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Evaluation of Thermal Characteristics of Oil Chiller for Various Coolants in CNC Machines by CFD Analysis

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Abstract: Machine tools are characterized by their large number of spindle speeds and feeds to cope with the requirements of machining parts of different materials and dimensions using different types of cutting tool materials and geometries. Gearbox is mainly used in machine tool main-spindle drives, test-benches and applications where high torque is needed. Gearbox is mounted directly to the spindle. The gearbox is dedicated for today's high speed requirements in machine tools. The spindle gear box is lubricated with oils for the smooth operation of gears. These oils will be heated during the process. The gearbox is fully sealed, and the gears are immersed in lubricant, which is kept cool by an circulating oil chiller. In this thesis, heat transfer characteristics of the lubricant oil in the oil chiller are determined by CFD analysis when different lubricants are used. The lubricants considered in this thesis are hydraulic oil 32, Spindle Oil 22. The materials used for condenser and evaporator are Steel, Cast Iron, Copper and Aluminum alloy. 3D model chiller is drawn in Pro/Engineer and CFD analysis is done in Ansys to obtain the results are static pressure, velocity magnitude, heat transfer coefficient, heat transfer rate and mass transfer rate for spindle oil and hydraulic oil fluid mediums. And finally comparative analysis of thermal characteristics also done by both spindle oil and hydraulic oil

Keywords/ Index Term—Oil Chiller, hydraulic oil, spindle oil, pressure, velocity magnitude, heat transfer coefficient, heat transfer rate and mass transfer rate, CFD Analysis .

I. INTRODUCTION

A. CNC Machine

Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data. CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off. CNC stands for Computer Numeric Control. CNC machining involves using a machine controlled by a computer to machine material. Generally the machine is either a milling machine or a lathe. The earliest precedent to CNC machines may be the Jacquard loom, a mechanical process invented in 1801 by Joseph Marie Jacquard to simplify the process of manufacturing complex textile patterns. The Jacquard loom read punch cards. The holes in cards corresponded to the rows of design in the textile. This was pretty revolutionary, as an entire design could be stored on a set of cards, and changing production simply meant feeding a different set of cards through the system. The applications of CNC include both for machine tool as well as non-machine tool areas. In the machine tool category, CNC is widely used for lathe, drill press, milling machine, grinding unit, laser, sheet-metal press working machine, tube bending machine etc. Highly automated machine tools such as turning center and machining center which change the cutting tools automatically under CNC control have been developed. In the non-machine tool category, CNC applications include welding machines (arc and resistance), coordinate measuring machine, electronic assembly, tape laying and filament winding machines for composites etc.

B. Chillers

A chiller is a machine that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. This liquid can then be circulated through a heat exchanger to cool equipment, or another process stream (such as air or process water). As a necessary byproduct, refrigeration creates waste heat that must be exhausted to ambient or, for greater efficiency, recovered for heating purposes. Concerns in design and selection of chillers include performance, efficiency, maintenance, and product life cycle environmental impact. Process oil used for applications such as hydraulics, cutting, lubrication, broaching, honing, quenching, drilling, grinding etc., also aid as a cooling media. In other words, the heat dissipated during the process is carried away by the circulating oil. Now this oil needs to be maintained at a certain temperature rPange to retain its physical and chemical properties. A chiller operates by vapor-compression or absorption refrigeration cycle to remove heat from a liquid. Kaori provides high performance evaporators and condensers to work with a wide variety of refrigerants**.** Our BPHEs can also be used as economizers**,** super heaters**,** oil coolers**,** sub-coolers**,** intercoolers**,** or for heat recovery**.**

