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The Effects of DLC Coating To Camshafts Produced From 8620H Steel

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ABSTRACT
Diamond-like carbon (DLC) is a hard material with lubricity and chemical stability. Amid the growing awareness of environmental problems in late years, DLC films have been used to reduce the fuel consumption of automobiles by reducing friction loss. This study diamond-like-carbon (DLC) coating process was applied to 8620 H steel used for camshaft production. Coatings are only applied to cams on the camshaft. SEM analysis were made by taking sections from the cams and abrasion amount were measured at different distances. Coated samples were compared with uncoated samples. DLC coated cam surfaces improved, the amount of wear has been reduced.

Keywords*: Diamond-like carbon, 8620H Steel , Coating, Wear, Friction*

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I. INTRODUCTION

Carbon is one of the commonest elements throughout the universe. In the nature carbon is found as diamond, graphite and amorphous carbon. The name of DLC was first coined by Aisenberg in 1971 to describe the hard carbon films that he prepared by direct deposition from low energy carbon ion beams [1]. Now, DLC is the name commonly accepted for hard carbon coatings which have similar mechanical, optical, electrical and chemical properties to natural diamond, but which do not have a dominant crystalline lattice structure. DLC films have received much attention over recent years and been under intensive research since the middle of 1980s. DLC is a generic term that is used to describe a range of different amorphous carbon films whose properties range considerably depending on deposition conditions and method. DLC films are thin, usually in the region of 1–4μm in thickness and have wide ranging properties. The main factor that controls their properties is the proportion of sp2 (graphitically-bonded) to sp^3 (diamond-bonded) carbon atoms but additional factors such as the presence of silicon, hydrogen, nitrogen and metal dopants, the use of interlayers to promote adhesion and tailor residual stress levels, the surface roughness and interaction with lubricants are also key to their ultimate performance. DLC is not simply a single solution to a tribological problem as the range of mechanical properties and the potential for different tribochemical reactions with these films is vast. DLC films include hydrogenated DLC (a-C:H), hydrogenated tetrahedral amorphous carbon (ta-C:H); hydrogen free DLC (a-C); tetrahedral amorphous carbon (ta-C); and those containing dopants of either silicon or metal such as Si-DLC and Me-DLC, respectively. These materials depict the following valuable properties: Resistance to wear as the cause of a very high hardness; low friction coefficient; chemical inertness and electrical insulation; optical transparency and smoothness; and biological compatibility. [2]

Carbon has three different types of bonding configurations, namely sp^3, sp^2 and sp^1. The bonding configuration of carbon atom in diamond, DLC and graphite are illustrated in Fig. 1 [3]. In diamond, carbon has four sp3 hybridized orbitals. These sp^3 orbitals contribute to the formation of four equal carbon-carbon bonds with adjacent atoms, which produces the tetrahedral structure of diamond. This covalently bonded tetrahedral structure is the origin of the superior properties of diamond, like high hardness and high thermal conductivity. Graphite has three trigonally directed sp^2 hybrid orbitals, which lie in plane. Each carbon atom in plane is bonded to three other carbon atoms with strong covalent bonds. The layers of carbon atoms are attracted to each other by weak Van der Walls forces producing the layered structure of graphite. The layers can cleave easily, which accounts for the typical low friction property of graphite [4-5]. The DLC films have a mixed sp^3/sp^2 structure with different proportions of sp^3 and sp^2 bonds depending on the deposition techniques and deposition parameters used. The structure is claimed to consist of sp^2 bonded clusters embedded in an amorphous sp^3

bonded carbon matrix [6-7]. So the term "diamond-like" emphasizes a set of properties akin to diamond and, at the same time implies the absence of crystalline diamond order [8].

Basically, a-C:H is an amorphous network composed of carbon and hydrogen. The properties of these coatings depend strongly on the hydrogen content and the sp^3/sp^2 content, which in turn, depend on the deposition process and its parameters [9]. The hydrogen is important for obtaining a wide optical gap and high electrical resistivity and stabilizing the diamond structure by maintaining the sp^3 hybridization configuration [10]. For a-C films, hydrogen is generally treated as an impurity. The hydrogen-free amorphous carbon, which is highly sp^3 bonded, is known as ta-C. The compositions of DLC can be displayed on a ternary phase diagram of sp3 ratio, sp2 ratio and hydrogen content of the film, as shown in Fig. 2 [11].

