2 Days International Conference on Recent Innovations in Engineering, Science, Humanities and Management
Dev Samaj College for Women, Ferozepur, Panjab (India) (ICRIESHM-17)
18th -19th March 2017, www.conferenceworld.in ISBN: 978-93-86171-33-7

A PROPOSED METHOD FOR COOLING OF CONVENTIONAL MACHINES BY VORTEX TUBE REFRIGERATION

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ABSTRACT

The vortex tube also known as Ranque tube is a remarkably a simple device, reliable (since no moving parts) and produces hot and cold gas streams simultaneously from the source of the compressed gas. It is also light in weight, ozone friendly, free from pollution, low cost and effective solution to a wide variety of industrial cooling problems especially like drilling, turning and welding and heating problems as early start of the boilers and drying chambers etc.

1. *The vortex tube was first discovered by G. J. Ranque (1933) then Hilsch (1947) [1], a German engineer, performed comprehensive experimental and theoretical studies aimed at improving the efficiency.*
2. *Martynovskii and Alekseev [2] studied experimentally the effect of various design parameters of vortex tubes.*
3. *Hilsch [1] suggested that ratio L/D should be around 50 for good temperature separation.*
4. *According to Westley [3] the only requirement is that the tube exceeds 10D.*
5. *Gulyaev [4,5] determined that the minimum length for cylindrical hot tube was about 10D. If the hot tube is conical, rather than cylindrical, the minimum length must be increased, to about 13D.*
6. *Lewellen [6] stated that ‘‘as long as the tube wall is insulated the temperature separation in the tube remains unaffected by L/D as long as some minimum length is exceeded.*
7. *Takahama and Yokosawa [7] suggested a tube length L/D 100 in order to obtain a better performance.*
8. *Amitani et al. [8] indicated that the shortened vortex tube of six tube diameters length had the same efficiency.*
9. *Saidi and Yazdi [9] found that increasing tube length increases temperature differences and decreases exergy destruction. For L/D 20 energy separation was quite low.*
10. *Saidi and Valipour [10] concluded that the optimum value of L/D is in the range of 20–55. Singh et al. [11] concluded that length of the tube has no effect on the performance of the vortex tube in the range of L/D 45–55.*

Keywords: Vortex tube, waste energy, pressure energy, conventional machines, cooling.

I. INTRODUCTION

Machining is a process commonly used in the production of mechanical work pieces. Higher values of the cutting parameters offer the possibility to achieve higher productivity, but at the same time present a risk of deterioration surface quality and tool life. Cutting fluids are used in metal machining for a variety of reasons such as improving tool life, reducing work piece thermal deformation, improving surface finish and flushing away chips from the cutting zone. In order to increase the efficiency, there are incorporated some new parameters, such as environmental and social acceptability and greater economic profitability. More attention focused to the negative effects of the cooling and lubrication as well as the multiplication of these effects has led to the necessity of finding new solutions. Alternative types of cooling in combination with new materials for making tools and special coatings represent an area of finding appropriate replacement of the cooling and lubricating. Nowadays other less conventional fluids are also being studied with the aim of achieving a more ecological and efficient process in the machining of these difficult-to-cut materials. Examples of this are vortex cold air, among others. In this project a comparison is made between different cooling methods employed in lathe machine. Tool life and work piece surface finish have been analysed in each case, searching the pros and cons of each cooling technique. The results reveal the possibility of replacing traditional pollutant cooling fluids by other more ecologically friendly alternatives.

II. WASTE ENERGY SOURCES

A large number of industrial processes produce waste heat energy. Some of these which can act as major waste heat and pressure energy sources are tabulated below:

Source	Temperature ^oF	Pressure(bar)	Application of waste energy
Gas turbine exhaust	700-1000	6-100	Electricity production
Blast furnace exhaust	1650-3000	6-10	Steam generation for mechanical process
Envelope furnace exhaust	1400-1800	6.5-10	Combustion air preheat
Geothermal steam	212	6-8	Feed water heating
Steam boiler exhaust	450-900	3-5	Combustion air preheat
Reciprocating engine exhaust	600-1100	2-5	Transfer to low temperature process
Cooling water from engines, compressors, furnace doors	80-450	-	Space heating and domestic water heating