II. LITERATURE SURVEY

Mr. Jayesh S Arya , Dr. Neeraj K. Chavda. Have done research on A chiller is a device which cools a fluid by removing heat from it, either through a vapour – compression or absorption refrigeration cycle; with the key components being the compressor, condenser, evaporator and expansion device.. This paper emphasizes on studying the design procedure followed in the industries and performance evaluation of two different configruatons of 5 ton based chilling plant.The two such configurations studied are scroll compressor and plate heat evaporator and scroll compressor and shell and tube evaporator with R404A refrigerant.the results on basis of this experiment shows that the configruation scroll compressor and plate heat evaporator can give better results as compared to the configruation scroll compressor and shell and tube evaporator Mr.Ashish A. Wankhede , Dr.Kishor P. Kolhe were worked on Heat pipe is an essentially passive heat transfer device having high thermal conductivity. In hydraulic power pack use of traditional shell and tube heat exchanger would require lot of space, more power and maintenance cost. So heat pipe device is easily implemented for cooling of hydraulic oil. The heat pipe equipped hydraulic oil cooler uses a heat pipe module comprises of aluminium base block with oil channels machined on it. From hot oil chamber hot oil is passed through each modules of heat pipe. The hot oil passed through evaporator end transferring heat to condenser end. Heat transfer takes place by alternate evaporation and condensation of working fluid inside it. The condenser section of heat pipe is fitted with radial finned structure exposed to air to improve heat transfer rate. Ambient air is drawn over the fins using blower so that the fluid condensed and returns to heat source to repeat the process. In this hydraulic oil cooler heat is removed from hot oil to surrounding air using heat pipes and fins. The objective of the present experimental set up is to enhance the heat transfer of hydraulic oil using heat pipe. The study shows the heat pipe developments for cooling of oil for various applications like power pack, chemical industries etc. Sandip Kumar Das, Kedar Bhojak Several research work done on the area of The effect of oil temperature of the hydraulic system for Plastic Injection Moulding Machine is studied in this paper. Traditionally in India the hydraulic oil VG-68 for Plastic Injection Moulding Machine is used, which has an optimum temperature range with desired effective viscosity property is between 40°C to 50°C. The oil temperature goes high up to 55°c and even higher than that during summer, which is not desirable for the machine operations. It is found that the operation of the machine will get sluggish as the oil viscosity get decreases. This is due to continuous flow and heavy production schedule. The oil needs to be cooled down as fast as possible from the elevated temperature to required temperature. So it is very important to choose the correct type and size of oil cooler for hydraulic system.

III. CFD ANALYSIS OF OIL CHILLER

We are doing CFD Analysis by using Ansys tool. The Pro E Model of chiller is imported in Ansys and applying input and out parameter to conduct CFD Analysis. We have done CFD analysis in two fluid mediums are spindle oil and Hydraulic oil. The CFD analysis results are showing below figures as follows.