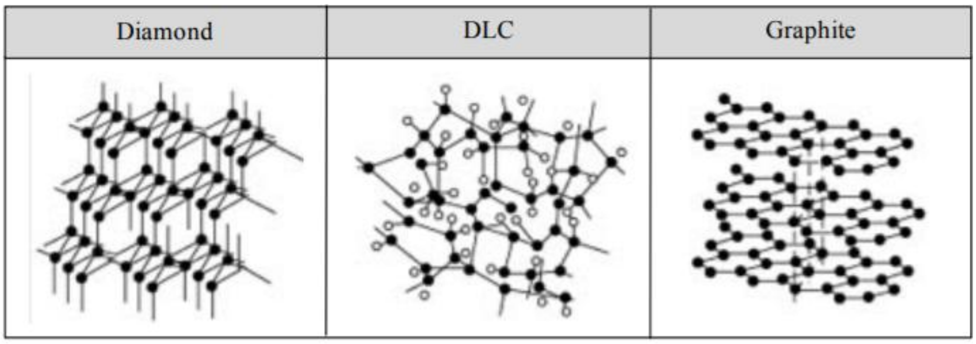

Fig 1. The bonding configuration and typical Raman spectrum of diamond, DLC and graphite [8]

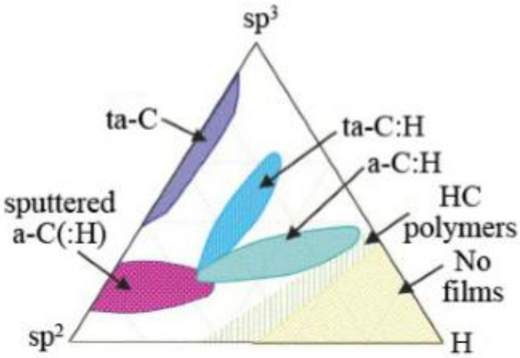

Fig 2. Ternary phase diagram of sp2, sp3, and hydrogen contents of various forms of DLC [11].

DLC coatings are increasingly being used to improve the tribological performance of engineering components. The coatings can possess high hardness, low coefficients of friction against materials such as steel, and they are generally chemically inert.

This study DLC coating operation was performed to the cam shaft manufactured from 8620H steel. Coated samples were compared with uncoated samples. The effects of the coating on the abrasion resistance were investigated.

II. EXPERIMENTAL STUDY

In this study 8620H steel was used for the production of camshaft. Steel chemical composition is given table 1.

Table 1. Steel camshaft chemical composition

Elements	C	Si	Mn	P	S	Cr	Ni	Mo	Cu
%Wt	0,198	0,284	0,886	0,01	0,013	0,566	0,412	0,17	0,174

Passenger vehicle group and fuel pump camshaft were used in the coating operation. Camshafts are produced by machining methods and polishing was applied to the cam surface. Then Cam shaft was hardened with cementation. 55 HRC hardness is obtained on the cam surface.

Fig 3. The camshaft model used in the work

The sections are taken from the cam shaft which is produced as steel and casting and made ready for coating process. CVD equipment was used for diamond like carbon (DLC) coating.

The coating was done under acetylene (C_2H_2) gas and lasted for 30 minutes. Sections made the coating process given in figure.4.

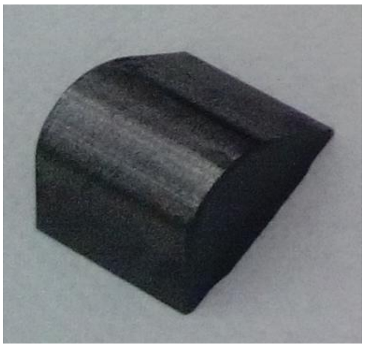

Fig 4. Coated specimens**;** Steel camshaft Section

SEM analyzes were performed on sections to determine coating thicknesses and morphologies. Wear tests performed to measure the abrasion resistance coating.

III. RESULT AND DISCUSSION

1. SEM Analysis

The morphology of the films prepared by both techniques was studied by scanning electron microscopy, which showed smooth and uniform surfaces. Optical micrographs were used to determine DLC film. The thicknesses of the DLC films were in the range of 3-4 µm.

