и концентрацией наноразмерной алмазосодержащей добавки в приработочной композиции. В частности, для пары трения «сталь 45 – медь М1» в присутствии смазки Литол-24 с алмазно-графитовой добавкой УДАГ наиболее эффективно процесс трибомодифицирования протекает при удельной нагрузке в зоне трибоконтакта p=10–20 МПа и концентрации УДАГ C_a=0,75–1,0 мас.% при параметре исходной шероховатости Ra=0,63–1,25 мкм. Интенсивность изнашивания обработанной поверхности составляет I_h=(3,5–3,8)$\cdot10^{-9}$.

MAGNETIC PULSED COMPACTION OF DIAMOND-COBALT GRANULE POWDERS

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A diamond core drill is an important perforating tool in the construction field. Drilling segments of this core drill are usually produced by compaction and subsequent sintering of the mixed Diamond and Co powders with a size of several μm (indicated as 'raw powders' hereafter) [1]. However, production automation for these drilling segments has been restricted due to the very small size of the raw powders used. In this respect, large efforts have been made to use the granule powders with a size of > 1 mm which are fabricated by the granulation of the raw powders. Nevertheless, when these granule powders are compacted by a conventional static compaction (CSC) method, the green density is too low to be sintered to the bulk with the requested density because of their large particle size [2]. To date, the CSCed compacts using the granule powders should be sintered with an additional high pressure to obtain enough density for the sintered bulk to be used for the drilling segments [3]. Despite such pressure sintering, the Diamond-Co drilling segments prepared by CSC using the granule powders still possese a cosiderable amount of pores, thereby revealing poor drilling performance.

Considering the limitation of CSC, magnetic pulsed compaction (MPC) has been applied to produce the Diamond-Co drilling segments using granule powders in this study. MPC is an effective method to obtain a high green density by applying a high pressure (up to 5 GPa) to each powder for a short period of time (~ 500 μs) [4,5]. This ultra high pressure in 500 μs causes an enhanced deformation and rearrangement of the compacted powders, resulting in the improved green density [6,7]. The priciple that anchors the MPC technique relates to sudden current flow in a coil, creating a magnetic field around that coil [2,5]. Also, nearby concentrator that can carry electricity will have a current induced in it in the opposite direction of the current in the primary coil. These opposing currents coincide with opposing magnetic fields and cause a pressure to develop between the primary coil and the concentrator. This pressure is known throughout the world of physics as the *Lorentz Force*. Finally, this force is transferred to the compacting tools, making powders be compacted.

In this study, the Diamond-Co granule powders were consolidated for drilling segments by the combined application of MPC and subsequent sintering. Density and hardness of the compacted and sintered specimens were measured, and all the results were compared to those for the drilling segments produced by CSC using the raw powders.

The mixed Diamond-Co granule powders were supplied from Shinhan Diamond Industrial Co., Ltd., Incheon, Republic of Korea. The particle size of the granule powders used was about 1 mm. The mixing ratio of the diamond was 1.54 cts/cc and the diamond had a typical hexagon morphology with a particle size of 300 μm ~ 500 μm. The mixed granule powders were compacted by MPC at the compaction pressure of 4 GPa. Subsequently, the MPCed compacts were sintered at 885 °C for 115 min in the hydrogen reduction furnace. The dimension of the final products was 16L × 8.7W × 3.5t in mm. The density of the compacted and sintered specimens was measured by the Archimedes mehod and their hardness was also measured using the Rockwell hardness tester. The fractured surface of the sintered bulk was examined using a scanning electron microscope (SEM) with an accelerating voltage of 20 kV.

Fig. 1 shows the examples of the drilling segments produced by MPC followed by thermal sintering. As shown in Fig. 1, the segment with such a complex shape could be fabricated without forming any crack or defect up to a compaction pressure of 4 GPa. However, several cracks were observed at the surface area when the compaction pressure exceeded 4 GPa. This was attributed to the excessive strain energy induced by too high compaction pressure. At this high compaction pressure, the excessive strain energy could not be readily relaxed and was still stored in the compact, resulting in a cracking of the bulk during subsequent sintering. In our experiments, the compaction pressure of 4 GPa was the optimum value for fabricating a fine drilling segment without a crack.

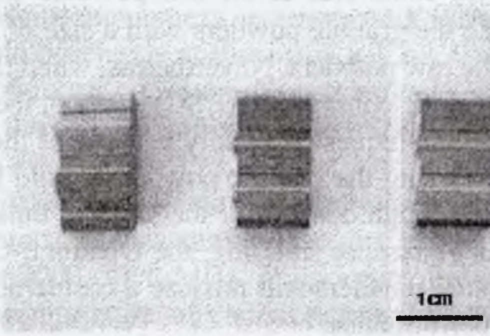

Fig. 1: Drilling segments produced by MPC and subsequent sintering

Table I shows the mearsured properties for the compacted and sintered bodies together with those for the specimens prepared by the conventional process. As shown in Table I, the green density of the MPCed compact using the granule powders is higher even than that compacted by CSC using the raw powders. In general, it is difficult to obtain a high green density using large granule powders because more empty space exists between the granule powders as compared to the raw powders [8]. The lager the particle size is, the more the powders shold be deformed to eliminate pores. On the other hand, the green density was enhanced up to 86.4 % by the application of MPC, as MPC could apply an ultra high pressure to each powder in a very short duration, improving deformation and rearrangement of the compacted powders. The sintered density was also higher than that prepared by the conventional process (Table I). The MPCed compact had a denser structure and more contact areas between particles, so the sintering rate at the same temperature was faster as compared to the CSCed compact. The maximum attainable density was 99.6 % by the MPC process, but it was limited to 98 % when using CSC process. Moreover, the drilling segment produced by MPC revealed the higher hardness value due to the higher density of the sintered boby as indicated in Table I.

Table I: Properties of the compacted and sintered bodies

Compaction Process	Green Density (%)	Sintered Density (%)	Hardness (HRB)
MPC	86.4	99.6	99.8
CSC	82.6	97.9	95.9

Fig. 2 shows the fractured surfaces of the sintered bodies prepared by MPC and CSC, respectively. It was noted that both the specimens fractured by the ductile mode with dimples on their fractured surfaces. However, more dimples were observed and the particle size was much smaller in the specimen fabricated by MPC as compared to the specimen prepared by CSC. This was ascribed to the limited particle growth by the nearby particle during sintering. Since the neighbor particle existed more closely in the denser MPCed compact, the particle growth during sintering could be considerably restricted as compared to the CSCed compact.

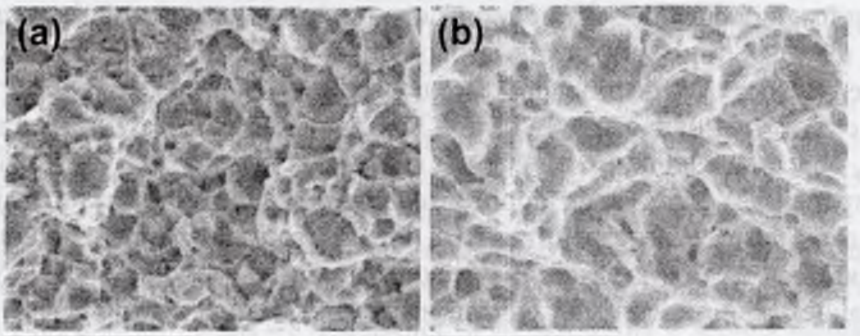

Fig. 2: SEM micrographs of the fractured surfaces of the sintered bulks fabricated by (a) MPC and (b) CSC

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