A. CFD analysis of oil chiller using fluid as spindle oil

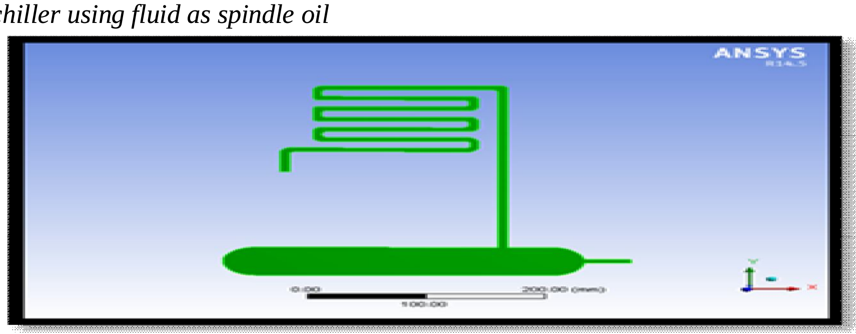

Fig 1: Imported chiller model

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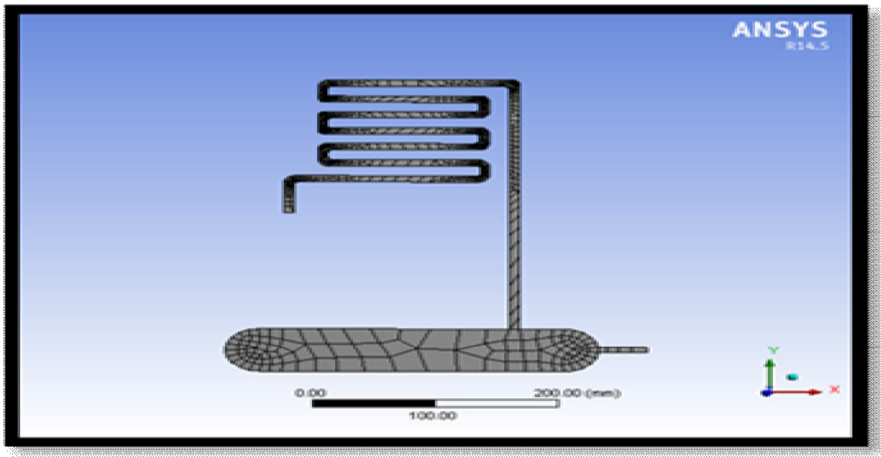

