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# An Overview on Vortex Tube Applications

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**Abstract**— Vortex tube is a simple device with no moving parts. It separates inlet high pressure stream of air into two lower pressure streams of cooler temperature at one end and hotter temperature at other end. It is basically of counter flow type and parallel flow type. It has many advantages and wide range of applications, mostly using counter flow owing to better performance than parallel flow. Most of the applications reflect the benefits in terms of performance, energy, compactness or as an alternative to the conventional method. Few applications are highlighted in this paper. Variable temperature system uses vortex tube along with liquid nitrogen cooled heat exchanger to maintain lower temperature as the biochemical samples are prone to change properties in unconditioned environment. In case of high speed machining tools, vortex tube cooling improves the performance and tool life along with better finish of workpiece. Laser cutting system uses vortex tube cooling to minimize heat affected zone. Vortex air coolers are preferred for different industrial applications. The personal air suit uses vortex tube to allow workers to work under adverse conditions for longer hours. Vortex tube refrigeration is alternative way to the conventional refrigeration in some applications.

**Index Terms**— Vortex tube, counter-flow, temperature separation, cold effect, low temperature applications, refrigeration, Ranque-Hilsch tube .

## 1 INTRODUCTION

THE vortex tube is a simple and compact device with no moving parts. It is capable of separating a high-pressure flow into two lower pressure flows of different temperatures. Basically vortex tubes are of two types i.e. counter-flow and parallel-flow types. The figure-1 shows the counter-flow type vortex tube. It consists of a simple circular tube, one or more tangential nozzles, and a throttle valve. The vortex tube works when high pressure gas enters tangentially into the vortex tube after passing through the nozzle(s). The circular motion depends on speed and inlet pressure of air. The gas expands through the nozzle and achieves a high angular velocity, causing a vortex-type flow in the tube. There are two exits to the tube: the hot exit is placed near the outer radius of the tube at the end away from the nozzle and the cold exit is placed at the center of the tube at the same end as the nozzle. By adjusting a throttle valve downstream of the hot exit it is possible to vary the fraction of the incoming flow that leaves through the cold exit, referred to as the cold fraction. There is pressure difference and hence speed difference between tube wall and center of tube due to high speed circular motion of air. The streams of gas leaving through the hot and cold ends of the tube are at higher and lower temperature, respectively, than the gas entering the nozzle.

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This effect is referred to as the temperature separation effect.The exact phenomenon of temperature separation is not yet completely understood by researchers and the research is still ongoing to understand it. [1]

## 2 ADVANTAGES OF VORTEX TUBE

There are several advantages of using vortex tube for different applications like there is no leakage problem as it uses only air as the refrigerant; no spark and explosion hazard; it is simple in design and needs only control of valves for appropriate functioning as it has no moving parts; light in weight and portable; requires less space; highly reliable; virtually maintenance free; initial costis low and at places where compressed air is readily available working expenses are also low. It also does not require expertise attention and has wide variety of applications both for cooling as well as heating. But there are disadvantages also like low COP, limited capacity and not very efficient as cooling device.

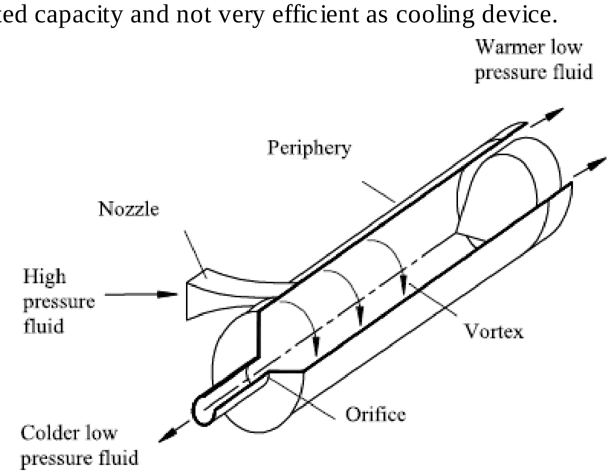


Fig. 1. Counter flow vortex tube [1]

In most of the open literature it is found that the common classification of vortex tube is counter flow type and parallel flow type.

In counter flow type the cold and hot exits are on opposite sides of the tube and in parallel flow type both the ends are on same side of the tube.

In this paper an overview is provided on various applications of vortex tube. It is found that applications are on heating side as well as cooling side.

