A Review on Replacement of Conventional Grinding Wheels with Super Abrasive Grinding Wheels

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Abstract - *Abrasive machining is an often employed finishing process for different materials such as metals, ceramics, glass, rocks, etc. with which close tolerances and good dimensional accuracy can be achieved. Grinding wheels are considered to be the key product for abrasive machining in this era of advanced manufacturing processes. High material removal rate and enhanced finishing can be obtained with it if combined with raw and finishing machining. In this present paper we are going to review such high abrasive efficiency grinding wheels, which have a keen potential to replace the conventional grinding wheels and rejuvenate the technology of grinding. Our paper primarily deals with CBN (Cubic Boron Nitride) grinding wheels with the purpose of identifying the state of art in grinding machining and serving for the future researches.*

Key Words: Super high speed grinding, high efficiency abrasive machining, machining, grinding wheel, CBN, OEM, Super Abrasive.

1.INTRODUCTION

The vast development in manufacturing industry has led to inventions of techniques and machines for mass production, better accuracy and reliability, and that too keeping the cost of product in mind. The need of quality and functionality of industrially manufactured components, which have become the factor of major concern in past few decades, have led to rapid production of better quality components. The manufacturing of precision machine consists of using parts with controlled geometric and dimensional tolerances and high surface finish. Simultaneously these parts are supposed to provide maximum production at minimum cost. This performance of machining operation basically depends upon the operator's skills as well as the dressing condition of the grinding wheel. The optimization of machining operation can be done by changing a process input parameter.

Abrasive process is a designation for the material removing process with hard abrasive grains being used as the cutting tools. The technique which uses abrasive wheel or belt for material removal is used more often for this purpose of grinding. Presently, over 25% of total metal cutting machines in industrial countries are grinders. In 1998, China had this quantity as 13% of total machine quantity.

With the increasing requirement of modern industrial technology and high performance products for part precision, surface integrity, production quality stability, grinding has played a major role. Now it has become a prominent part of advanced machining technology and equipment.

Today, the superabrasive grains of Cubic Boron Nitride (CBN) are used in many of the industrial applications. But certain industries are still unaware about the latest advancements in grinding like super abrasives (here concerned with CBN). This has led to use of less productive conventional grinding wheels till date. One of the conventional materials for grinding wheels is Aluminium Oxide. This Aluminium Oxide ($Al2O3$) wheel along with others has its own certain drawbacks. It needs frequent dressing of the wheel in order to keep its performance upto its specified level and efficiency. (Dressing means removal of burr or deposited carbon during the process of grinding). Also these conventional low speed grinding wheels cannot be run at high rpm, so the obtained surface integrity cannot be upto the mark. These drawbacks of conventional grinding wheels have led to replacement of them by high speed or super high speed, super abrasive grinding wheels (CBN/ Diamond).

2. LITERATURE REVIEW

Qiang Liu, in 2005, has worked on assessment of Al2O3 and superabrasive wheels in Nickel-based grinding alloy, in it he said that Nickel alloys are broadly used in aerospace industries due to their superior performance at an elevated temperature. According to his thesis these Nickel based alloy when coated on superabrasive grinding wheel, can be used for large depth of cut, fast feed-rate, which in turn will achieve high efficiency grinding. When conventional Al2O3 grinding wheels are used for such operation, they will quickly wear out and will demand a dressing for further operation.

S. Wang and C. H. Li, in October 2012, have worked on Application and Development of High-efficiency Abrasive Process. His work stated that the electroplated CBN grinding wheel can func function properly even upto grinding speed of 150m/s to 250m/s. This can be seen as a blend of high speed as well as excellent and high efficiency grinding process. According to this theory a very high production efficiency can be easily achieved with replacement of conventional Al2O3 grinding wheel with the superabrasive electroplated CBN grinding wheel.

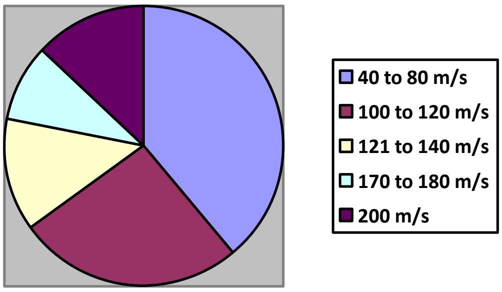

Fig-1: Speeds currently used with CBN wheel

Eduardo Carlos Bianchi, Paulo Roberto de Aguiar, Rodrigo Daun Monici, Luiz Daré Neto, Leonardo Roberto da Silva, through their material research provided thorough information about the superabrasive materials. They found that the G Ratio for resin bond superabrasive wheel was far more superior than that of alumina wheel (upto 30 times more superior).In simple words, the CBN grinding wheels they were allowing the removal of the same amount of material as that of the alumina grinding wheel, but the wear of CBN grinding wheel was far more inferior comparatively.