Fig 2: Meshed chiller model in Ansys

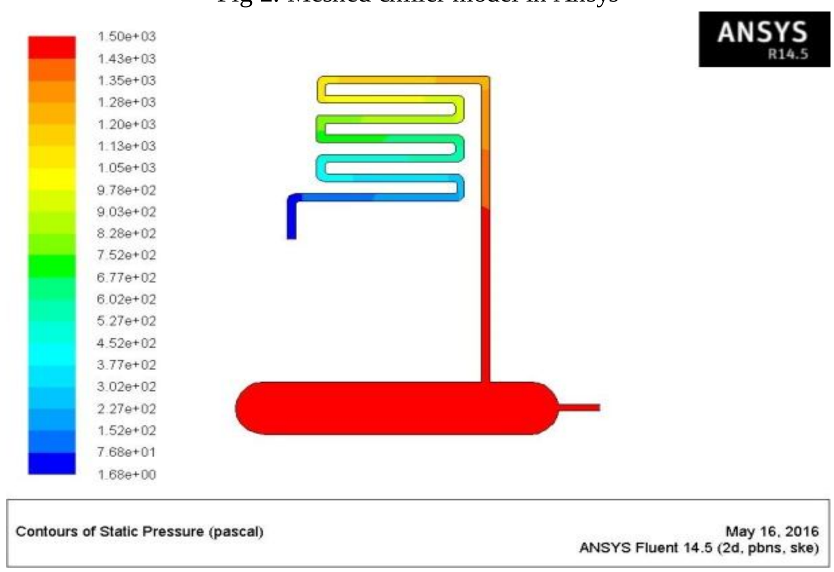

Fig 3: Static Pressure values of chiller in spindle oil as fluid

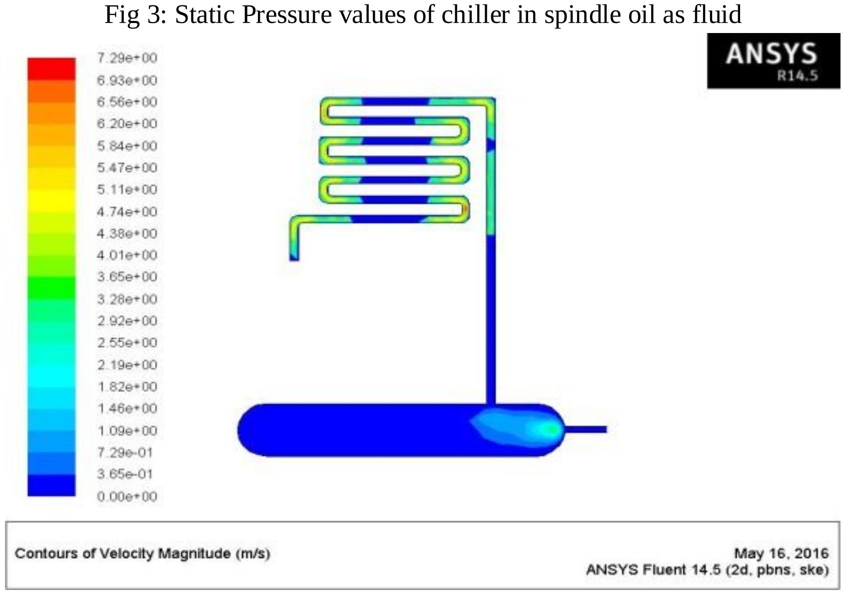

Fig 4: Velocity magnitude in chiller in spindle oil as fluid

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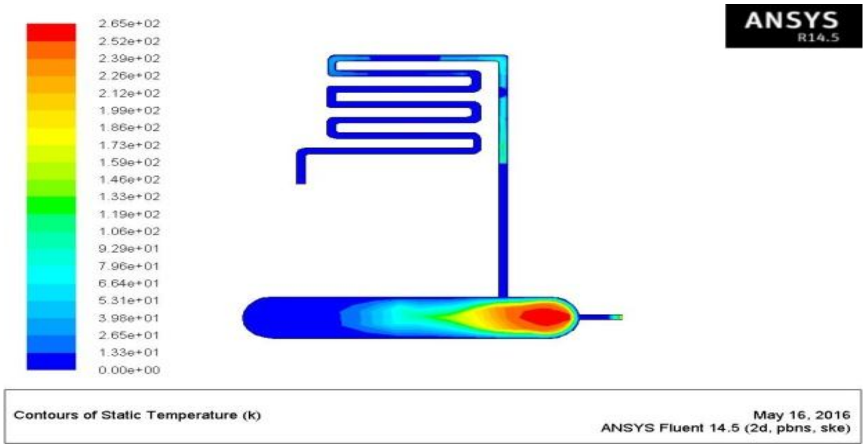

