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Sfero chill döküm kam millerinde mangan fosfat kaplamanın aşınma direncine etkisi

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ÖZET

Sfero döküm kam milleri yüksek tokluk ve mukavemek özelliklerinden dolayı otomobil sektöründe tercih edilmektedir. Kam millerinin üretiminde kullanılan soğutucular sayesinde yüksek yüzey sertlikleri elde edilmektedir. Bu çalışmada sfero chill olarak üretilen kam millerinin mangan fosfat ile kaplanarak aşınma dayanımına etkileri araştırılmıştır. Kam milleri sfero chill olarak üretilmiş yüzeyleri mangan fosfat ile kaplanmıştır. Kaplama yüzeyleri scaning electron microscope (SEM) ile gözlemlenmiştir. Mangan fosfat kaplamanın kam milleri üzerindeki aşınma dayanımı motor test düzeneğinde 1000rpm de 30 dakika aralıkla çalıştırılarak kam profillerinde meydana gelen değişimler ölçülmüştür. Sonuç olarak fosfat kaplı kamlar kaplamasız kamlara göre 2,8 kat daha az aşınmıştır. Mangan fosfat kaplı sfero chill kam milleri, kaplamasız olan millere göre mangan fosfat kaplamanın yağ tutma özelliğinden dolayı daha az aşındığı bulunmuştur.

Anahtar Kelimeler: Kammili, Mangan fosfat kaplama, Sfero chill döküm, Aşınma direnci

The effect of manganese phosphate coating wear resistance of chilled ductile iron camshaft

ABSTRACT

The ductile iron camshaft are preferred due to high toughnees and strength features in the automobile industry. Through the coolants used in the camshaft production high surface hardness is achieved. In this study, the wear resistance effects of ductile iron chill produced camshafts coated with manganese phosphate are researched. The camshaft surfaces produced as ductile iron chill are coated with manganese phosphate. The coating surfaces are observed with scanning electron microscope (SEM). The changes occurring on the cam profiles are measured with running the wear resistance of the manganese phosphate coating on the camshafts on the engine test rig with 30 minutes interval in 1000rpm. In order to compare the results of uncoated camshafts run on engines are checked against simultaneously. As result, the manganese phosphate coated cams were 2,8 times less worn up than the uncoated cams. The manganese phosphate coated ductile iron chill camshafts are less worn up according to uncoated camshafts because of the oil holding feature of manganese phosphate coating.

Keywords: Camshaft, Manganese phosphate coating, Chilled ductile iron, Wear resistance

1. INTRODUCTION

Cast iron has become a popular cast metal material which is widely applied in modern industrial production because of its low cost and desirable properties such as good castability, convenient machining property, better wear resistance, etc [1]. Nowadays, nodular cast irons are significant and preferred type of cast irons. Nodular cast irons that are similar to steels from the point of mechanical properties are most popular engineering materials [2]. When manufacturing a camshaft using chilled ductile iron, casting techniques ensure that the cast iron solidifies more quickly, increasing the hardness. In order to obtain a wear-resistant cam surface of cast camshafts, chills are used to increase the cooling rate and create a hard cementite structure [3].

Camshaft is one of the key parts or components in the engines of automobile and other vehicles. The performance is to control the open and close intervals of the inlet and exhaust poppet valves by its cams. Due to the cyclic impact loading on the contacting surfaces of the cam and the follower, it often gives rise to premature wear of cam profile and affects a routine run of the valve gear such as the rotational speed, valve displacement and the torque [4-5].

Many researches on improving wear resistance of cam and the follower by surface hardening have been reported in recent decades [6-9]. The manganese phosphates widely used in the automotive industry are the best to improve the ease of sliding and the reduction of associated wear of two steel surfaces sliding one against the other [6].

