity Lubrication (SQL) cooling System

Rajkumar D. Patil

Assistant Professor, Mechanical Engineering,
DKTE Society's Textile and Engineering Institute, Ichalkaranji, Maharashtra, India

Abstract

Machining is an important part of any production industry. During machining operation, large amount of heat is generated between contact of tool and work piece which is not desirable because it increases power consumption, affects product quality and also results in early failure of cutting tool. Cutting fluids are applied to avoid the heat generated during machining to ensure good quality of the work piece. But, conventional cutting fluids are harmful to human health. Adopting sustainable machining offers a cost-effective route to improve economic, environmental and social performance of any manufacturing industry. A possible solution in searching for the optimum lubrication system is small quantity lubrication (SQL), which is becoming increasingly important. Compared to conventional wet machining, where up to 1200 liters of coolant is used per hour and must be reconditioned again, the user of the SQL system does not need a higher quantity than a few milliliters. The optimum lubrication considerably reduces the frictional heat. With SQL, the machining costs can be reduced considerably. The environment is also protected and possible health risks for the machine operator are reduced.

Literature Review:

P.A.Thakare (2012) have studied Cutting fluids widely used in machine operations. Machining is a major secondary manufacturing process in the metal cutting industry. In India 50000 Kiloliter of metal working fluids produced from mineral oil are consumed annually. During turning operations, high temperatures are produced. Such high temperatures often lead to several problems like a large heat affected zone, high tool wear, change in hardness and in the microstructure of the work piece, burning, its consequences and micro cracks. Application of cutting fluids in conventional method reduces the above problem to some extent through cooling and lubricating the cutting zone. But in this process the cooling rate is low [1].

Branislav Sredanovic et al. (2013) have used the machinability criteria, cutting force, intensity of tool wear and surface roughness. Analysis of machinability was performed using different cooling and lubrication conditions: conventional flooding, minimum quantity lubrication (MQL) and high-pressure jet-assisted machining (HPJAM). Technological parameters were adjusted to the semi-finish regime, with the use of the highest parameter values possible. During the research, cutting forces, chip shapes, tool wear and surface roughness were monitored and measured. The influence of different cooling and lubrication techniques and the relationships between process performance indicators on C45E steel machinability are analyzed [2].

T.Eswara Raoand and G.BalaMurali (2014) have done the research by introducing the green concepts in machining operations is being envisaged by introducing different echo friendly cooling systems in the modern machine shops. The role of cutting fluids usage in metal cutting is predominant as it influences the surface quality and production cost. The current work mainly focuses on the study of chip tool interactions viz. contact pressure, temperature and chip flow pattern on the rake surface in plain turning operation for different cutting parameters without any cooling medium and analyze the influence of high pressure air jet as the cooling medium on the chip tool interactions like contact pressure reducing the tool wear, cutting temperatures thereby increasing tool life [3].

Vasim Shaikh (2015) has invented Micro lubrication or also known as minimum quantity lubrication (MQL) serves as an alternative to flood cooling by reducing the volume of cutting fluid used in the machining process; but not without significant health concerns. Flood cooling is primarily used to cool and lubricate the cutting tool and work piece interface during machining process. The objective of this paper is to review the state of the art literature in machining using MQL, highlight the benefits, but also stress the adverse health effects of using minimum quantity lubrication [4].

Mozammel Mia and Nikhil Ranjan Dhar (2015) have concluded that the hard turning of harder material differs from conventional turning because of its larger specific cutting forces requirements. The beneficial effects of hard turning can be offset by excessive temperature generation which causes rapid tool wear or premature tool failure if the brittle cutting tools required for hard turning are not used properly. Under these considerations, the concept of high-pressure coolant (HPC) presents itself as a possible solution for high speed machining in achieving slow tool wear while maintaining cutting forces at reasonable levels, if the high pressure cooling parameters can be strategically tuned. This paper deals with an experimental investigation of some aspects of the turning process applied on hardened steel (HRC48) using coated carbide tool under high-pressure coolant, comparing it with dry cut [5].

I.Olaru (2016) has analyzed the type of coolants and the correct choice of that as well as the dispensation in the processing area to control the temperature resulted from the cutting operation and the choose of the cutting operating modes. The coolant chosen can be a combination of different cooling fluids in order to achieve a better cooling of the cutting area at the same time for carrying out the proper lubrication of that area. A minimal amount of lubricant may have a better impact on the environment and the health of the operator because the coolants in contact with overheated machined surface may develop a substantial amount of these gases that are not always beneficial to health [6].

