Cryogenic Grinding Using Liquid Nitrogen

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Abstract--- In the present day situations with the growing demand for increasing the production and also making it economical is an issue of concern. Added to this is the concern of improving the accuracy and the quality of the product. Though high speed machining of materials is made possible it is limited to certain rate because of the fact the high speeds produce higher heat production and if sufficient time is not given for that heat to radiate or proper means of heat transfer lacks then it would result in permanent deformation (plastic deformation) of the grains away from their boundaries. This leads to the wear of both the tool and the job. Hence in order to implement high speed machining we have to find an alternative way to bypass the heat produced quickly and efficiently. That's where the concept of cryogenic grinding comes into play which uses liquid nitrogen as the coolant medium.

Keywords:- *Heat production, machining sector , plastic deformation, coolant selection , utility*

1. INTRODUCTION

Grinding is an abrasive machining process that uses an abrasive grinding wheel as the cutting tool. Grinding practice is a large and diverse area of manufacturing and tool making.

It can produce very fine finishes and to accurate dimension. Yet in mass production it can also rough out large volumes of metal quite rapidly. It is better suited to the machining of very hard materials. Each grain of the abrasive in the grinding wheel functions as a microscopic single point cutting tool edge and shears a tiny chip that would what be called as a "cut chip".

Selecting which of the following grinding operations is to be used is determined by the size, shape, features and the desired production rate. Grinding process includes so many sub-types such as surface grinding, cylindrical grinding, creep-feed grinding, high efficiency deep grinding, peel grinding, ultra high speed grinding, form grinding, internal grinding, pre-grinding, electrochemical grinding, electrolytic in-process dress grinding and so many other types for specific applications based on the material of the job and is ever growing so as to accommodate for its ever expanding processes in the manufacturing sector.

2. GRINDING WHEEL

A grinding wheel is an expendable wheel used for various grinding and abrasive machining operations. It is generally made from a matrix of coarse abrasive particles pressed and bonded together to form a solid, circular, other various profiles and cross sections that are required depending upon the intended usage for the wheel. The grinding wheel is also selected based upon its specification chart.

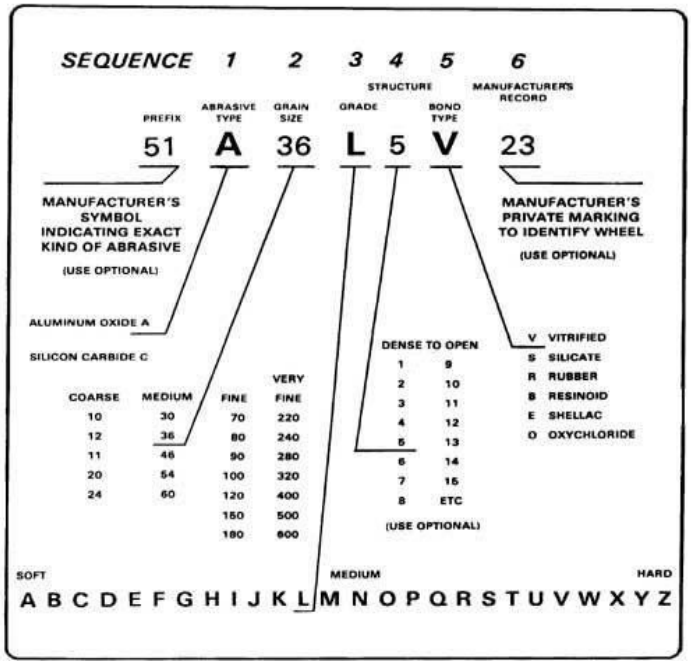

Figure 1: Specification of grinding wheel

Grinding wheel may also be made from a solid steel or aluminum disc with particles bonded to the surface. The most common grinding wheel materials are the aluminum oxide (Al_2O_3) and silicon carbide (SiC). Other materials like Cubic Boron Nitride (CBN), diamond and ceramics are comparatively hard materials basically used for very fine finishes.

3. PROBLEMS FACED

The technological advancements have made the concept of high speed machining possible in order to meet the demands of higher needs. But what lacks now is the possibility of implementing it economically and the present day situation is the lack of proper lubrication to cool the heat generated during the machining between the tool and work piece interface which is due to frictional resistance acting at a micro scale.