Table 1: Waste heat and pressure sources

III. WASTE ENERGY RECOVERY

First step to be taken is to reduce the waste energy production to minimum. This can be done by increasing process efficiency and reducing losses but waste energy below a certain level is unavoidable and thus various techniques are employed for recovery of this waste energy. The technique that should be applied to recover waste heat and pressure energy depends upon the pressure, temperature and quantity of the source and the type of fluid exhausted. The conventional objective of waste energy recovery is electricity generation from high pressure exhaust gases from furnaces and engines. Methods for waste heat and pressure recovery include transferring heat between gases and liquids, transferring heat to the load entering furnaces, generating mechanical and/or electrical power, or using waste heat with a heat pump for heating or cooling facilities and piezoelectric generation. Some common applications of waste heat and pressure energy are listed below:

1. Boiler feed-water preheating
2. Load preheating
3. Power generation
4. Steam generation for mechanical work
5. Space heating
6. Transfer to liquid or gaseous process streams
7. Combustion air preheating

Setup & Application of Vortex Tube for Energy Recovery

A vortex tube also known as the Ranque - Hilsche tube, is a device that separates a stream of gas into two streams simultaneously, one at a higher temperature and other at a lower temperature than input stream. It is a simple three end tube having no moving parts and does not require any energy input for operation. Vortex tube is applicable to various situations where simplicity and robustness are required. Vortex tube is used for space heating and cooling, cooling circuits and weld spots etc. The inlet nozzles are tangential to the main tube in order to impart vortex motion to the entering gas. The fixed flow restriction on one side of inlet is termed as the cold orifice while at the other end of the main tube is a variable flow restriction called the hot fraction control valve. The stream coming out of orifice is colder than the input stream and the stream coming from the valve is hotter. The temperature deviation is controlled by varying the relative amounts of flow through each side with the help of control valve. Higher the cold stream flow higher its temperature. Fraction of air coming out of cold end is called cold mass fraction and fraction of air coming out of hot side is called hot mass fraction. The vortex tube works as a plain energy separating device. Redistribution of energy takes place through vortex generation without any external heat exchange or work. The input stream gets divided into two streams, one of higher energy than surrounding fluid and other of lower energy.

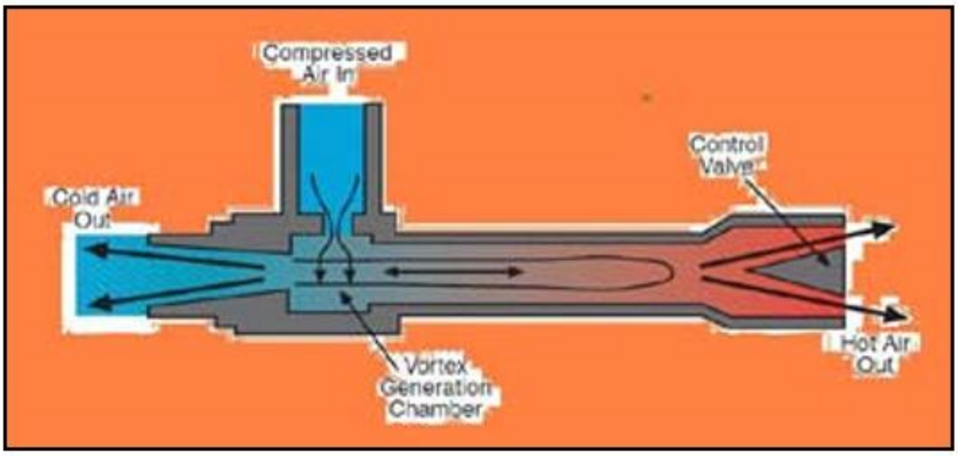

Fig. 1: Vortex Tube Schematic

Experimental Setup

A labelled schematic sketch of the setup is shown below.