Manganese phosphate is an industrial coating commonly used to reduce friction and improve lubrication in sliding components. Manganese phosphate coatings are created by chemical conversion and the main component of the film is hureaulite, $(Mn,Fe)5H_2(PO4)_2$. It is claimed in the literature that they have excellent lubricity and anti-scuffing properties [10-12].

2. MATERIAL AND METHOD

In this study, manganese phosphate coating was investigated to the wear behavior of chilled ductile iron camshafts. As the first step camshaft was simulated and chilled ductile iron camshaft was produced. After the cast process the camshafts were taken to the machining and were made to end products. Some of the shafts were coated with manganese phosphate which was pre-prepared in manganese phosphate bath. In the trial, manganese phosphate coated camshafts and uncoated camshafts were run in the same engine in order to measure abrasion on the cam surfaces as result of the change in cam profile.

2.1. Material

The chemical composition of the camshaft is given in Table 1. Chemical composition shows that the material is a nodular graphite cast iron (generally called as ductile iron). This material has good fluidity and castability, excellent machinability and good wear resistance. In addition, nodular graphite cast iron has a number of properties similar to those of steel such as high strength, toughness, ductility, hot workability and hardenability.

Table 1. Chemical analysis of the tested camshaft (wt%)

Fe	**C**	**Si**	**Mn**	**P**	**S**
Balance	3,61	2,25	0,217	0,043	0,013
Mg	**Cr**	**Ni**	**Mo**	**Cu**	**Al**
0,041	0,035	0,01	0,392	0,587	0,006

For the casting of the camshafts, pitches with length of 600mm, width 450mm and 350 mm depth were used. Camshaft models were located in advance to the molds. Half coolants produced of ductile cast iron material were located to the sand mold in order to create chill on the cam surfaces. The melting was conducted in an induction furnace with a holding capacity of 2500 kg, power of 120 kW and a frequency of 50 Hz. The casting temperature was determined as 1440°C and the casting of the camshafts was realized. In Figure 1 the 3D solid model of half coolant and camshaft model is shown.

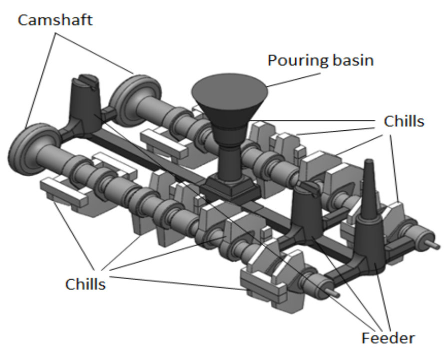


Figure 1. Camshaft model and chills assembly on camshafts

Milling, turning, grinding and drilling operations were applied to camshaft which were casted to sand molds.

2.2. Manganese Phosphate Coating of Chilled Ductile Iron Camshaft

Samples of chilled ductile iron camshaft were used for manganese phosphate coating. The treatment implemented for the study is described in Table 2. The manganese phosphatation process mainly consists of four sequences: degreasing, rinsing, activating, actual phosphating.

Two washing bath were prepared at the washing operation. During the bath preparation RİDOLİNE 7163CF/AR 10ml/L and RIDOSOL 1561 1g/L was used. The second bath is also prepared in the same composition. The camshafts have waited in both bath for 9 minutes and the oil and dirt were cleaned. After the washing process the camshafts were put into rinsing bath prepared with pure water. The camshafts have waited here for 1 minute and were taken after this to the activation bath. The activation bath was prepared with FIXODİNE 5026 solution in a rate of 10 gr/L. The camshafts have waited in the activation bath for 3 minutes at room temperature. With the activation bath the part surface was activated for manganese phosphate coating. After the activation process we passed to the manganese phosphate coating process. From the solution THERMOIL GRANODINE 117 M was put a rate of 6g/L to pure water and a bath at 95°C was prepared and the camshafts have waited here for 10 minutes. The manganese phosphate coated camshafts were taken to the washing bath and after the lubrication the coating process was finished. The SEM photo of the coating on the camshaft surface of the manganese phosphate coated shafts is given in Figure 6 and the microstructure of the coating thickness of the manganese phosphate coating is shown in Figure 7.