Ravindra S Surase et al. (2016) have studied in contrast to conventional flood lubrication; minimum quantity lubrication uses only a few milliliters of lubrication per hour for the machining process. Minimum quantity lubrication today uses such precise metering that the lubricant is nearly completely used up. Typical dosage quantities range from 5 ml to 50 ml per process hour (tool cutting time). The use of lubrication is necessary for dissipated the maximum heat generated from the machining process, the analysis of this heat generated is proposed to carry out by using ANSYS software [7].

Katja Busch et al. (2016) have studied optimal and efficient machining of high-temperature alloys is one of the main goals set by the manufacturing technology today, taking into account the unique properties of these materials, the required performance and the process parameters. One of the most important parameters investigated and presented in this paper is the optimal cooling and lubrication strategy. The application of various hybrid cooling strategies such as high-pressure cooling, cryogenic cooling and aerosol dry lubrication offers the potential to extend profitability and energy efficiency as well as high performance and improved surface integrity [8].

Christoph Baumgarta et al. (2017) have used a grinding wheel rotating at high circumferential speed induces a boundary-layer airflow which possibly can detain the coolant from submerging into the grinding zone, in order to prevent thermal damage. To study the profile of the airflow, general laws of fluid dynamics are applied and the analytical results compared with results from CFD simulations. These are used to investigate the interaction of the coolant with the grinding wheel under the influence of the airflow with different coolant nozzle types and parameters. For validation high speed imaging is employed. The conclusions may help for a general understanding of the interaction between wheel-airflow-coolant [9].

Anup Junankar et al. (2017) have concluded that the metal cutting fluid changes the performance of machining operations because of their lubrication, cooling and chip flushing functions. The metal industries using the cutting fluid has become more problematic in nature and working employee health. But the use of cutting fluid machining operations of metal became easier to maintain the work piece surface properties without damages. To reduce the use of cutting fluid in machining operation minimum quantity lubrication (MQL) is used. Such machining inherently produces high cutting temperature, which not only reduces tool life but also impairs the product quality. MQL is able to reduce the heat which is generated in tool work piece interface [10].

Gaurav M. Gohane et al. (2018) have studied the effects of cooling with CO2 by dry and conventional wet machining in spite cutting temperature. They found that cryogenic machining is an effective matter to minimize the cutting temperature found during the machining process [11].

Anup Junankar et al. (2018) have tried to reduce use of cutting fluid by implementing Minimum Quantity Lubrication (MQL). MQL system uses only 5ml to 50ml/hr of lubricant in machining, where in flood this quantity is very much high. This paper also concentrate on better surface finish and reducing cutting fluid cost and investigation of tapper turning operation on EN- 31 material, for optimization of surface roughness, material removal rate in dry, flood and MQL system by considering three controllable input parameters that are cutting speed, feed rate, depth of cut[12].

Design and Development:

Design and development of SQL cooling system is done to achieve following goals,

- To reduce the consumption of lubricant during the material removal operation.
- To carry away the majority of heat generated during chip shear.
- To reduce the friction between the cutting tool and work piece.
- To improve the surface finish characteristics.
- To optimize the process parameters based on surface roughness.

Components used for SQL cooling System:

1. Air compressor: As shown in fig.1 air compressor is a device that converts power into potential energy stored in pressurize. By one of several methods, an air compressor forces more and more air into a storage tank, increasing the pressure.

Fig.1: Air compressor

The specifications of the compressor used are as follows:

- Type – Reciprocating compressor (low pressure).
- Pressure capacity – 10 bar /145 psi.
- Two stage type compressor.

2. Pipe: The purpose of the piping system is to deliver compressed air or fluid to the points of usage. The pipe used in the system is as shown in fig.2.

Fig. 2: Air pipe

The specifications of the pipe are as follows

- Size – ϕ 10mm
- Air hose length – 3meter
- Material – plastic

3. Mist with Connectors:

The mist with connectors used in the pipe system are shown in fig.3.

Fig.3: Mist with connector

Following Specification connectors are used.

- 3 way mist
- Material: Metal & brass
- Size: 36cm (L), hose about 1M.
- Fit for 10 mm air pipe

4. Fluid flask:

Fluid flask as shown in fig.4 is used to store the fluid. It is made up of Plastic material and its capacity is 2 liters.