1. Compressed air Receiver,
2. Hand operated Valve,
3. Pressure gauge,
4. Counter flow Vortex Tube,
5. A set of orifice flow meters,
6-7. Orifice Flow meter,
9. Cone-shape valve
10. A conventional machine

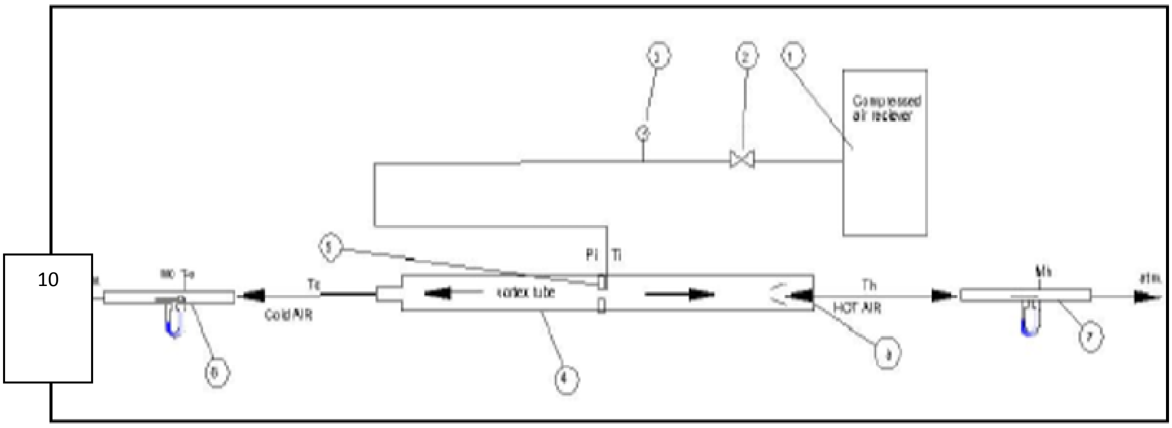

Fig. 2: Experimental Apparatus

Evaluation

Experimental results for a vortex tube setup recorded with varying input stream pressures are provided below.

Tube diameter (mm)	Cold end diameter (mm)	Inlet diameter (mm)	Nozzle diameter(mm)	Length of cold tube (mm)	Length of hot tube (mm)	Hot end angle (degrees)
12	6	4	2	120	30	45

Table 2: Tube dimensions

Procedure

It consists of a two stage compressor and a receiver as a source of compressed air, auto pressure cut-off switch, an air filter and a counter-flow vortex tube. Compressed air from the receiver of compressor is supplied through a hand operated control valve to control the pressure at the inlet to the vortex tube as shown in figure. The pressure at the inlet to the vortex tube is measured with the help of a calibrated pressure gauge indicator. The temperature of the hot air and temperature of the cold air coming out of the vortex tube is measured with the thermocouple located immediately on the downstream of the cone shaped valve, and downstream of the orifice located next to the inlet respectively. The temperature of the air is also measured at the inlet to the vortex tube to calculate the temperature drop of the cold. The thermocouples along with the digital indicator used in this experiment are calibrated to an accuracy of ±0.1°C.The mass flow rates of the cold air and hot air discharges are measured by calibrated orifice flow meters. The pressure difference across the orifice is measured by an inclined tube manometer connected to the pressure tapping at distance d (orifice diameter) on the upstream side and d/2 on the downstream side of the orifice. The ratio, called a cold mass fraction is changed by regulating the cone-shaped valve opening. Now the cooled end of vortex is used for cooling purpose through the channels. And after that we compare this new approach of cooling with other coolant in term of their effectiveness, chemical properties, effect on material tool properties etc. to decide whether our method is feasible to overcome the limitations of traditional methods or not.

IV. RESULTS AND OBSERVATIONS

Specimen	Cutting tool	Cutting fluid	Speed (rpm)	Temperature after turning (^{0} C)
1.	HSS	Water	355	33
2	HSS	Dry cutting	355	37
3	HSS	Palm kernel oil	355	36
4	HSS	Soluble oil	355	34
5	Carbide	Water	355	34
6	Carbide	Dry cutting	355	39
7	Carbide	Palm kernel oil	355	38
8	Carbide	Soluble oil	355	32.5
9*	HSS*	Vortex cooled*	355*	31*
10*	Carbide*	Vortex cooled*	355*	29*

Ambient temp. =30 degrees ; Theoretical Data*

Table 3: The variation of temperature of the work piece using different cutting fluids on a lathe machine