## 3. Application of Vortex Tube Cooling in Variable Temperature (VT) System for Low Temperature Magic Angle Spinning (MAS) Nuclear Magnetic Resonance (NMR) System [2]:

It mentions the use of vortex tube in variable temperature system. Variable temperature system uses fast MAS probe to investigate biological macromolecules or biochemical sample studies which are often temperature sensitive as well as prone to dissolution of crystals, loss of activity, or disruption in structure. Structural studies of samples at high magnetic field needs reproducible measurement and temperature control over a period of several days.

In the described VT system cold gas enters through the bottom of the probe via a flexible connection allowing samples to be conveniently changed at low temperature, to enable studies of samples that must be constantly kept cold. When temperatures no lower than 200C are required, use of a vortex tube popularly known as Ranque–Hilsch vortex tube to supply the cold air stream is preferable which uses only high-pressure room temperature air supply. For lower temperatures requirement a commercial liquid nitrogen cooled heat exchanger was used which cools the VT gas on passing through a coil immersed in liquid nitrogen.

Figure A shows that temperatures below -20$^0$C are achieved using a liquid nitrogen heat exchanger. Nitrogen gas is delivered from this apparatus to the probe via a flexible stainless steel dewared transfer line as shown.

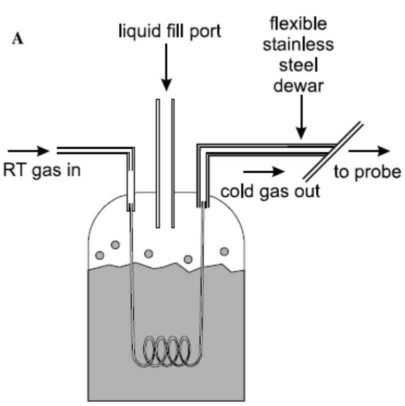


Fig.2 (A) Flexible stainless steel dewared transfer line [2]

Figure B shows that temperatures down to -20$^0$C can be maintained using a vortex tube. A cross-section of the vortex tube is shown. The right inset shows the brass piece that is responsible for inducing rotation of the compressed air, forming a vortex. The left inset shows a barrier placed in the warm end of the tube to partition the air flow.

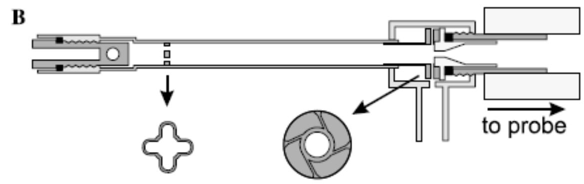


Fig. 2 (B) Cross-section of the vortex tube [2]

Figure C shows the schematic depiction of the air flow within the vortex tube. Compressed air at room temperature enters the device producing a rotating vortex that is separated into a warm stream to the left, and a cold stream that is diverted to an expanding nozzle to the right.

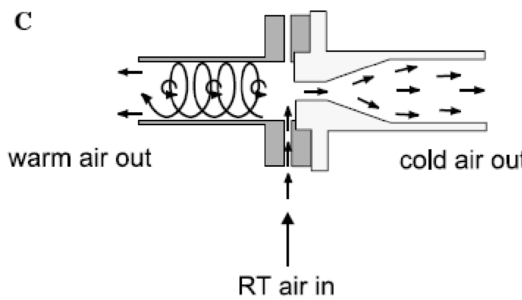


Fig.2 (C) Schematic depiction of the air flow within the vortex tube [2]

Pre-cooled VT nitrogen enters at the bottom of the probe and travels to just below the stator via a glass dewar near the center of the probe body. The entire top assembly including the MAS stator has a Teflon insulating cavity attached to the outer probe shield. The vortex tube is connected to the probe via a plastic adapter with the same diameter as the flexible stainless steel dewared transfer line of the liquid nitrogen-cooled heat exchanger. The cooling achieved by the vortex tube is limited by back pressure produced by the small inner diameter of the glass dewar at the cold end. If lower temperatures are not required, more efficient sample cooling is possible by directly connecting the vortex tube to the MAS stator.

