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Design of a Submerged Cooling System for a Vertical Axis CNC Milling Machine

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***Abstract*— In a modern industrial scenario, manufacturing a component to a greater accuracy is necessary need in order to sustain in this competitive world. Machining of the components needs high material removal rate, good surface finish and less tool wear. In order to achieve this proper coolant system has to be provided. This paper deals with a new design representing a submerged cooling system and its advantages over a flood cooling system. A model is developed in Solid works and analysis is carried out using FEA in Ansys. By doing so, the chip removal becomes very much easy and excess spraying of coolant as in the flood cooling system is avoided. The analysis is carried out in order to make sure that the stresses developed within the system are well within the permissible limits.**

***Index Terms*—tool wear, surface finish, submerged cooling system, flood cooling system, solid works, Ansys.**

I. INTRODUCTION

In metal cutting operations, the condition of a cutting tool plays an important role in the achievement of the quality of the component. The main problem faced by the cutting tool is that it is exposed to high operating temperature due to friction between the cutting tool and the component. This heat generated is intense when harder material is to be machined [1]. At this elevated temperature the cutting tool tends to lose its properties such as hardness, strength, etc. [2, 3], which results in dimensional in the accuracy of the component and shortens the tool life. In dry cutting operations, the friction and adhesion between the chip tool tends to be higher which causes high operating temperature, higher tool wear rate and shorter tool life [4-6]. Dry cutting is not suitable for many machining operations. Since cutting fluids are necessary to control the tooltip temperature and to prevent the chip to stick to the tool and causing its breakage. Cutting fluids also controls the friction between the tool and chip by reducing the cutting force as compared to dry cutting operations. The major needs in machining are high material removal rate, good surface finish and low tool wear. These can be achieved by using a proper cooling system applicable for the particular machining operations. The different types of cooling systediscussfurther.

A. Flood Coolant System

In this system, the coolant is splashed onto the cutting zone. The coolant is usually supplied with the help of the flexible hose. This system greatly reduces the heat generated in the cutting zone, some of the disadvantages are

a. Maintenance of the coolant system.
b. Cleaning the work area of the machine tool.
c. High monitoring of the coolant condition
d. Cleaning up spills from leaks that present a health and safety hazard in the workplace.

B. Submerged Coolant system

This system provides a continuous flow of the coolant through the cutting zone. Here, the work piece is placed in a container and it is filled with the coolant. It is made sure that a layer of coolant will always be present above the work piece. Since the coolant is confined within a container, there is no problem of coolant being wasted due to splashing nor is there a problem of cleaning as in the flood coolant system. It also results in a better surface finish as the coolant is always present at the interface between the tool and the work piece. Hence, the drawbacks of Flood coolant system are taken into account and a submerged cooling system is designed. This paper deals, with detailed design and analysis of the different components of the submerged coolant system [7]

II. PROPOSED DESIGN

A. Design Of Submerged Coolant System

The initial design consists of a container (400 mm x 400 mm) which is capable of holding the work piece that is to be machined as shown in the Fig 1. It has a depth of 60mm. Coolant is circulated through this container using a pump of proper rating. The coolant is recirculated by passing it through the filter. To make sure that the chips formed while machining remain within the compartment, steel meshes are provided at the openings. In the model without the Reservoir as shown in the Fig. 2, cleaning the compartment requires some external reservoir to discharge the coolant. The external reservoir cannot be placed on the workbench as it would constrain the easy movement of the workbench. It would also make the arrangement bulkier. Therefore, the reservoir must be placed out of the CNC cabin. Hence, draining the coolant into this reservoir would require many pipe connections that would make the entire system complicated. In addition, filling back the coolant would require a powerful pump. Hence, modifications are made in the initial design, providing the reservoir with the system as shown in the Fig 2. Providing reservoir within the system makes the entire system simple and compact. A platform is attached to the system to hold the pump and provision for the slots is provided at precise locations so as to fix the system onto the workbench.

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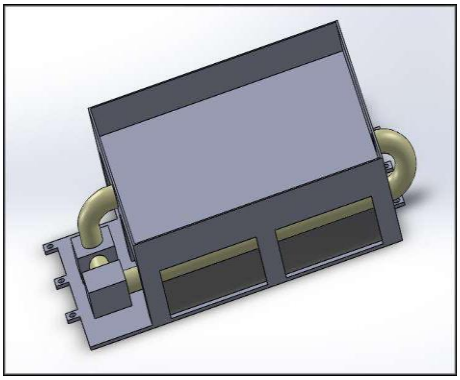