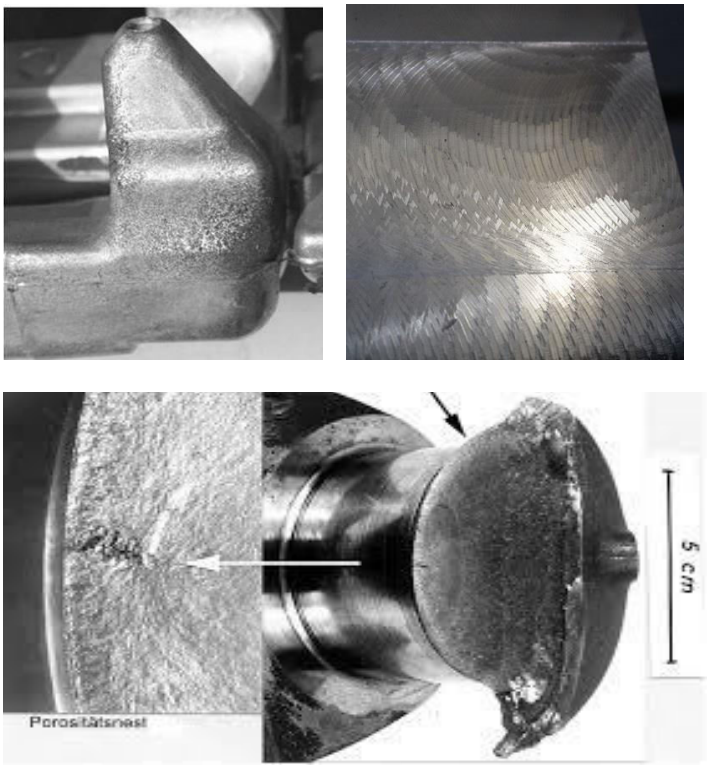

Figure 2 : Grinding failures due to improper lubrication (high temperature failure)

The temperature generated is not only high the temperature gradients are also severely alarming, Under abusive or rough grinding operations, the formation of the heat affected zone was observed to raise as high as 1000°C which damages the ground surfaces of both the tool and work piece.

Also due to excessive heat and high impact loading the tool also becomes soft, tool insert breaks eventually leading to a situation where the tool just rubs the surface of the work piece and no cutting action occurs and the tool becomes useless for further machining of the work piece.

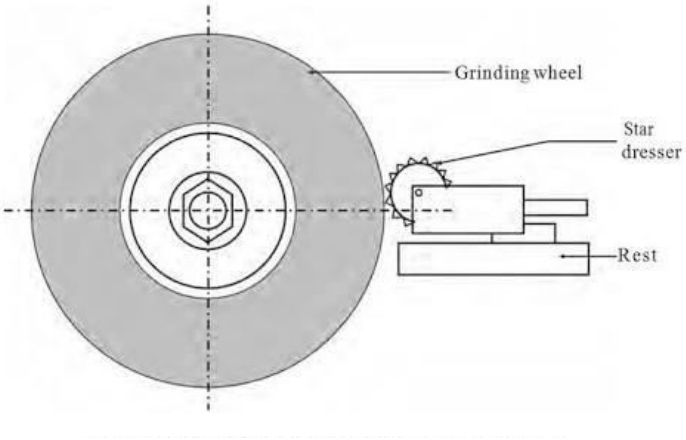

Figure 3: Dressing of grinding wheel

This would result in higher capital so as replace the tool often in addition to the regular dressing and truing process. Eventually the cost of production also increases in addition to poor surface finish of the job.

4. PROPOSED SOLUTION

Though alternative means of high speed manufacturing is being made possible through other methods that could also be lean but would require highly sophisticated machinery which in turn increases the cost of production. The can be very much handy incases of production of materials that requires high durability and strong mechanical properties that would be possessed by the materials produced through this method. Moreover this method is in its development stage and would take time to experimentally verify its viability against the current practice methods in manufacturing.