## 4. Cryogenic Cooling in High Speed Machining (HSM)

Heat generated during metal cutting affects the quality of a workpiece and limits the life of the cutting tool. Heat is dissipated through the cutting tool, the workpiece, the chip and the cooling fluid. The cooling mechanism is used for circulation of the cooling fluid.Better machining performance can be achieved by using proper workpiece material, cutting tool material, cutting conditions and parameters, also by cooling the cutting tool, freezing the workpiece, cooling the tool-chip and tool-workpiece interface, or with the chip draining the heat away, unwanted heat can be eliminated.

Heat dissipations studies through various theories, models and simulations as well as experiments have been attempted by researchers to understand the mechanism and theory behind the temperature built-up during machining for optimising machining procedure, workpiece results and cost effective output. One such attempt is using chilled air or cryogenic cooling. Few researchers have used Ranque-Hilsch vortex tube (RHVT for the cooling purpose for experiments related to metal cutting. Four cooling approaches are found.

a) pre-cooling the workpiece by refrigerated gas and metals which aredifficult to machine to be first frozen and cut to shape while in the frozen condition. E.g. chilling aluminium castings prior to machining, can prevent the castings from moving during and after machining.

b) Indirect cryogenic cooling of cutting tool. Cooling isonly attempted at cutters or inserts and no attempt were made on the workpieces.

c) Cryogenic spraying withjet for grinding of cutting tool using cooled air to ensure longer tool life and the lower surfaceroughness compared to that with oil-basedgrinding.Alsousing vortex tube cooling ejectedair and liquid coolant misted by the air while machining could ensure machining hard materials at low cost using TiN coated tools compared to high cost CBN material. Another advantage was achieving dry machining using cold air on interface than wet machining.

d) Direct cryogenic treatment (of cutting tools) reduced cost to about half due to increase of hardness of tool.

Common advantages of machining incorporating cryogenic cooling are retaining of workpiece material properties, cutting temperature according to cooling approach, tool wear reduction and increase in tool life, workpiece surface roughness improved, lower tool/ workpiece friction ratio and cutting forces were affected.

## 5. INDUSTRIAL APPLICATION OF MULTI-PURPOSE VORTEX AIR COOLERS [4]:

The temperature distribution of the high-speed turbulent flow of air (gas) in the field of centrifugal forces is used on an increasing scale in industry. The first generation of multi-purpose vortex air coolers was produced commercially in the former USSR to ensure availability of vortex refrigerators in any area of the plant.

The industrial verification of first generation vortex coolers was needed:

- obtain practical technological information on the technological and service properties of vortex refrigeration technology;
- select preferred design for development and new generation efficient coolers;
- compare vortex coolers with "conventional" system air conditioning,
- Develop a rapid method of efficiency evaluation and economic information for production of vortex refrigerators.

Various fields using vortex air coolers are:

- industrial electronics like in cooling of control blocks of program-controlled lathes, automatic lines, robotized sections, automatic production systems;
- hot and harmful production processes like air screens of painting chambers, forging shops, electroplating and metallurgical production; also cooling of sand in equipment with rapidly hardening mixtures, cooling of agricultural production; production of sheet materials, production of glass;
- metal working e.g. blowing cold air flow into the cutting zone;
- Self-propelled systems for hot climate e.g. cooling of working zones in cabins of cranes, in trucks of drill operators, etc.;
- transport of vegetables and fruit e.g. cooling of food storage facilities in small ships and transport vehicles;

The vortex refrigerators, powered by compressed air from the plant pneumatic circuit or by an existing source fixed on the self-propelling object, promotes freon-free refrigeration technology with possibility of multi-branch application and promising future.

## 6. AIR SUITS AND MASKS [5]

Fig. 3. Worker with air suit [5]

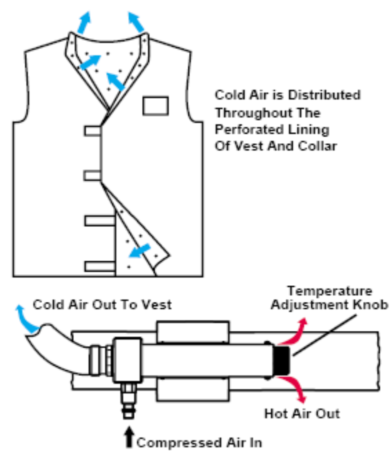


Fig. 4. Air-suit [5]

There are some areas in fields where space conditioning as well as full automation is not possible.

