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Finding Effective Heat Transfer Rate by Cooling Oil Flashing in Cutting Tool

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ABSTRACT:
Flash cooling is a method for rapid cooling of vessels or other areas, often by using a gas or mist. Flash cooling system is used for cooling of liquids, utilizing thermo compressors, steam ejectors or vacuum pumps. Tool wear of machine tools and large usage of cutting fluids is one of the major problems in manufacturing. Cutting fluids are used to cool down the tool and have been shown to cause environmental problems in machine shops. Tool life and temperature have an inverse relationship, namely that the higher the temperature at the tool-chip interface is, the lower the tool life will be, and vice-versa In this thesis the comparison of flash cooling (i.e.) by providing holes on the cutting tool for passing fluid from them and external cooling of cutting tool is done by determining the heat transfer rate. 3D models of the shrink fit chuck with flash cooling and external cooling is done in Pro/Engineer. Thermal and CFD analysis is done to determine the heat transfer rates in Ansys by changing the cooling fluids and also the material of the cutting tool.

I. INTRODUCTION:
Flash Coolers are similar to evaporators in that they utilize a vacuum vessel to reduce the temperatures at which the liquid boils. The flash cooler's purpose is not to concentrate products but rather to cool them, by admitting them into a vessel, in which the boiling point has been reduced by the vessel being operated under vacuum. Many liquid products benefit by prompt cooling after thermal processing, either in pasteurizers or evaporators. The Marriott Walker Corporation offers two types of flash coolers, one for use on conventional liquid products and the other is suitable for use with viscous liquids such as barbeque sauce and soy protein isolate.

Easily pumped liquids can be quickly cooled in flash coolers with tangential, centrifugal inlets. This approach lays the liquid to be cooled in a thin film against the side-wall of the cylindrical vessel and water vapor is immediately "flashed off", providing for prompt cooling of the liquid product.

Functional Principle:

In the Cool Flash system - similar to the Cool Jet system - coolant bores are made in the tool holder with which the coolant is transported up to the face surface of the chuck. There is a pad placed on the face surface of the Cool Flash chuck which leaves a narrow circular gap leading up to the tool. The coolant is collected in this chamber, creates high pressure and is distributed over the entire circumference of the tool shank.

It flows out of this small reservoir like a closed housing directly along the tool shank. At the end of the shank area, the coolant is pressed into the T-slots, rinses them free and even at the highest speeds it reaches the cutting edges directly, without sputtering, where it can deploy its cooling effect.

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With the Haimer Cool Flash System, there is a disc at the end of the shrink fit chuck that releases a narrow circumferential gap in the direction of the tool. This allows the coolant to wrap itself around the tool like a jacket.

Benefits at a Glance:

- Coolant directly to the cutting edge
- Extended tool life up to 100 %
- Eliminates balls of chips on the cutting tool
- Also for high rpm
- Optimized run out accuracy! No additional unbalance! No disturbing clearance!
- Low acquisition costs & can be added later
- Cool Flash is available from shank diameter 6 mm up to 20 mm

Cutting Tool:

In the context of machining, a cutting tool or cutter is any tool that is used to remove material from the work piece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. Single-point tools are used in turning, shaping, planning and similar operations, and remove material by means of one cutting edge. Milling and drilling tools are often multipoint tools. Grinding tools are also multipoint tools.

Each grain of abrasive functions as a microscopic single-point cutting edge (although of high negative rake angle), and shears a tiny chip. Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the work piece without the rest of the tool dragging on the work piece surface. The angle of the cutting face is also important, as is the flute width, number of flutes or teeth, and margin size.

In order to have a long working life, all of the above must be optimized, plus the speeds and feeds at which the tool is run.