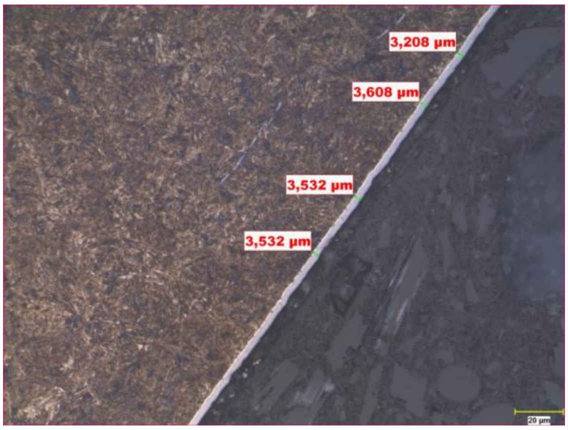

Fig 5. DLC film coating thickness

The images taken from the cam surface are given in figure 5. When the pictures are examined the steel material was found to be lighter in color, while the coating material was found to be darker in color. It is known that DLC type coatings have crystal densities of 2.8 g/cm^3 and it is thought that graphitic carbon structures are materials that are shielded or not adhered to the surface.

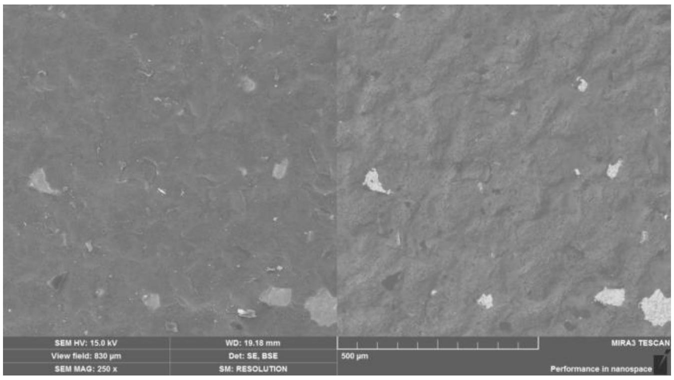

Fig 6. Cam surface SEM image

When SEM images were examined, it was observed that the coating was homogeneously distributed on the camshaft surface. This is because low carbon content in steel. So the coating penetrates the steel surface.

2. Wear Test Result

Wear tests were carried out by UTS brand "Ball-on-disc" type wear apparatus. The wear tests were carried out under load of 10 N, at 300 rpm speed and sliding distances of 100m, 400m, 700m and 1000m. Then the friction coefficient and weight loss were measured. Table 1 shows the relationship between weight loss.

Table 1. Wear quantities and friction coefficients of coated and uncoated samples

Wear Distance	DLC Coating Sample ($1x10^{-4}$ gr)	Uncoated Sample ($1x10^{-4}$ gr)
100 mt	2	4
400 mt	3	9
700 mt	6	12
1000 mt	8	14

Friction coefficient of DLC coated samples was 0.13, while friction coefficient of uncoated specimens was 0.55. The largest wear rate was observed for an uncoated sample.

Optical micrographs were used to determine the wear mechanism. The wear surface photographs of uncoated samples are given in Figure 6 and 7 illustrates the wear pictures under the different test conditions. The uncoated steel disc worn (Fig. 6) shows signs of abrasive wear. The coating showed wear resistance to the coating until the coating was worn. Diamond-like carbon (DLC) coatings must have excellent wear and tear resistance, high adhesiveness and very low friction coefficient.

