Technology Course

Structure of Grinding Wheel

(Structure and Concentration)

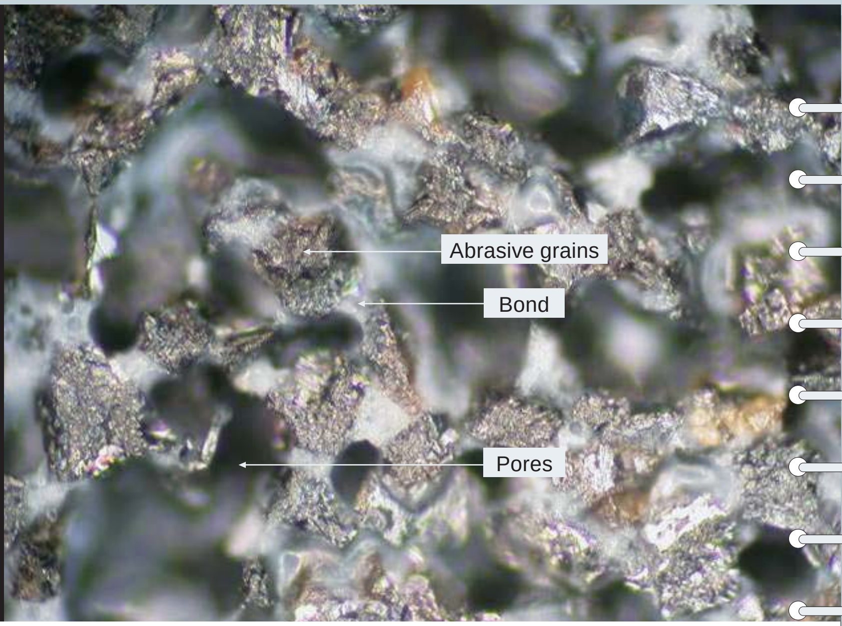

Fig. 1 Grinding wheel photo (vitrified-bond CBN wheel)

Grinding wheel and specs

A grinding wheel is one of the tools used in machining, but what exactly is a grinding wheel? Let's take a particular grinding wheel as an example, and have a closer look at the structure using a microscope. Grinding wheels are generally composed of the 3 elements "abrasive grains (grains)", "bond" and "pores" as shown in Fig. 1, and each of these plays the following roles.

1. Abrasive grains: Grain act as cutter, and mainly they remove the surface of workpieces.
2. Bond: Bond ties grains together, and holds them in position when loads are applied during grinding.
3. Pores:
   · Provide gaps necessary to remove chips produced during grinding .
   · Hold, and supply coolant to grinding points.
   · Release heat generated at grinding points into the atmosphere.

These 3 elements are closely related to the grinding wheel specs. In other words, whenever you use grinding wheel, by understanding its spec, you'll know what that grinding wheel is.

Example	*WA*	*80*	*J*	*7*	*V35*
	Grains	Size	Grade	Structure	Bond

Grinding wheel specs are indicated with 5 factors: "abrasive grains", "grit size", "grade", "structure", and "bond". These 5 factors are described briefly below.

■ **5 factors of conventional wheels**

1. **"Abrasive grains"**: Type of grain used to grind objects
2. **"Grit size"** : Size of abrasive grains
3. **"Grade"** : Abrasive grain bonding strength
4. **"Structure"** : Abrasive grains content
5. **"Bond"** : Type of material used to bond abrasive grains together

Note that grinding wheels are referred to as conventional wheels* and diamond/CBN wheels* depending on the raw material used, and with diamond/CBN wheels, "structure" is expressed as "concentration". As grinding performance is greatly affected by 5 factors, it is important to understand the effect of these factors to grinding performance in order to obtain the required accuracy.

Often on the job floor, multiple issues occur and it may be difficult to solve such issues with incumbent grinding wheels. Noritake developed a new grinding wheel which may be the solution to such issues by focusing on structure homogeneity. Before discussing the influence of homogeneity on grinding performance, we will explain the factors of structure and concentration.