Cutting Fluid Selection Criteria:

The principal criteria for selection of a cutting fluid for a given machining operation are:

- Process performance :
  - Heat transfer performance
  - Lubrication performance
  - Chip flushing
  - Fluid mist generation
  - Fluid carry-off in chips
  - Corrosion inhibition
  - Fluid stability (for emulsions)
- Cost Performance
- Environmental Performance
- Health Hazard Performance

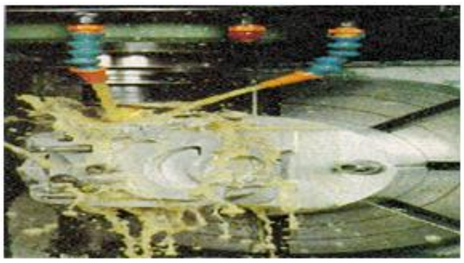

Fig 2.5 cutting fluid effect on machines

3D MODEL OF CUTTING TOOL WITH FLASH COOLING AND EXTERNAL COOLING

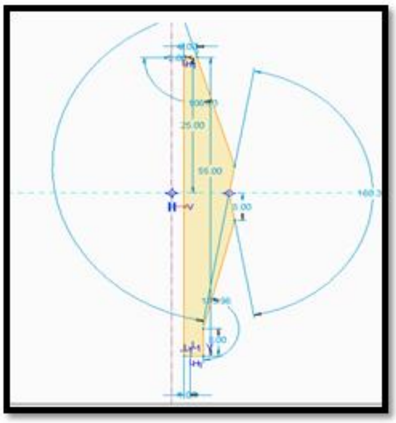

Fig - 2D Sketch

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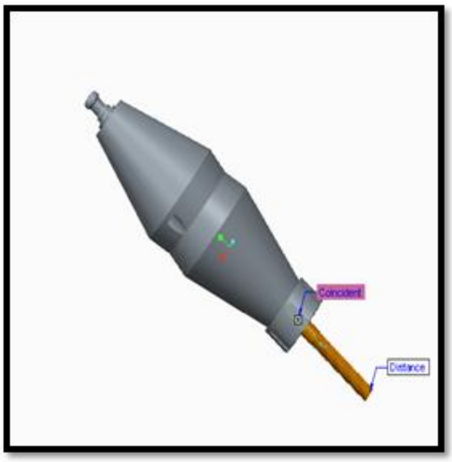


Fig – Assembly

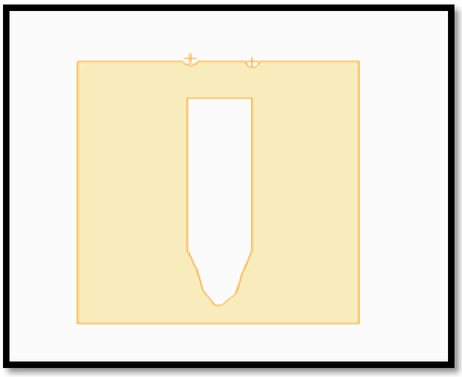


Fig - 2D sketch for CFD

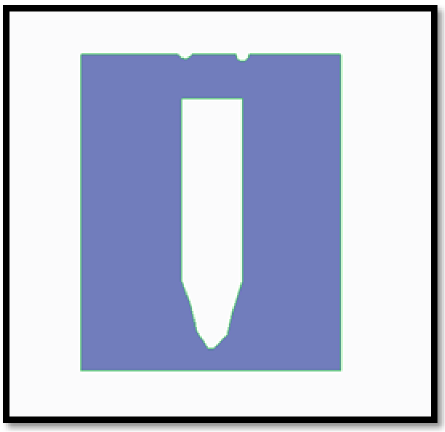
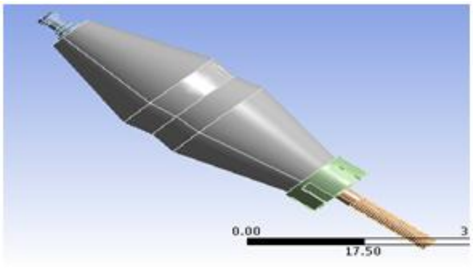
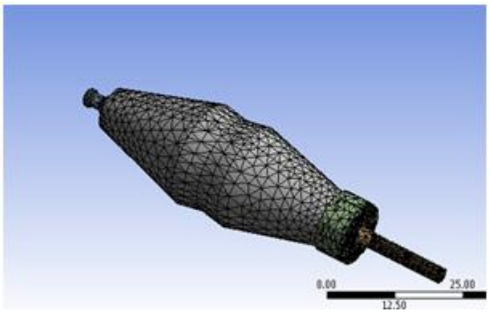