After going through the combined analysis of data provided, we can sum up by saying that the Superabrasive grinding wheel(may it be CBN or Diamond) can obtain better results as compared to the conventional Al2O3 Grinding wheel in most important aspects such as surface integrity, high speed machinability, saving of time required for conditioning of wheel.

3.MACHINING WITH CBN GRINDING WHEEL

CBN grinding wheel nowadays is considered as a cost efficient solution for machining various types of materials that are considered as difficult to grind. This includes any carbon steel or alloy hardened to 50HRC (Rockwell Hardness on C-Scale) or more, cast iron, abrasion-resistant steel alloys, and special materials like Stellite.

The benefits of machining the surface with CBN grinding wheels are better geometric and dimensional consistency, better surface integrity, greater productivity, and also the machining cost is considerably low. When machined with CBN grinding wheel, the cost per product may be higher as compared to Aluminium Oxide grinding wheel, but it has an advantage of lower work cost and overall expenses per tool due to its shorter machining time. Also it requires fewer tool changes, less conditioning of grinding wheel, and has faster finishing cycles. The total cost of machining per tool may be 45% lower, this makes the CBN grinding wheel an excellent option. It has an advantage like it requires less frequent conditioning which makes sure that the geometry of grinding wheel is unaffected for longer period and most importantly it saves the valuable time of an operator for conditioning of wheel after shorter intervals like time required for dressing of grinding wheel.

If comparison is to be done between CBN and conventional aluminium oxide wheel on the basis of diametral wear, CBN wheel is definitely superior to conventional Aluminium Oxide wheel.

Under the survey carried out with the help of Original Equipment Manufacturers, the reasons observed for not using high speed grinding are:

The requirement of complex as well as additional systems was found out to be the main reason for not using CBN. Improved balancing, coolant system were listed as a required additional systems. Also the requirements for machine rigidity, power demands for grinding, and improved spindle technology were the factors of machine complexity. The second major issue observed was economical aspect. The customers of OEM were observed to be losing their interest in CBN grinding due to its cost. Thermal issues constitute 12% share for rejection of CBN grinding process along with the 10% of safety issues. To resolve these thermal issues a capable coolant system was suggested to be used. Even some of the consumers believed that CBN was of no use to them due the vibration and maintenance.

So there is still need of awareness about the CBN grinding process and development of the low cost machine features that would tackle the problems related to current scenario.

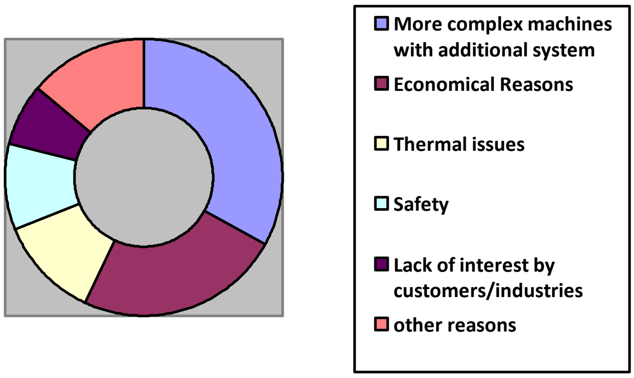

Fig-2: Reasons for not using high speed

4. TYPES OF BOND

Fixing of the abrasive grains on the surface of grinding wheel's core is required for machining a large number of parts. For this purpose variety of bond systems are used. The four commonly employed bond materials used for super abrasive grinding wheels are: Resin, Vitrified, Metallic and Electroplated types. So basically it is important to know how actually the types of grinding wheels are manufactured and effect exerted by the manufacturing process on the wheels. These properties help us to determine the procedure of recovery and sharpening. These are considered to be the most important factors for the effectiveness of grinding wheel.

A measured amount of phenolic resin or polyamide and fillers is mixed with the proper weight and size of CBN abrasive with a metallic layer for manufacturing of grinding wheels with resin bond. This mixture is then used to fill the mold of the cavity, so as to form the section of the machining end around the core of grinding wheel. As soon as the cavity is filled, the mixture of resin and abrasive is subjected to pressures and temperatures of up to 400°C, which then fixes the abrasive to the core of the grinding wheel. After removal of the grinding wheel from the mold, a second heat treatment polymerizes and reinforces the resin bond.

Such grinding wheels with resin bond can remove material rapidly but on the other hand they have limited aggregation characteristics and shape characteristics as well. Some of the main characteristics of grinding wheel with resin bond are:

- They can be used for a very large variety of applications.
- They are available in large variety of shapes and sizes.
- They can be used for refrigerated machining as well as dry machining.
- They have inherent good cutting qualities.