Fig 5: Temperature distribution of chiller in spindle oil as fluid

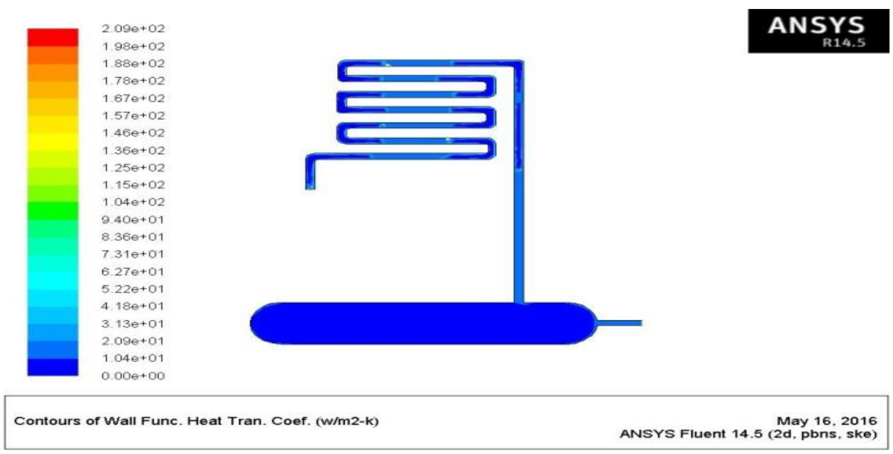

Fig 6: Heat transfer coefficient of chiller in spindle oil as fluid

B. CFD analysis of oil chiller using fluid as hydraulic oil

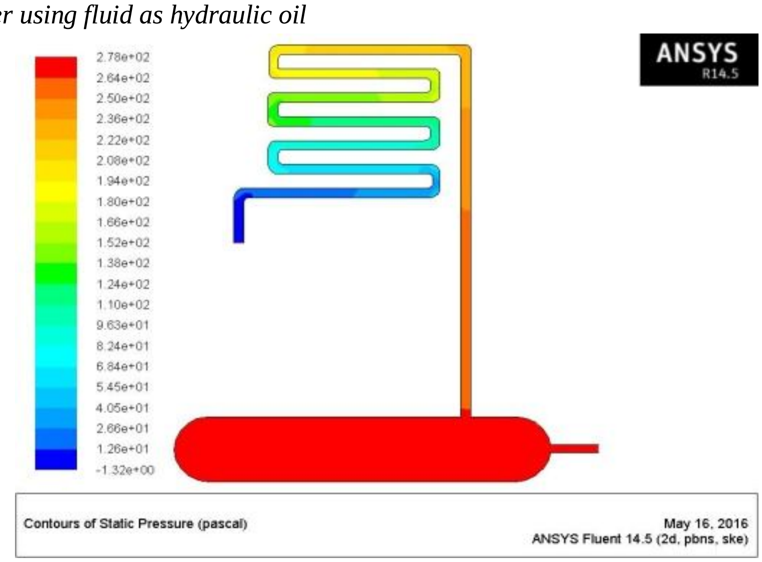

Fig 7: Static Pressure of chiller in Hydraulic oil as fluid

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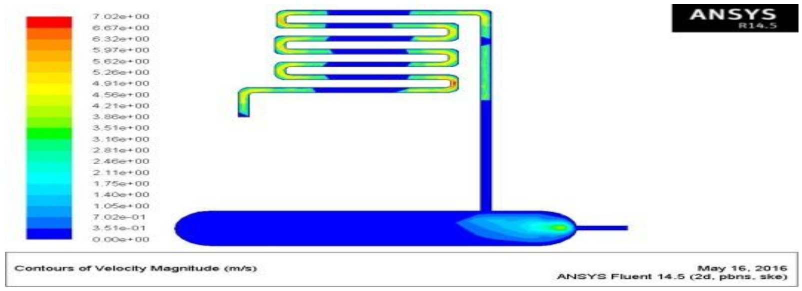