In such places, a one piece air-cooled suits for operators is very much helpful. Few places include entering the vessels, the tanks, etc. where there are chances of dust, fumes and toxic environment, or locations like coal mines, foundries, sand blasting, welding, furnaces, etc.

This suit protects the workers as well as increases working hours due to conditioned environment given to the body of the worker in the unpleasant or unhealthy working conditions.

## 7. VORTEX TUBE BASED REFRIGERATION [5]

Refrigeration is widely used in different sectors like, agriculture, transportation, domestic, industrial, food, medicine, commercial, etc. Storage of fishes by an average fishermen, medicines and vaccines transportation to villages and remote places, etc can be tried using vortex tube refrigeration system. Industries having facility of compressed air or waste gases at low pressure, etc utilise vortex tube concept to minimise the wastage of their air or

gases and get benefited by use of vortex tube for cooling or heating applications.
There are many applications of vortex tube, few of which are highlighted above, including process industry, production operations, simultaneous heating and cooling, etc. Vortex tube thus find varieties of applications as it is very compact and fail-safe device.

## 8. Laser cutting of GFRM using assisted cooling-air generated by vortex tube [6]:

$CO_2$ Laser processing system mainly consists of a $CO_2$ laser source, a beam expander, turning mirrors, aperture, focal lens, scanning set, moving stages and working specimen.

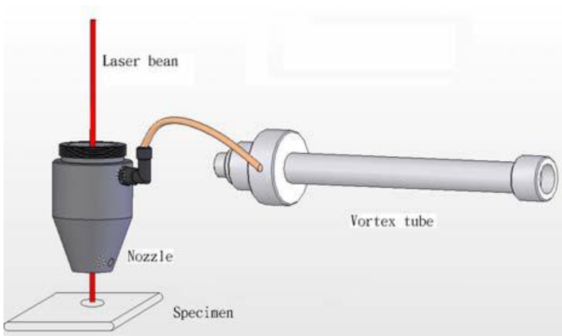

Fig. 5. Low temperature air materialsprocessing used by a vortex tube in the machine tool [6]

The specimen is fixed on the moving tables by using vacuum adsorptive.For the laser processing of materials, the heat affected zone (HAZ) is an important indicator for themicroelectronics manufacturing.

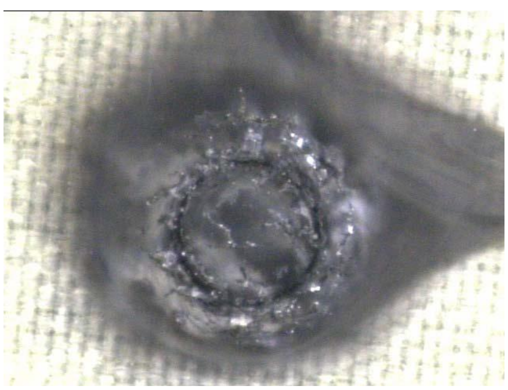
Fig. 6. Laser cutting without any assisted gas [6]

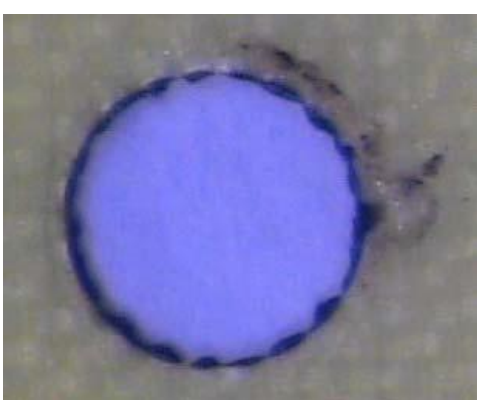
Fig. 7. Laser cutting with the cooling-air [6]

The way of laser cutting is using focused beams to heat the surface of the material upto high temperature and melt situation for removal materials. Because melt condition and high temperature generate theburned black droplets and HAZ, the properties of the processing medium are easily influenced. Therefore, decreasing-heat affected zone area is a key point of the manufacturing technology.
Vortex tube is used as there is no refrigerant requirement, no effect on environment, can generate low temperature cooling-air and can diminish HAZ with the laser cutting for glass fibre reinforced composite materials (GFRM).

## 9. Conclusion:

It is seen that the vortex tube has many applications out of which few are mentioned in this paper. Also it is very useful and simple device with benefits comparable to the conventional technology.

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