Fig - 2D model for CFD

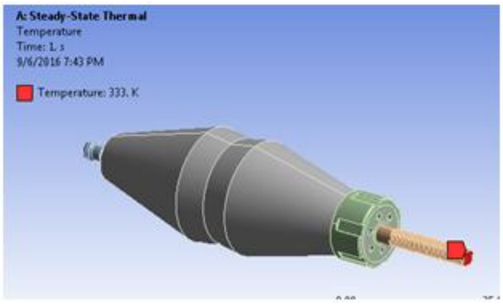
THERMAL ANALYSIS
TOOL MATERIAL – HIGH SPEED STEEL
FLASH COOLING



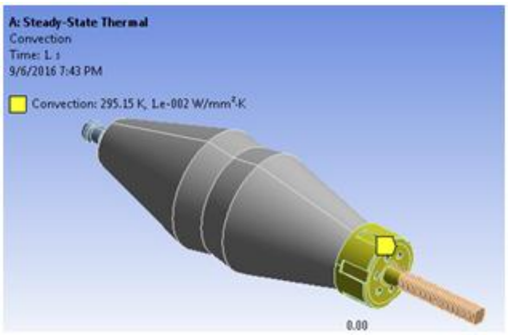
Meshed



Temperature



Convection



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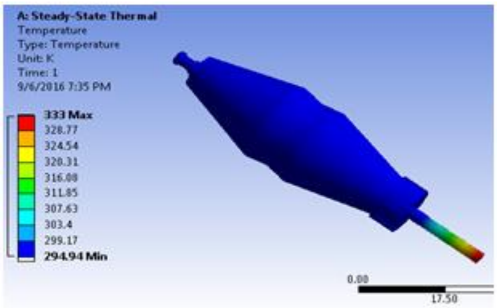
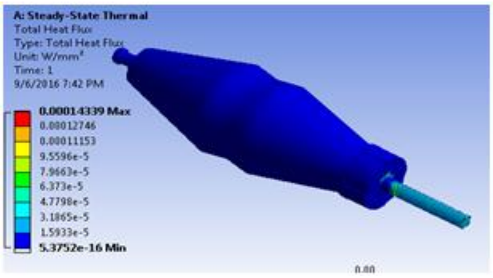
Temperature