Table 2. Manganese phosphate coating treatment

Degreasing1	RIDOLINE 7163CF/AR 10 ml/L and RIDOSOL 1561 1g/L solutions 60ºC 9 min
Degreasing2	RIDOLINE 7163CF/AR 10 ml/L and RIDOSOL 1561 1g/L 60ºC 9 min
Rinsing1	Water, room temperature 1min
Rinsing2	Water, room temperature 1min
Activating	FIXODINE 5026 solution 10gr/L room tempature 3 min
Phosphating	THERMOIL GRANODINE 117 M solution 90~95ºC 10 min
Rinsing	Water, room temparature
Lubricating	Anticorit 340A(lubrication process for corrosion resistance)

2.3. Method

The manganese phosphate coated ductile iron chill camshafts and the uncoated camshafts were fixed to the test setup as in Figure 2.

Figure 2. The location on the engine of camshafts

In the test setup the 4 cylinder Mercedes vehicle engine was used. The drive was given to the camshafts using the chain with the 14 kW electrical engine in the test setup. In order to prevent the abrasion of the shaft bearing and co-working parts, the camshafts and the oil pump were run in oily medium. Not all the tappets on the engine block were fixed, in order to see the wear quantity on the 3rd, 4th, 5th and 6th cams, tappet were fixed in these areas. In the trials we used tappets with surface hardness of 58 HRC and a working torque value of 28Nm. In Figure 3 you can see the test setup.

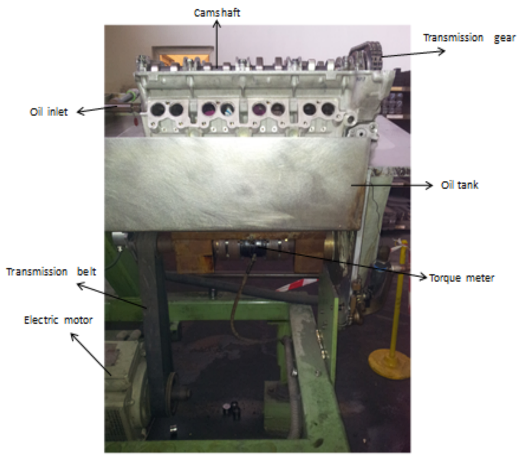


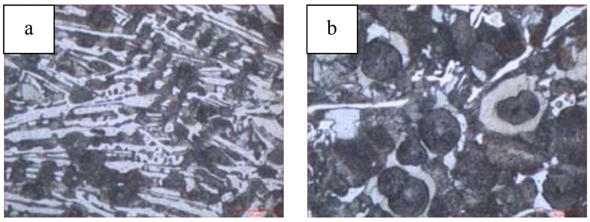
Figure 3. Camshaft wear test machine

The manganese phosphated and non phosphated camshafts were run at the same time in 30 minute intervals with a speed of 1000 cycle per minute. In each beginning and finish the cam profile values were measured and the change in the cam profiles was calculated as result of the engine tests.

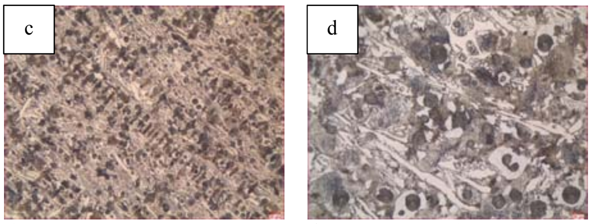
3. RESULTS

3.1. Microsucture and Hardness

The microstructures of camshaft are shown in Figure 4. The microstructure in its non-chilled zone consists of the pearlite, a little amount of cementite and small graphite nodules, and the microstructure in the chilled zone consists of primary cementite, eutectic ledeburite which in the later stage has changed into eutectoid cementite + pearlite as well as a very little amount of dot-shaped graphite. The hardness of the non-chilled zone was of 26-35 HRC, and the chilled depth was up to 3~6 mm with the hardness being higher than 45 HRC.



a)Cam nose(1000X) b)Cam core(1000X)



c)Cam nose(200X) d)Cam core(200X)

Figure 4. Microstructure photographs of cam lobe.