What are “structure” and “concentration ”?

Conventional wheel “structure” and diamond/CBN wheel “concentration” express the volume percentage of grains exist in the grinding wheel or abrasive material layer, and this percentage is referred to as “grain content”. The higher the grain content, the more grains exit in the grinding wheel, resulting in a “dense” structure. On the other hand, a lower grain content results in a “open or porous” structure.

Table 1 shows the relationship between conventional wheel structure and grain content, and Table 2 shows the relationship between diamond/CBN wheel concentration and grain content.

A structure value of 6 represents a grain percentage of 50%, change in 1 structure value changes 2Vol% grain content. JIS standards state a range of 0 to 25, however, a structure of 7 to 10 is commonly used for grinding. A concentration of 100 represents a grain percentage of 25%, and grain content is calculated with dividing the concentration by 4.

Table 1 Relationship between conv. wheel structure and grain content

Dense ← → Open

Structure	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Grain content (Vol%)	62	60	58	56	54	52	50	48	46	44	42	40	38	36	34

Table 2 Relationship between diamond/CBN wheel concentration and grain content

Open ← → Dense

Concentration	25	50	75	100	125	150	175	200
Grain content (Vol%)	6.25	12.50	18.75	25.00	31.25	37.50	43.75	50.00

How is grinding performance affected by changes in “Structure” and “Concentration”?

How is grinding performance affected by changes in “structure” and “concentration”? Consider a case where the strength of the bond between grains is uniform, and only the ratio of grains and pores varies.

With a dense structure, the content of grains increases, while the volume of pores decreases, the distance between grains in the grinding wheel becomes short (Right in Fig. 2). In such case, there are many points of contact between the grains and workpiece during grinding, thus smaller load is applied to each individual grain. As a result, grains are less likely to break down, and the tips of the grains tend to wear down smoothly. Cutting ability is therefore sacrificed, however, the workpiece surface roughness becomes finer.

With a open structure, on the other hand, the content of grains decreases, while the volume of pores increases, and so the distance between grains in the grinding wheel becomes wider (Left in Fig. 2). In such case, as opposite to the dense structure, there are fewer points of contact between the grains and workpiece durling grinding, and greater load is applied to each individual grain. Grains are more likely to crack, and the tips of grains form sharp cutting edges.

Cutting ability is therefore good, however, the workpiece surface roughness becomes rougher.

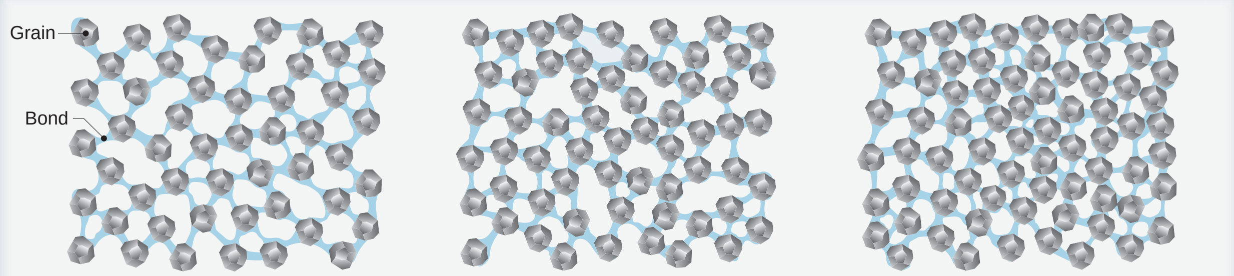

Fig. 2 Schematic diagram of various structures

Fig. 3 shows the results of Noritake's evaluation of grinding performance with different structures. Here, the grinding wheel cutting ability is expressed as the main spindle power consumption.

Generally speaking, the lower the power consumption , the better the cutting ability. We can see that when the structure actually becomes open, the power consumption tends to be low, and the surface roughness tends to be coarse.