Fig.4: Fluid tank (flask)

5. Nozzle:

Nozzle as shown in fig.5 is a device designed to control the direction of a fluid flow as it exits an enclosed chamber or pipe. Nozzle is a precision device that facilitates dispersion of liquid into spray. Nozzle are used to distribute a liquid over an area.

Fig. 5: Nozzle

Specification of the nozzle is as follows,

- Material : Plastic
- Nose diameter : 6 mm

6. Connectors:

Connectors as shown in fig. are used to connect Mist and pipes. These connectors are having diameter of 10 mm made up of steel and plastic.

Fig.6: connectors

7. Pressure gauge:

Fig.7: Pressure gauge

To measure the pressure value pressure gauge is used as shown in fig.7.

Following Specification pressure gauge is used,

- Pressure limit – 0 to 10 kg/cm^2
- Type – Bourdon tube pressure gauge
- Manufacturer – HI- TECH INSTRUMENTS

8. Flow control valve:

The flow control valve as shown in fig.8 is used to control the flow of the fluid in the system.

Fig. 8: Flow control valve

Specifications used for the flow control valve are as follows,

- Size – 1/4 inch
- Material – Brass
- Type – ball type flow control valve

9. Piston type pump:

The piston type pump used for set up is as shown in fig.9.

Fig. 9: Piston type pump

Following Specification piston pump is used,

- Type – Piston type
- Piston diameter – 6mm
- Power supply – 12V,DC
- Discharge – 800ml/min

10. Coolant:

Fig. 10: Sunshine oil

The coolant used for SQL system is as shown in figure 10 and its specifications are as follows,

- Mineral oil content - 15% minimum
- Water content – 20 % maximum
- Flash point – 90 to 100° C
- Product – SAZEROL ™ SS SYNTHO 01
- Viscosity – 58mm^2/sec

Conceptual Drawing: The Figure 11 shows the conceptual drawing of SQL cooling system. The CAD modelling is done by using CATIA software.

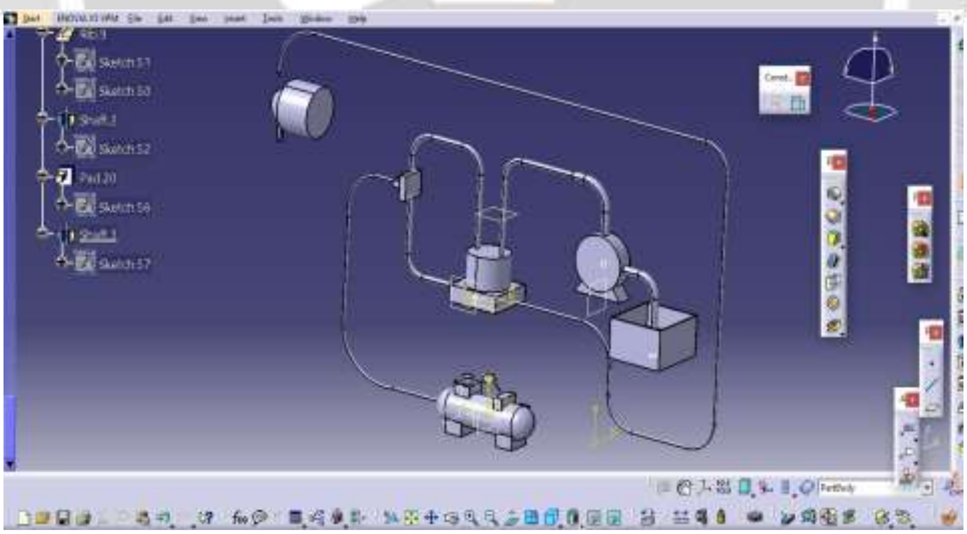

Fig.11: Conceptual Drawing

Experimental Setup: The experimental set up for SQL cooling system attached to the machine is as shown in figure 12.

Fig.12: Attachment of SQL cooling system setup with machine

Conclusions:

The SQL cooling system is developed which has following advantages,

- Application of high pressure coolant jet can be used to reduce tool wear, good dimensional accuracy and surface finishes that are acceptable for most applications.
- Pressurized cooling system reduces the consumption of lubricant during the material removal operation.
- It reduces the friction between the cutting tool and work piece. It carried away the majority of heat generated during chip shear.
- It improves the surface finish, reduce production cost of a product and increase the cutting tool life.