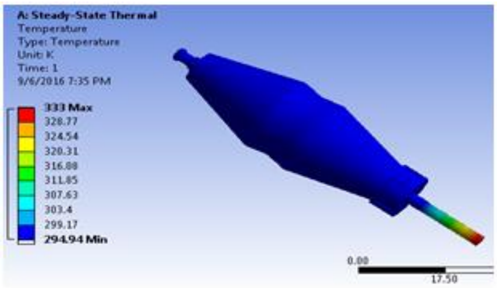


Heat flux

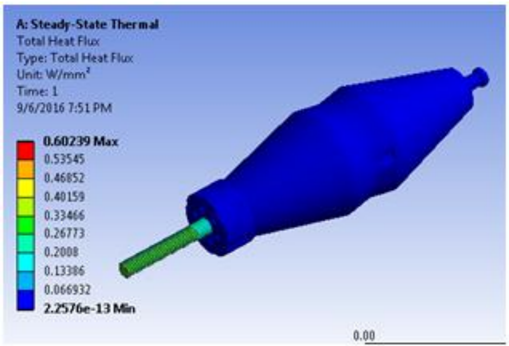


TOOL MATERIAL – TUNGSTEN CARBIDE

Temperature



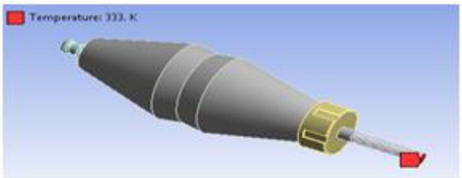
Heat flux



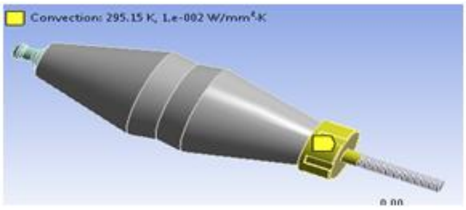
EXTERNAL COOLING

HIGH SPEED STEEL

Temperature



Convection



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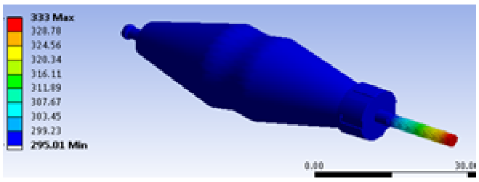
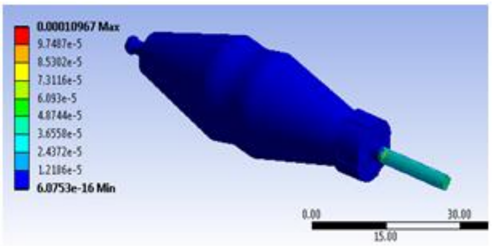
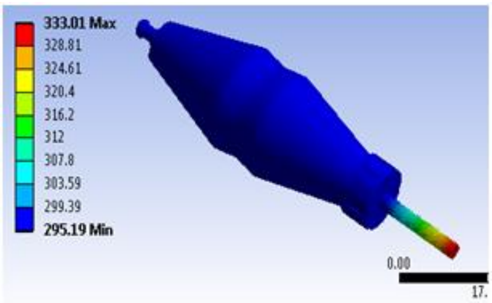


Heat flux



TUNGSTEN CARBIDE

Temperature



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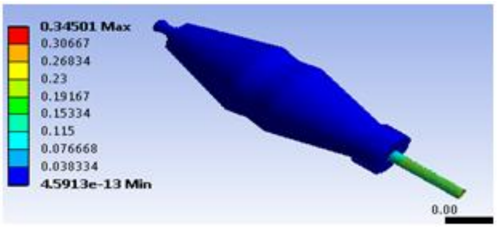
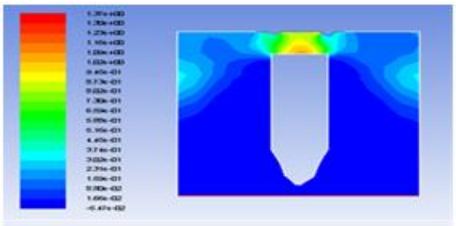
Heat flux



CFD ANALYSIS
FLASH COOLING
FLUID - WATER AT 20 ^{0}C
Pressure



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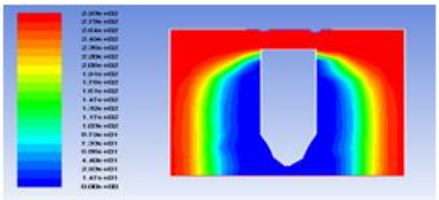
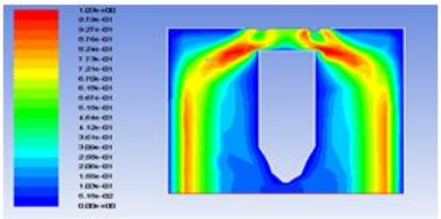
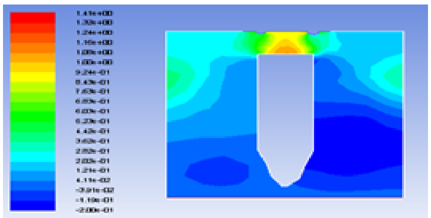