The microstructure photos of chill areas (a and c) and non-chill areas (b and d) of camshafts produced as ductile iron chill are shown in Figure 4.

The surface hardness of the camshaft used in the test is measured nearly as 45HRc (1kgf). The hardness depth graph in the chill area is shown in Figure 5.

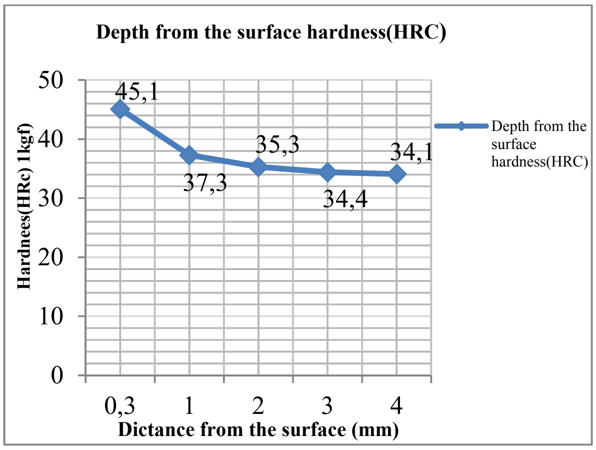


Figure 5. Material hardness depth of the surface

3.2. Manganese Phosphate Coating

The coating SEM photo on the cam surface of the ductile iron chill after manganese phosphate coating process given in Table 2 is seen in Figure 6. Because of the long coating time, a very intense and frequent coating layer could be seen. The coating density is measured as 8,78-8,80gr/m^2.

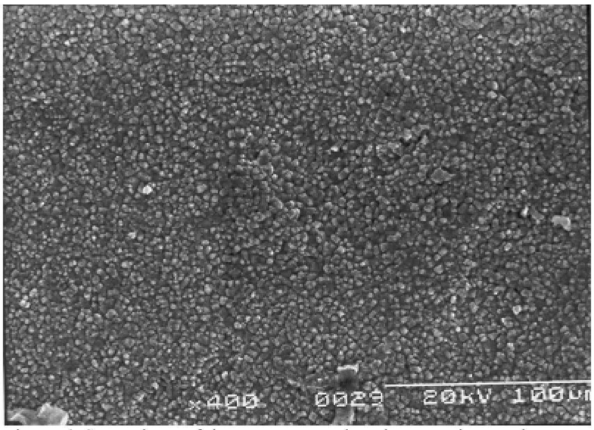


Figure 6. SEM photo of the manganese phosphate coating on the chilled ductile iron camshaft

The coating thickness on the cam surface was measured with Nikon MA200 optical microscope. The coating thickness in the cam peak and the cam flank area were measured between 6,7-8 micron and 6,8-8,5 micron respectively.

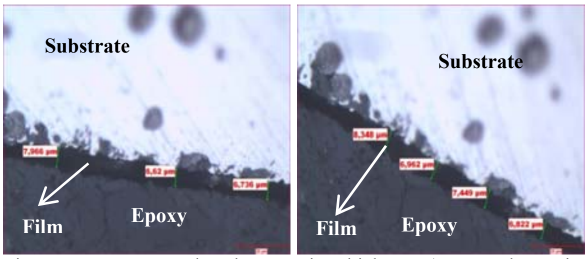


Figure 7. Manganese phosphate coating thickness a)cam peak, coating thickness between 6,7 to 8 µm b) cam flank area, coating thickness between 6,8 to 8,5 µm

3.3. Test Results

The engine tests of the manganese phosphated and non-manganese phosphated ductile iron chill camshafts were realized in test setups. The camshafts were run in oily medium with a speed of 1000 cycle per minute in intervals of 30 minutes for 150 minutes. After and before each test the cam profile measures were made with cam profile measuring device (Adcole 911) which can measure with a precision of 0.00001 mm. The distance from the cam profile perimeter to base circle was measured in one degree intervals. On parts working on the engine the maximum wear quantity would be on the cam nose, therefore measures taken from 0 degree on the comparison values were used.