The CBN grinding wheels with electroplated bond have a single layer of abrasive grains that are bonded to a metallic core with the help of an electrodeposited nickel bath. The electroplated nickel matrix provides better retention for the abrasive.

The process of manufacturing a grinding wheel with a vitrified bond consists of following steps:

1. The sufficient amount of powdered vitrified material, known as "FRIT", is mixed with the desired type, weight and grain size of CBN.
2. Now the mixture of this is placed in a mold right around the core of the grinding wheel. It is made of ceramic which can withstand temperatures of up to 1000°C.
3. As the "green grinding wheel" is now prepared, it is now to be carefully removed and placed in a furnace which has controlled temperature and atmosphere. The time factor is also considered as an effective factor.
4. When the grinding wheel is inside the furnace, a chemical reaction causes a bond to transform into hard vitrified bond, which then causes the CBN abrasive to stick to the grinding wheel's core.
5. The vitrified grinding wheel with a greater width can be made of small radial segments that are carefully placed and cemented right around the periphery of grinding wheel's core.

The main characteristics of superabrasive grinding wheels with vitrified bond are:

- It has good abrasion resistance
- Good capacity to maintain their geometric shapes
- Service life is long
- Easier to recover and sharpen as compared to other bonds
- Better surface finish is obtained (use of concentrations of up to 150 to 200 is recommended for best results)

Apart from these advantages, CBN grinding wheel has its own certain disadvantages:

- Increased grinding temperature
- Difficult fluid delivery
- Require high speed bearings
- Increased risk of resonance

5.COST ANALYSIS

Detailed cost analysis has become an aspect of prime importance in industries for new process developments. Cost per part for grinding process can vary depending upon many different factors, such as parts per dressing, wheel life, rate of production, need of maintenance or refinements, dressing time and others. The common trend in industry is to compare grinding cost by simply comparing the tool costs when the production rate is kept similar. Various factors that make this happen are high process instability which may require high variable human assistance or correction, the factors which are not often measured or evaluated. The major mistake committed here is not to consider the most indirect grinding cost. The parameters such as machine investment, cost of dressing, cost of fluid, labor needs can be more expensive than the direct tooling cost. This cost comparison since to be very obvious and easy, however it is very complex process.

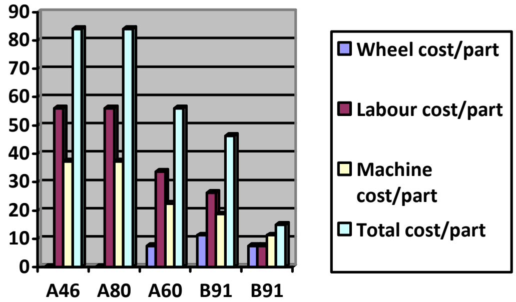

Fig-3: costs per part when grinding aisi 52100. from left to right, the values of redress life used were, 35,75,25,75 and 330 parts/dress respectively.

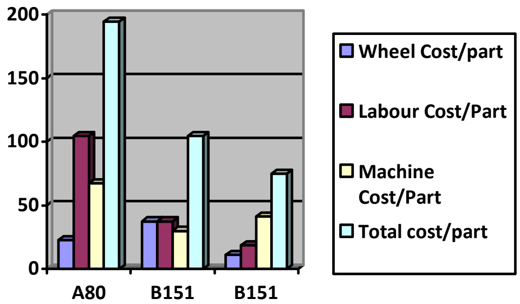

Fig-4: Comparison of costs per part when grinding Inconel 718. From left to right, the values of re-dress life used were 1, 25 and 30 part/ dress respectively.

We have been gone through the problems/disadvantages regarding CBN wheel. To avoid these problems at high speeds, a 150% more expensive special purpose machine was previously used. Its features were high dynamic stiffness, hydrostatic bearings for high speeds, high pressure as well as temperature controlled coolant delivery. Electroplated CBN was compared at some variable speeds so as to get the required cost per part. Thus the results obtained are shown in graphical form below.

6.CONCLUSION

High efficiency superabrasive grinding wheels are a part of the advanced manufacturing processes. It can increase the manufacturing efficiency and finish quality upto a larger scale. On the other hand it also diminishes the manufacturing cost. It is clear that there is still a big scope for the implementation of CBN wheels in grinding operations. The only need is the better understanding of cost and process reliability. The replacement of the conventional Al2O3 grinding wheel with the CBN grinding wheel will help in development of better grinding process and experience the excellency of finished products. As for our findings on surface roughness, the CBN grinding wheel has shown better results under the same machining conditions and apart from that saved a valuable time required for dressing of conventional grinding wheel.

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