Fig. 1 Isometric model without Reservoir

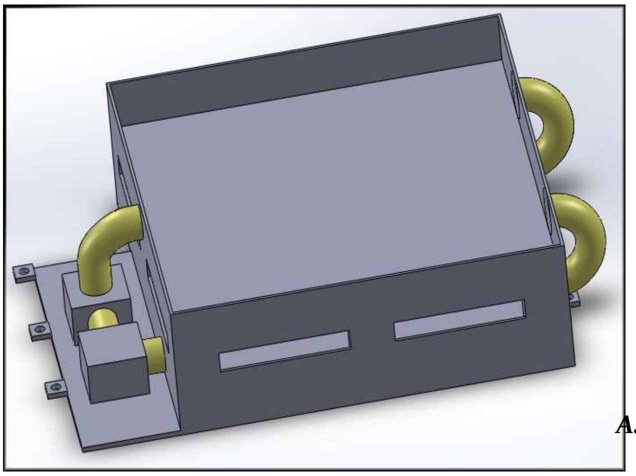

Fig. 2 Isometric view of a model with reservoir

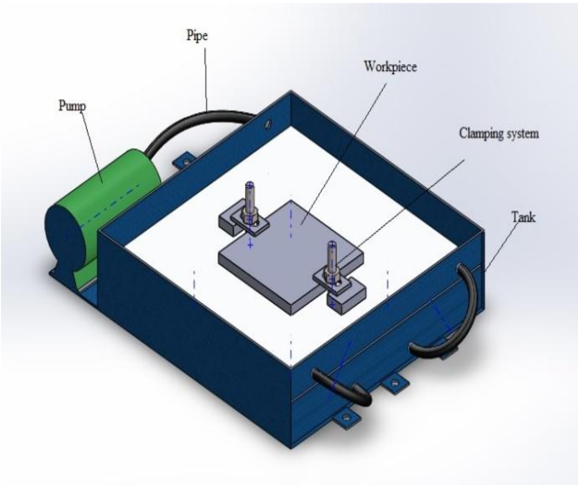

Fig. 3 Isometric view of a model with reservoir

The Dimensions of the guide ways were taken. The process of fabricating the coolant tank consisted of arc welding process. The metal sheets of 3 mm thickness were welded to form the tank. The tank is provided with columns or supporting fixtures at the bottom of the machining zone to resist displacement of the work piece during machining and also to reduce the stress so that it does not breach the safety limit. The Tank is made leak proof by welding and corrosion resistant by paint. The work piece was placed on the tank and tightened with the help of the straps, washers and nuts. The weight of the tank is also an important factor that has to be taken into consideration. The weight of the tank is much lesser than the current clamping fixtures that were used for flood coolant system and were made of Cast iron. Hence making the guide ways take much lesser weight and susceptible to lesser vibrations are the pros of submerged cooling system. Moreover, the clamping system has been designed and is provided with slots in order to employ various sized work pieces. The proposed model is shown in Figures 3 and 4.

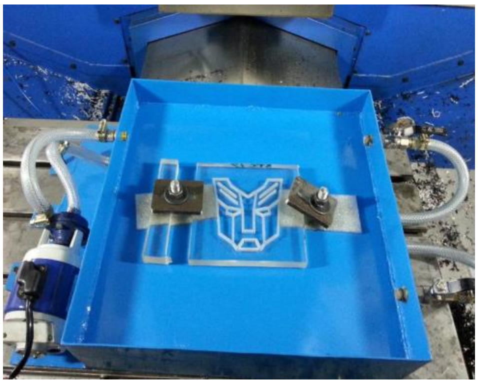

Fig. 4 Actual model with clamping system

III. COMPONENT SELECTION

A. *Selection of Pipe*

Pipes are used to circulate the cutting fluid in the submerged coolant system. Plastic pipes are used for the following reasons:

- They are light in weight, tough, resistant to chemical attack and available in large lengths.
- They reduce the cost of handling, transportation and installation.
- They are rust resistant.
- Smooth internal surface of the pipes offers less friction.
- ***Selection of pump***
- The pump is employed to force the stream of cutting fluid into the machining area at the required flow rate. A centrifugal pump is mainly used because of the following reasons:
  - Wide range of pressure, flow and capacities.
  - Utilizes small floor space and can be used in different positions.
  - Impeller and shaft are the only moving parts.
  - Simple operation.
  - Low first cost and maintenance.

The coolant system integrated with the vertical milling center had a flow rate of 1300 litreper hours. So it was decided to use a pump with the similar flow rate, having a diameter of 12.7 mm. The velocity of the liquid is calculated by using Eqns (1) and (2)

Area of the pipe A=$\frac{\pi}{4}D^2$ (1)

Rate of flow (Q) = A xV (2)

Where, D-Diameter of a pipe;
V- Velocity of flow
Velocity, V) =2.852 m/s.

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B. Selection of Filters

Filters trap the chips formed during the machining operation and hence protect the pump from damage. They are selected based on the following:

- The amount of material they trap.
- Size of the trapped particles.