Fig 8: velocity magnitude of chiller in Hydraulic oil as fluid

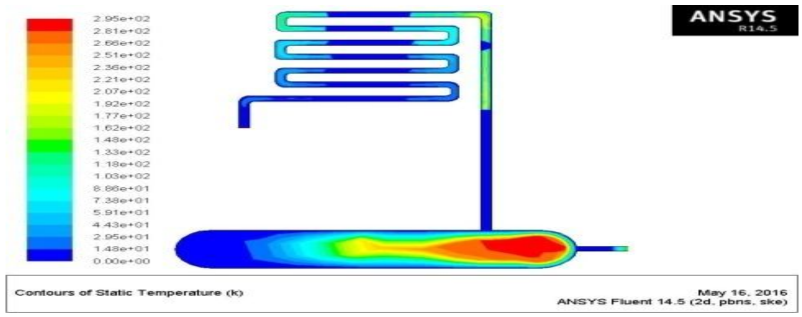

Fig 9: Temperature distribution of chiller in Hydraulic oil as fluid

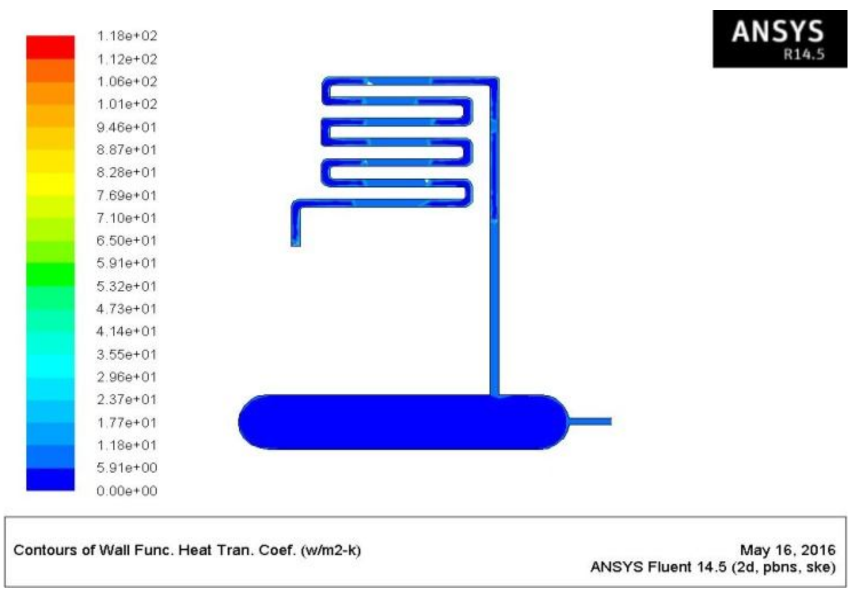

Fig 10: Heat transfer coefficient of chiller in Hydraulic oil as fluid

IV. RESULTS AND DISCUSSIONS

We are using spindle oil and hydraulic oil to perform chiller in CNC machine. Table 1 shows the results of CFD analysis. We are going to analysis static pressure, velocity magnitude, heat transfer coefficient, heat transfer rate, mass transfer rate and maximum temperature by using CFD analysis. After the analysis we are deciding that the velocity magnitude remains common in both spindle oil and hydraulic oil. Static pressure and temperature distribution, mass flow rate is more in hydraulic oil compared to spindle oil. By observing results heat transfer coefficient and heat transfer rate is more for spindle oil compared to hydraulic oil.

The comparative analysis of velocity, temperature, pressure, heat transfer coefficient, heat transfer rate and mass transfer rate of chiller used in CNC machines is graphically shown in below figures for both spindle oil and hydraulic oil

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Table1: Thermal Analysis Results for Spindle oil and Hydraulic oil

	Spindle oil	Hydraulic oil
Velocity Magnitude (m/s)	7.29	7.02
Static Pressure (pascal)	1500	278
Temparature (k)	265	295
Heat transfer coefficient (w/m² k)	209	118
Mass flow rate (kg/s)	-5.48E-05	0.001727041
Heat transfer rate (w)	-32.879456	0.001727041