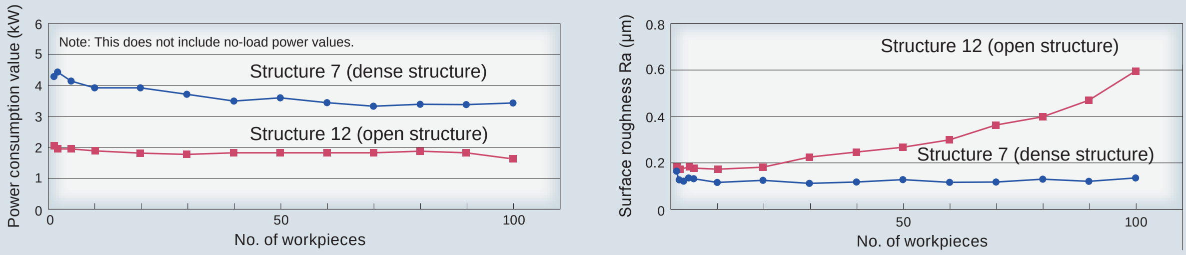

Fig. 3 Difference in grinding performance based on different structure

Dispersibility and grinding performance

Even with the same grain content, grinding performance differs depending on pore size and the dispersion of grains inside the grinding wheel. At Noritake, we refer to the homogeneity of the grain arrangement as dispersibility. The grain content is the same for both (a) and (b) in Fig. 4, and so the "structure" is the same. However the grain arrangement homogeneity is different. If the grain arrangement is not homogenous (poor dispersibility) (Fig. 4 (a)), the pores tend to be large even though there are areas where grains are clumped together. The strength exhibited through the narrow gap between grains and extremely powerful bonding strength in these clumped areas, as well as the role played by the deep chip pockets created by the areas with large pores ensures good grinding performance when employing specific grinding methods and under specific grinding conditions. However, depending on the conditions, the clumps of grains may cause loading, or grinding burns (grains may fall off in large cluster if this deteriorates). It is now known that in such cases, the types of grinding wheels with homogenous grain arrangement with better dispersibility shown in Fig. 4 (b) are most suitable. We will now explain the benefit of the structure with homogenous grain arrangement brings to grinding using model case, as well as the mechanism involved.

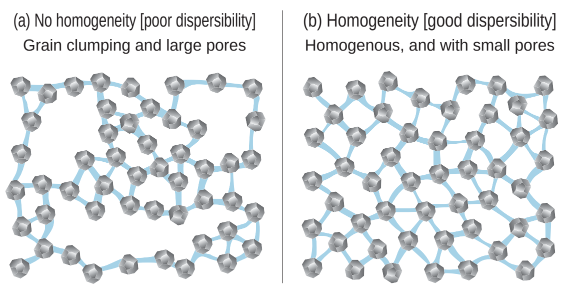

Fig. 4 Schematic diagrams of grain arrangement

Benefits of homogeneous structure and its mechanism

Grinding is a phenomenon in which countless grains on the grinding wheel surface chip away workpiece in microscopic scale while creating chips. With grinding wheels having good dispersibility, the load applied to each grain during grinding is almost uniform. Let's now consider this taking standard surface grinding as an example.

Fig. 5 shows a model which explains how grains act on the workpiece, and how chips are produced under conditions of both poor and good dispersibility.

"g" in Fig. 5 is a parameter known as grain cutting depth. The derivation of a detailed equation has been omitted here, however, the theoretical formula derived from the "g" grinding theory in surface grinding is as shown in formula 1.