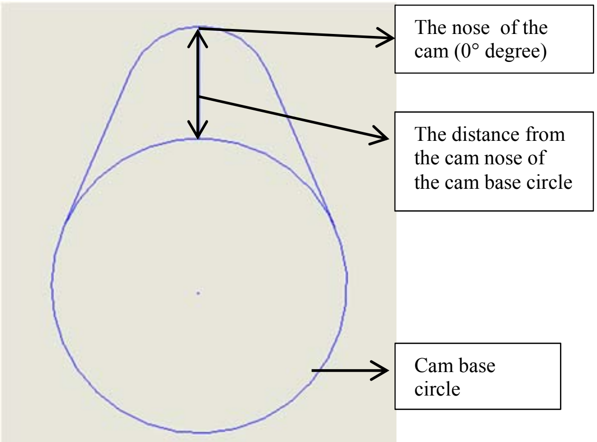


Figure 8. The cut view of the cams on the camshafts and the parts on the cam.

The abrasion quantity on phosphated and non-phosphated camshafts are given from figure 9 to 12. Here is the distance from the cam peak to the base circle diameter measured. After each period, measurements are taken from the run cams. As the camshafts were run, abrasion on the cam peaks appeared. So, the distance between cam peak and base circle was reduced. In the figures the distance values between cam peak and base circle is seen. In the graphics the values of the first measurement and after 150 minutes run of the cam peak and base circle distance is seen. The part between cam peak and base circle diameter is seen in figure 8. The values here are written in milimeters and only the abrasion values of cams 3rd, 4th, 5th and 6th are seen.

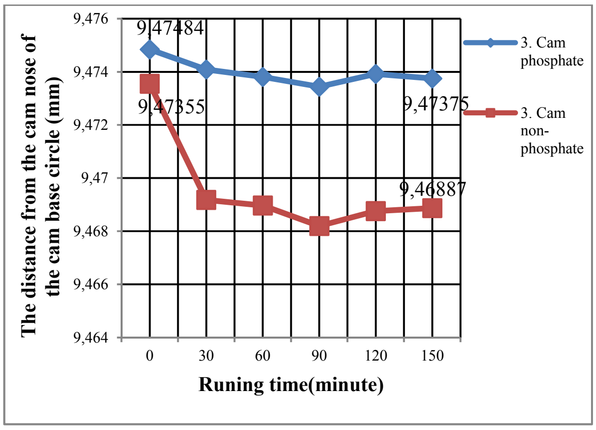


Figure 9. The change on the points of the 3rd cam on phosphated and non-phosphated camshafts

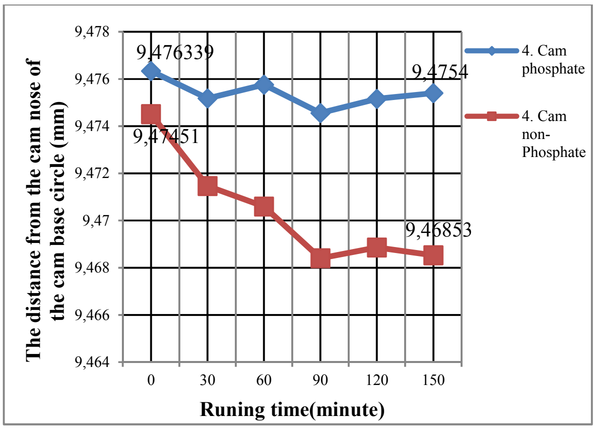


Figure 10. The change on the points of the 4th cam on phosphated and non-phosphated camshafts