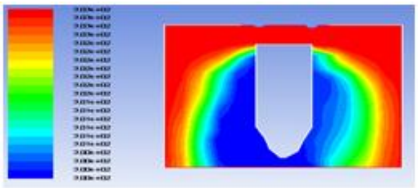
Velocity



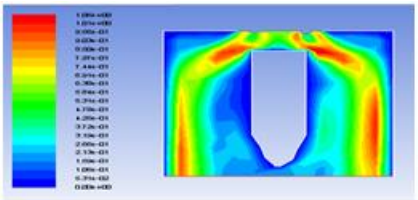
WATER AT 40^{0}C
Pressure



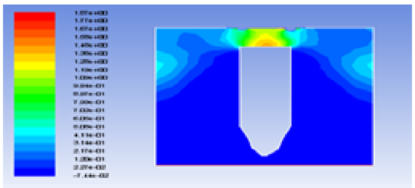
Temperature



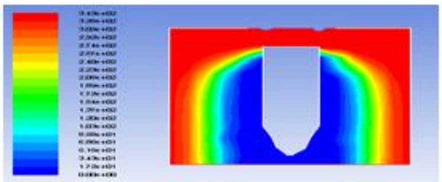
Velocity



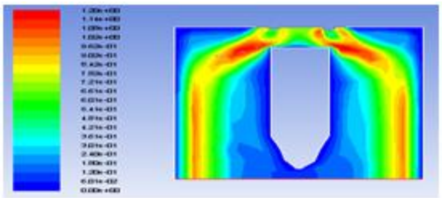
FLUID WATER AT 60 ^{0}C
Pressure



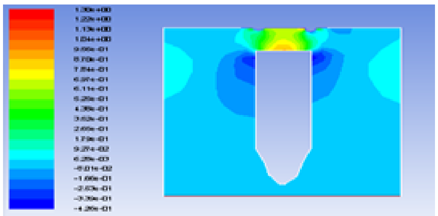
Temperature



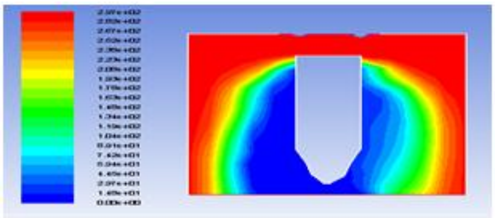
Velocity



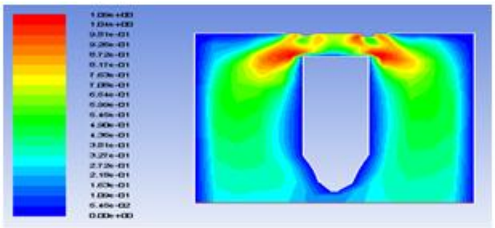
AIR
Pressure



Temperature



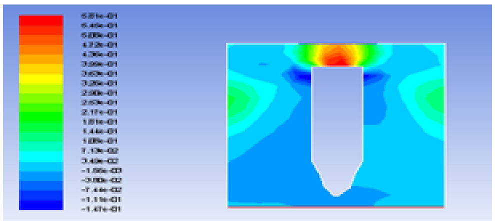
Velocity



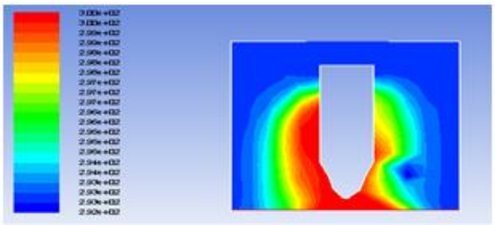
EXTERNAL COOLING

WATER AT 20^{0}C

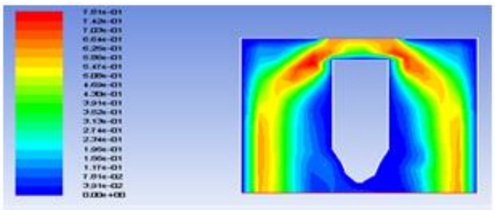
Pressure



Temperature

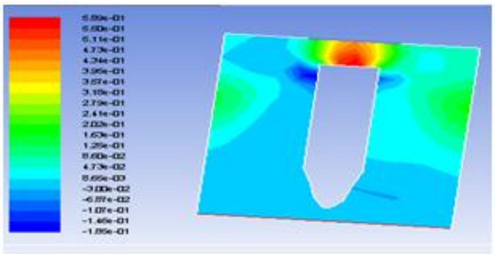


Velocity

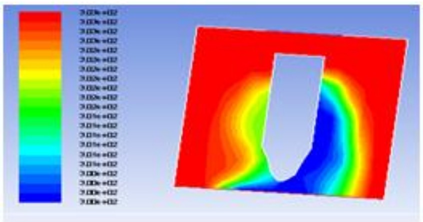


WATER AT 40^{0}C

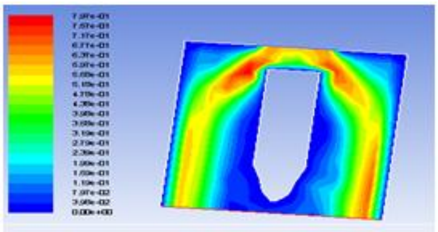
Pressure



Temperature

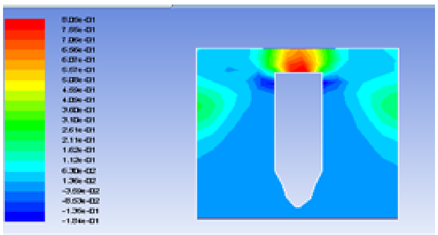


Velocity

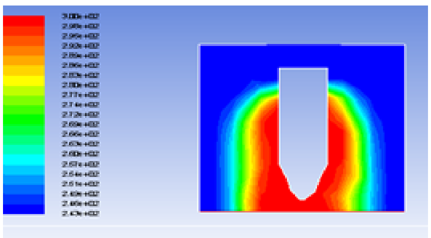


WATER AT 60^{0}C

Pressure



Temperature



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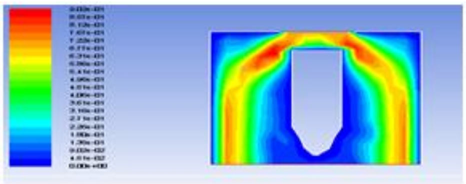
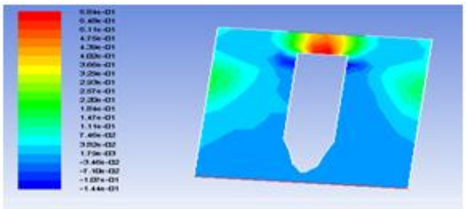
Velocity

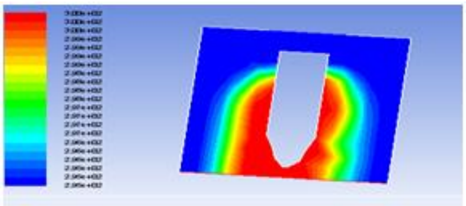


AIR

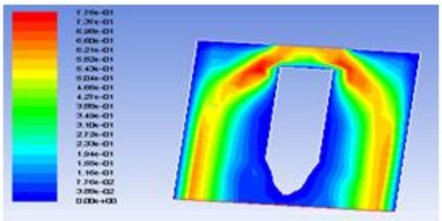
Pressure



Temperature



Velocity



RESULTS & DISCUSSIONS

THERMAL ANALYSIS –WITH HOLE

Materials	Temperature(K)	Heat flux(W/mm^2)
High speed steel	333	0.00014339
Tungsten carbide	333	0.60239

THERMAL ANALYSIS –WITH OUT HOLES

Materials	Temperature(K)	Heat flux(W/mm^2)