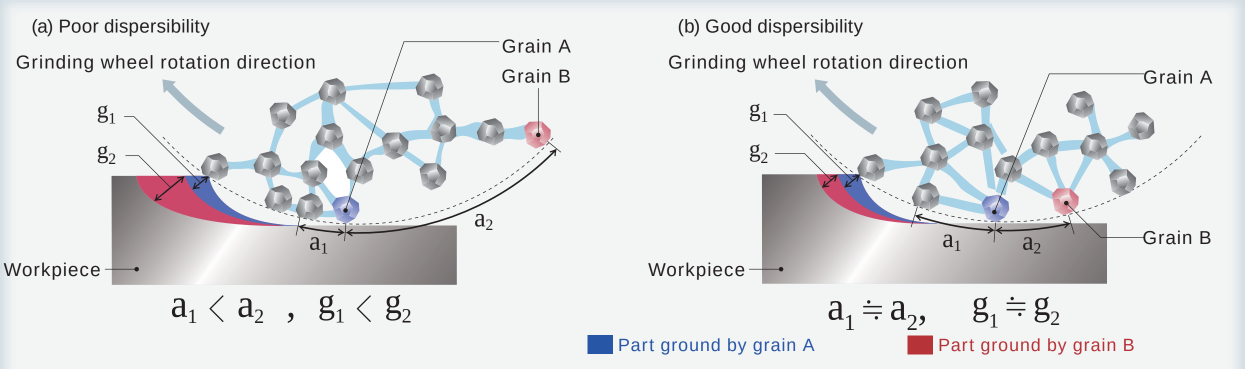

Fig. 5 Relationship between grain gap and grain depth-of-cut (surface grinding)

$$g = 2a\frac{v}{V}\sqrt{\frac{t}{D}}$$ ....Formula 1 [1]

g: grain depth-of-cut a: distance between grains V: grinding wheel speed
v: workpiece peripheral velocity D: grinding wheel diameter t: grinding wheel infeed per pass

"a" in Fig. 5 indicates the distance between grains, and is closely related to structure as mentioned earlier. "Grain cutting depth" is approximately equal to "chip thickness" , and if a is large, i.e. if the distance between grains is wide, the depth at which the grains cut into the workpiece becomes deeper, and the load applied to the grains increases.

With poor dispersibility as shown in Fig. 5 (a), the distances between grains varies as a_1, and a_2, and the load applied to each the grains differs. This can therefore lead to unstable grinding performance.

With a_2 shown in Fig. 5 (a), grain B's cutting depth g_2 is greater than grain A's cutting depth g_1, and so grain B generates a greater grinding load than grain A. If the grinding load is too great, grains will crack, and/or the bond which holds each of the grains together will be damaged, resulting in grain loss before the grain exhibits expected grinding performance.

On the other hand, cutting depth of gain A at section a_1 is smaller than that of grain B at section a_2, and so the load applied while grinding decreases. With small grinding load, self-sharpening* caused by the crushing of grains becomes difficult, the tips of the grains are worn down through friction, and grinding wheel cutting ability deteriorates. This results in greater frictional heat between the grains and workpiece, creating defects such as grinding burns.

With good dispersibility as shown in Fig. 5 (b), grain A and grain B cutting depths are the same. Here, the grinding load is almost the same for all grains, and so grinding performance tends to be stable. By preventing extreme grain loss and grain wear, and through an appropriate level of self-sharpening, we believe it is possible to achieve stable grinding performance.

[Notes]

* Conventional wheels: Grinding wheels manufactured using grains made primarily of alumina (Al_2O_3) or grains made primarily of silicon carbide (SiC)
* Diamond/CBN wheels: Grinding wheels manufactured using diamond grains or cubic boron nitride (CBN) grains.
* Grain loss: Phenomenon in which grains fall away from the grinding wheel
* Self-sharpening: As the tips of grains become blunt through wear, localized crushing occurs, producing a new cutting edge. If grain retention drops to a certain level or below following repeated crushing, grains will eventually come away, and new grains will appear from the lower layer, providing continued sharpness.

[Literature]

[1] Satoshi Isogimi: "Grinding Wheel Basics", Mechanical Engineering, Vol. 65, No. 4 (2017). 32.

[Author] Masayuki Yamamoto
Industrial Products Group, Technical Div.
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