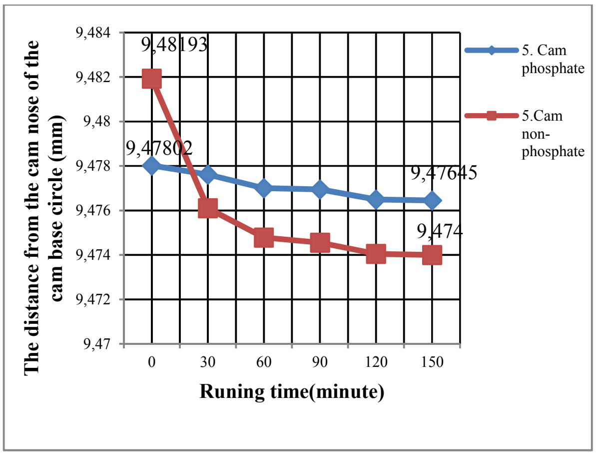


Figure 11. The change on the points of the 5th cam on phosphated and non-phosphated camshafts

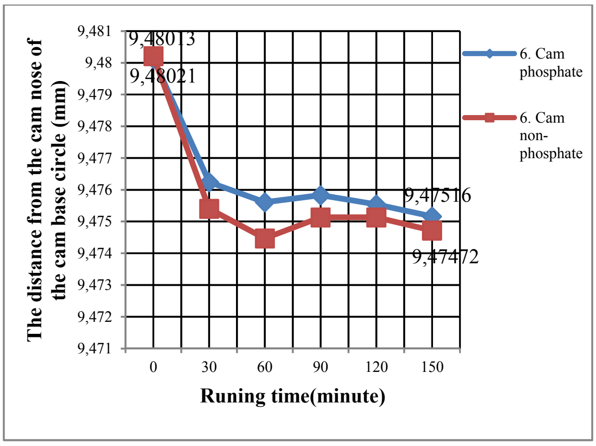


Figure 12. The change on the points of the 6th cam on phosphated and non-phosphated camshafts

The cams wear rates are given in table 3.

Table 3. Wear rates of the phosphated and non-phosphated cams.

	3.Cam	**4.Cam**	**5.Cam**	**6.Cam**	**average**
Cam phosphate	%0,0115	%0,0099	%0,0166	%0,0524	**%0,0226**
Cam non-phosphate	%0,0494	%0,0630	%0,0836	%0,0579	**%0,0635**

4. CONCLUSIONS AND DISCUSSION

1. The phosphate coated cams were 2,8 times less worn up than the uncoated cams. (Table 3)

2.It is thought that the diversity of the abrasion quantities on the cams is sourced of the positioning on the tappets and of the compression ratio.

3.With extending the times in the coating bath during the coating process the thickness of the coating and the density can be increased and the abrasion ratio can be reduced.

4.With extending the time in the activation bath it can be ensured that the coating holds the part surface better and the abrasion resistance can be increased.

5. Both manganese phosphate coated and uncoated camshafts were run in 30 minutes intervals for total 150 minutes.

6. It is thought that because of the oil holding feature of manganese phosphate coating and the coating hardness the abrasion values are lower.

7. The surface hardness of camshafts produced as ductile iron chill are achieved as 45 HRC.

8. As result of the study the life resistance of the cam profiles can be increased by coating with manganese phosphate of the cam surfaces.

9. In a different study the camshafts can be run in oil-free medium in order to investigate the wear behavior of manganese phosphate coating.

10. The wear behavior can also be investigated in working case with different coating condition changing the coating thickness and the grain structure of the coating.

11. Furthermore, the effects of manganese phosphate coating on the wear behavior of camshafts produced without coolants and with different materials can be researched.

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