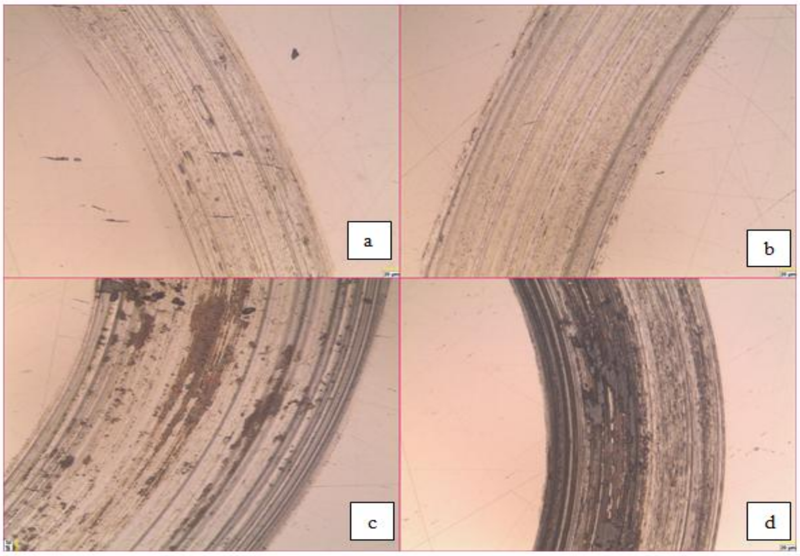

Fig 7. The wear surface images of uncoated parts;a)10N,100m b)10N, 400M c)10N, 700M d)10N, 1000m (200x)

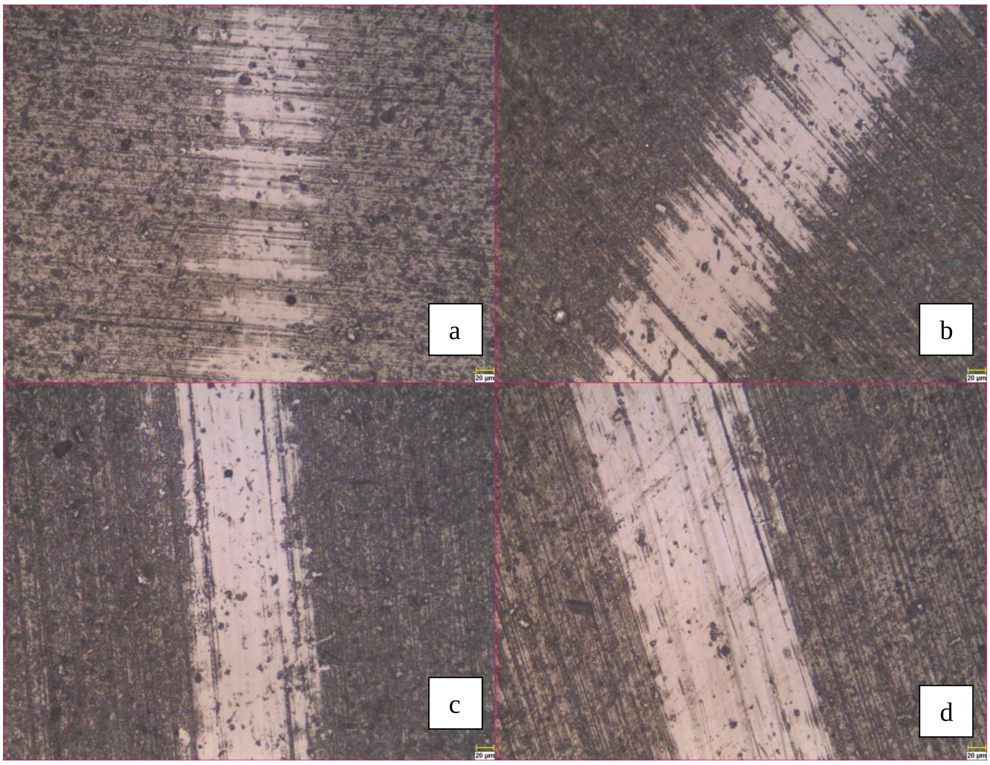

Fig 8. The wear surface images of coated parts; a)10N,100m b)10N, 400M c)10N, 700M d)10N, 1000m (200x)

IV. CONLUSION

Positive results were achieved in the coating processes on the camshaft produced from 8620H steel. No work on DLC coating related 8620H steel was found. Furthermore, wear tests of the cam shaft produced from this steel have not been carried out. After the DLC coating of the cam shaft produced from 8620H material, the data on the wear mechanism have been obtained. Smooth and uniform DLC film were prepared by CVD method. The abrasion values of the cam shaft are reduced and friction losses are minimized. Fuel savings can be achieved by expanding the use of DLC coatings in the automotive industry. In addition, the life of contact parts can be increased.

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