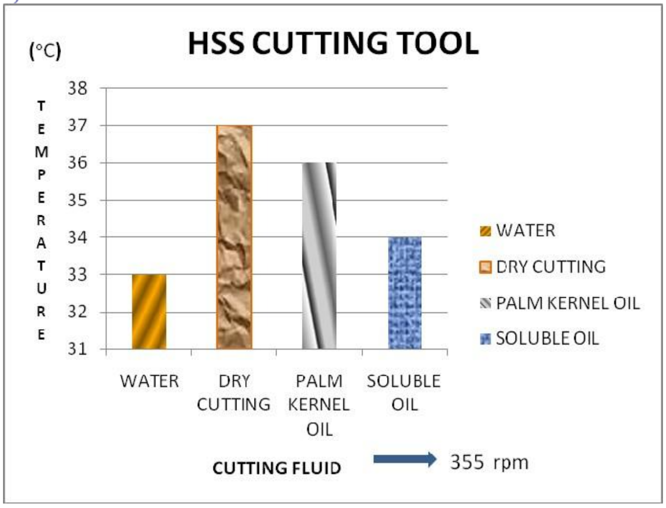

Fig 2: Graph of temperature variation during cutting and cooling for HSS cutting tool

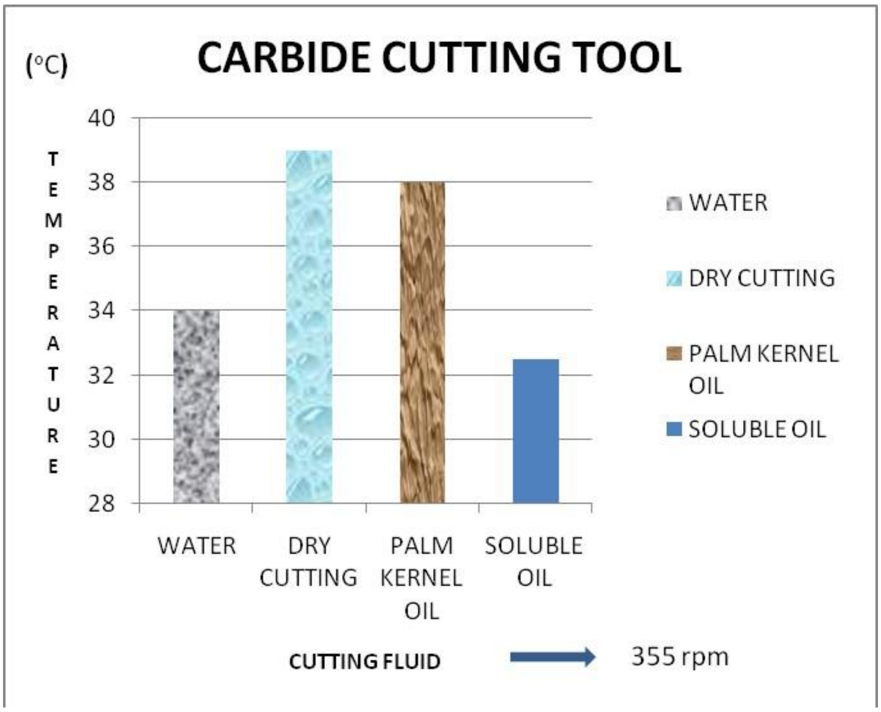

Fig 3: Graph of temperature variation during cutting and cooling for carbide cutting tool

V. CONCLUSION

From the above observation and Theoretical data we are able to provide an alternative method of cooling conventional machines (such as Lathe machine, Milling machine etc.) which is by using vortex cooled air.

From the above data we also observe vortex refrigeration method is more effective and efficient as large scale temperature drop has been seen as compared to conventional cooling method, hence better cooling rate is observed .In addition to that it also provides large tool life, reduces abrasion and deterioration of cutting tool surface. It also decreases the negative effect of coolant and lubrication which were used in past .This method is also economically feasible and eco-friendly.

Hence we can conclude that vortex tube refrigeration is able to improve the tool life, reduces work piece thermal deformation, improve surface finish with better cooling rate, without causing any harmful effect on the surrounding

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