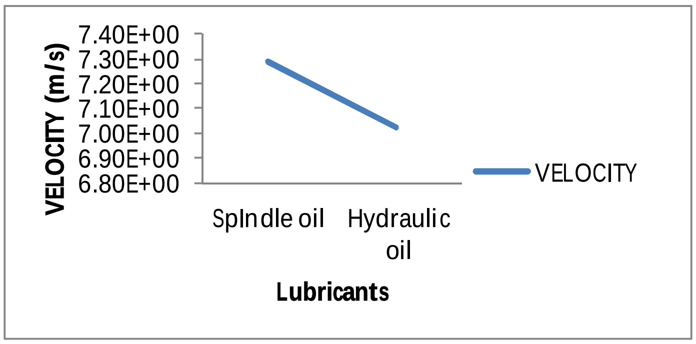

Fig 11: comparison of velocity values for two fluids

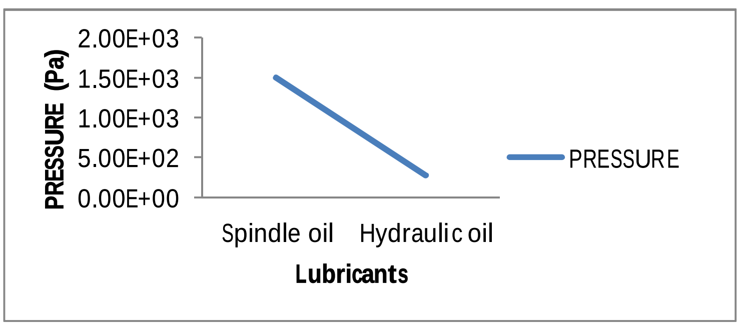

Fig 12: comparison of pressure values for two fluids

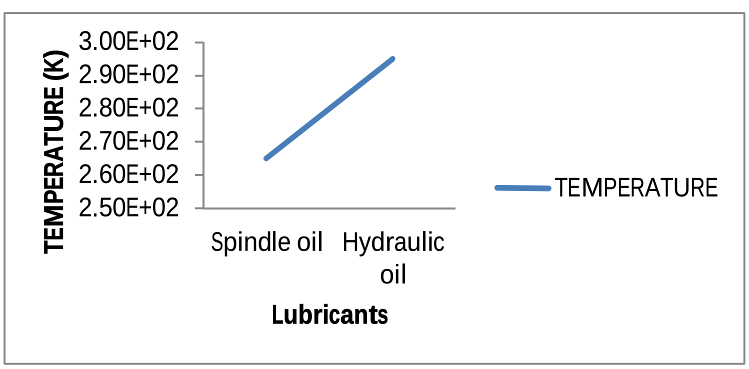

Fig 13: comparison of temperature values for two fluids

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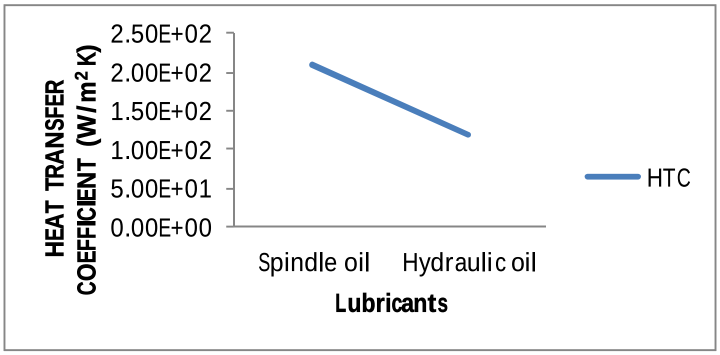

Fig 14: comparison of heat transfer coefficient values for two fluids

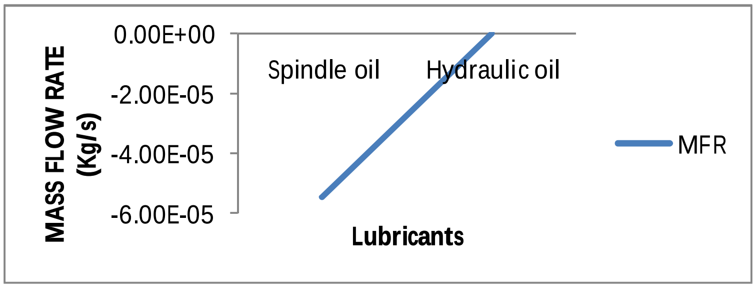

Fig 15: Comparison of mass flow rate values for two fluids

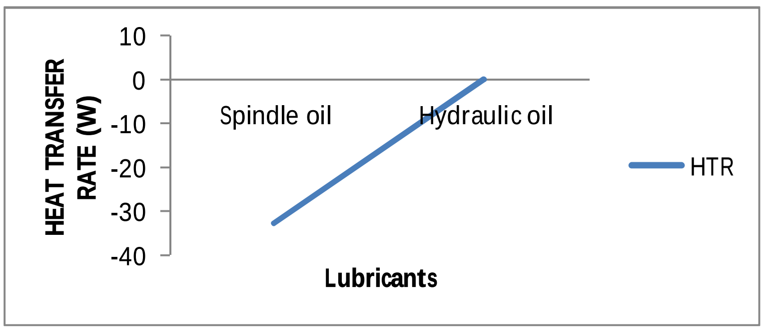

Fig 16: comparison of heat transfer rate values for two fluids

V. CONCLUSION

CFD analysis when different lubricants are used. The lubricants considered in this thesis are hydraulic oil 32, Spindle Oil 22.

By observing the CFD results, the pressure, heat transfer coefficient are more when Spindle oil is used and mass flow rate and heat transfer rate are more when Hydraulic oil is used for chillers used in CNC machines..