IV. ANALYSIS

Analysis is carried using the ANSYS software. The analysis involved following procedure

- The geometry of the component which was modeled in Solid works was imported for the analysis
- The problem being solved in Ansys workbench, where the required properties of the component were established.
- The component was divided into a finite number of elements by a process called meshing as shown in Fig. 5.

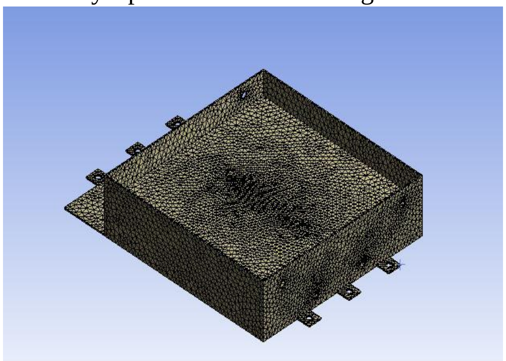

Fig. 5 Meshed Model

- The component is provided with the appropriate boundary condition and loading condition.
- The component is analyzed for deformation and stresses for two modifications, i.e. Component with columns and without columns as shown in the Figs. 6-9.

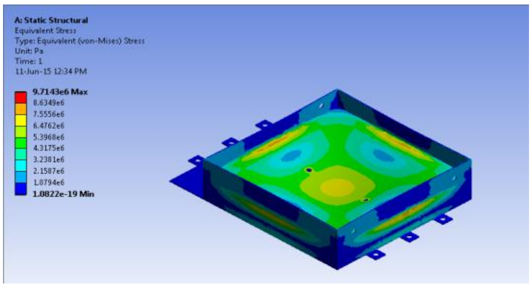

Fig. 6 Stress induced in a 3 mm sheet without columns

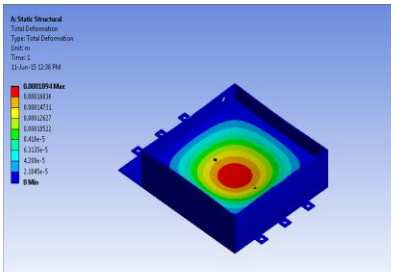

Fig. 7 Deformation in a 3 mm sheet without columns

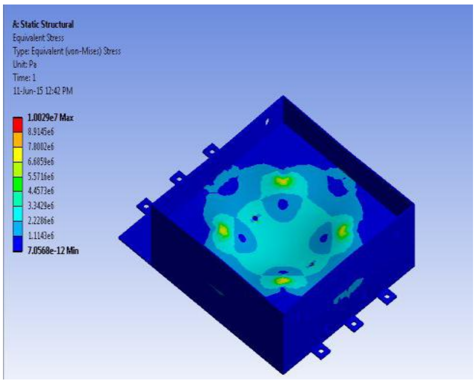

Fig. 8 Stress induced in a 3 mm sheet with columns

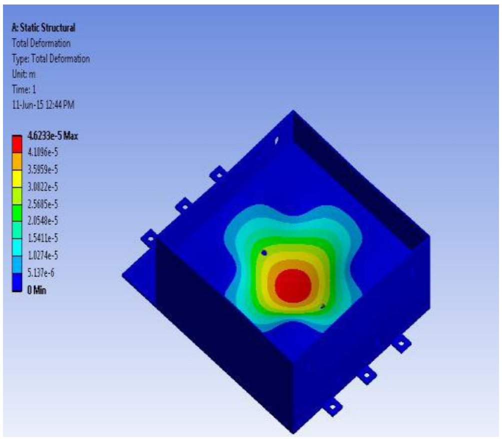

Fig. 9 Deformation in a 3 mm sheet without columns

V. RESULTS AND DISCUSSION

Analysis of both the modifications gave a clear idea about the performance of the cooling system. In this system, both the models can be considered as the deformation and stress induced is very negligible compared to the yield strength of the metal as shown in the table 1 below.

Table 1: Comparison of two different designs

Model Thickness	Load (N)	Max. Equivalent Stress (MPa)	Max. Displacement (m)
3mm without columns	400	9.7143	$18.94*10^{-5}$
3mm with columns	400	10.029	$4.6233*10^{-5}$

VI. CONCLUSIONS

From the design and analysis of the submerged cooling system, it can be justified that this coolant system is advantageous in several ways, such as economy of process, compactness, mobility, surface finish and cracks formed in the work piece during the machining process. Modeling is carried out using Solid works software and its analysis using ANSYS, which gave lots of insight regarding the machining process, design considerations, and financial constraints. Also, it can be seen that the stress and the deformation values

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are well within the permissible limits and hence the design is safe and hence adopted.

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