High speed steel	333	0.00010967
Tungsten carbide	333.01	0.34501

CFD ANALYSIS

WITHOUT HOLES

Fluid	Pressure(N/m^2)	Temperature(K)	Velocity(m/s)	Heat Transfer Rate (W)
Water at 20^0	1.37e+00	2.93e+02	1.03e+00	2.4261475
Water at 40^0	1.41e+00	3.03e+02	1.06e+00	3.5054321
Water at 60^0	1.87e+00	3.43e+02	1.20e+00	3.2851563

WITH HOLES

Fluid	Pressure(N/m^2)	Temperature(K)	Velocity(m/s)	Heat Transfer Rate (W)
Water at 20^0	5.81e-01	300e+02	7.81e-01	5.0693359
Water at 40^0	5.89e-01	3.03e+02	7.89e-01	10.908325
Water at 60^0	8.05e-01	3.00e+02	9.02e-01	14.87207

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WITH HOLES - AIR

Fluid	Pressure(N/m^2)	Temperature(K)	Velocity(m/s)	Heat Transfer Rate (W)
Air	1.30e+00	2.97e+02	1.09e+00	3.2346802

WITH OUT HOLES - AIR

Fluid	Pressure(N/m^2)	Temperature(K)	Velocity(m/s)	Heat Transfer Rate (W)
Air	5.84e-01	300e+02	7.76-01	2.7330933

CONCLUSION:

By observing thermal analysis results, the heat flux values are more for flash cooling than external cooling. That is the heat produced while machining is fastly removed by flash cooling than external cooling. For Tungsten Carbide tool, the heat transfer rate is more than that of HSS tool. By observing the CFD analysis results, the heat transfer rate is more for all fluids when flash cooling is provided than external cooling. By comparing the results for fluids, the water at 60^0C removes more heat from cutting fluid than other fluids.

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