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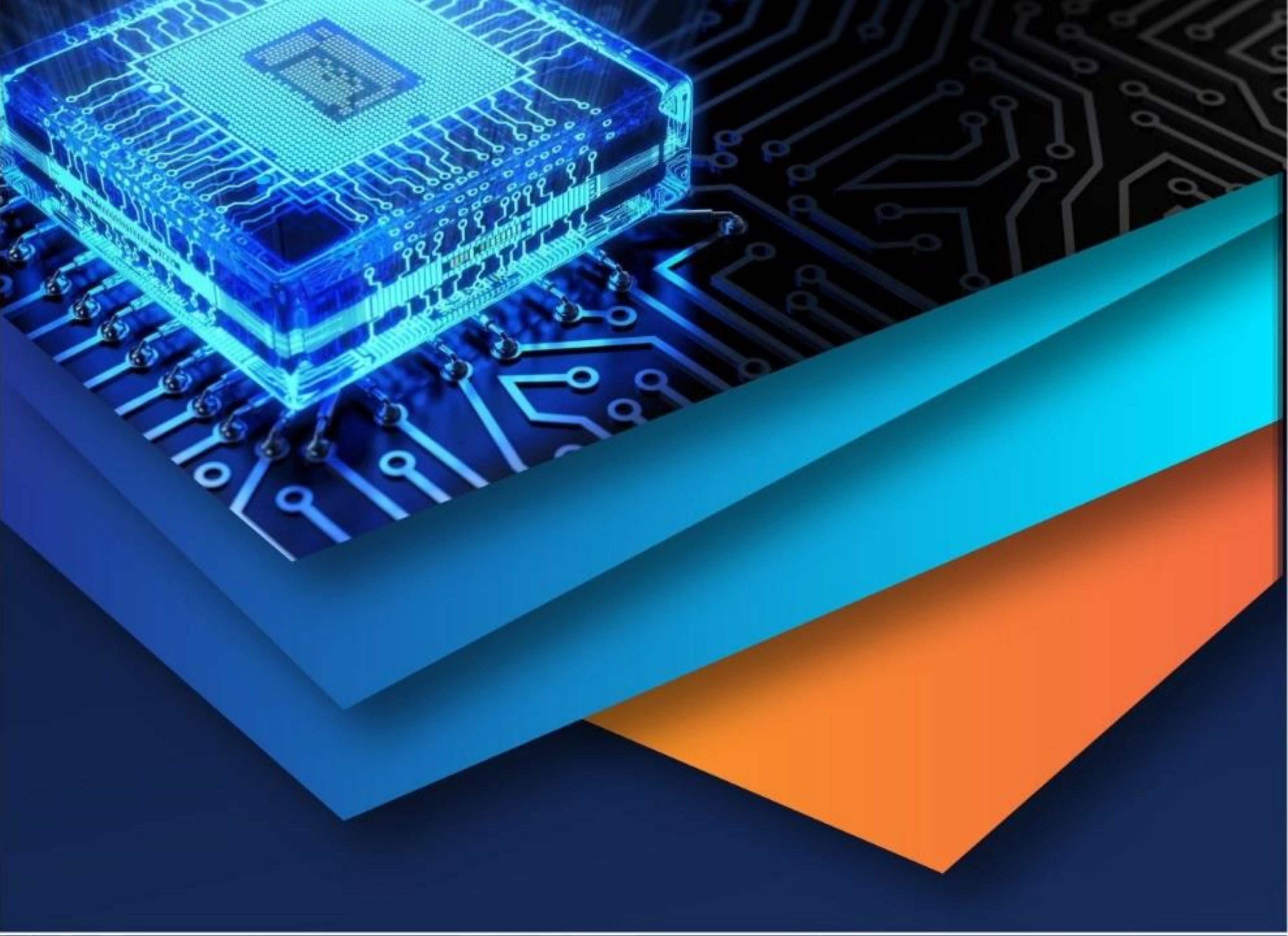

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