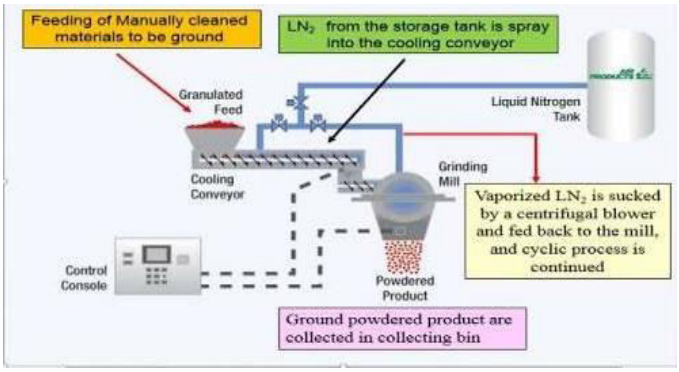

Figure 4 : Schematic diagram of cryogenic grinding system

In the present day situations we try and aim to find a solution to an already existing process. One could theoretically shell out so many ideas but this method of finding a suitable lubricant would be the most economical solution. When it comes to lubrication the said alternative liquid nitrogen would cost less than the conventional vegetable oil lubricant On an average vegetable oil coolant is Rs.65/litre whereas liquid nitrogen is Rs.35/litre. This is the prime importance as this plays the vital role in reducing the production cost that would else be wasted in replacement of tool periodically.

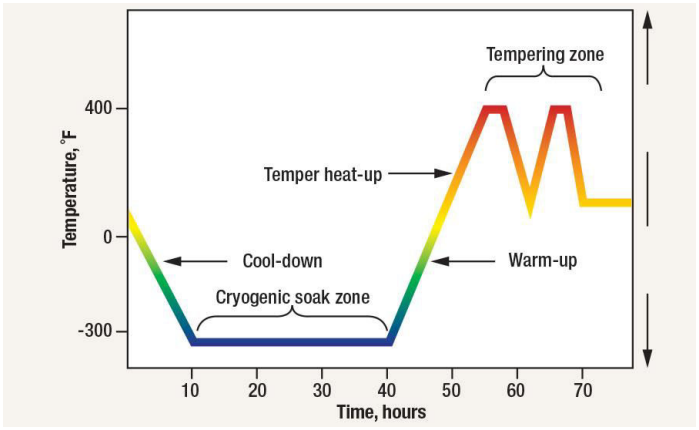

Figure 5 : Variation of temperature curve using cryogenic coolant

Also the method of reusing the coolant with minimal processing and minimal wastage by removing of the spurs mixed with the coolant during machining and by bringing back its due properties is easily possible in case of liquid nitrogen.

When it comes to usage of liquefied gases as coolant one could also use liquid carbon dioxide which costs similar to that of liquid nitrogen. The reason we do not tend to use liquid carbon dioxide is because of its two major properties:-

- The ability of it to easily break their O=C=O bonds when energy is given making it lose their aqueous nature tending to provide lesser cooling effect.
- Also due to breakage of bonds and very high temperature medium created during machining might produce atomic oxygen and carbon. There is always a possibility that this atomic oxygen might combine with atmospheric oxygen and form ozone that is highly toxic. The atomic carbon might either form carbon monoxide or carbon dioxide which are both global warming causing gases.

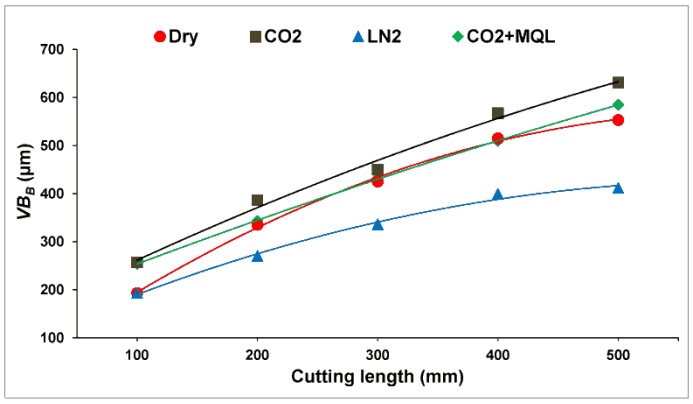

Figure 6 : Comparison of various coolants

Due the above said reasons liquid carbon dioxide is not preferred for very high speed machining however they can be used for a considerably slower speed machining and would provide better finish as compared to the vegetable oil coolant. The one disadvantage in using liquid nitrogen as compared to liquid carbon dioxide is such that the tool wear is found to be comparatively less in case of the latter.

5. CONCLUSION

After viewing through various possible solutions the lubrication through liquid nitrogen proves to be the rightful and efficient method. The coolant nozzle diameter required is slightly smaller for liquid nitrogen due to its higher value of its density to provide the same effects of the conventional coolant. Though not significant it reduces the overall mass of the machinery.

The liquid nitrogen lubricant is highly recommended for high speed machining but can also be used for normal machining processes with absolutely no modifications. The two major needs of the company, the capital and reusability and the most important eco – friendly nature are all satisfied by the usage of this lubricant – Liquid Nitrogen.

REFERNCE

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