Proceedings of ICOMAST2006
International Conference on Manufacturing Science and Technology
August 28-30, 2006, Melaka, Malaysia

INFLUENCE OF CRYOGENIC TREATMENT ON THE WEAR RESISTANCE OF PISTON RING MATERIALS

J.D.Darwin[1], S.K.Ramesh[2], A.Bensely[2], D.MohanLal[2], G.Nagarajan[2]

[1]*Department of Mechanical Engineering, Noorul Islam College of Engineering, Thuckalay-629175, India*
[2]*Department of Mechanical Engineering, Anna University, Chennai-25, India*
E-mails: jdarwa@yahoo.com

ABSTRACT

Cryogenic treatment, an add-on process to conventional heat treatment in steel materials, improves certain mechanical properties. It affects the entire section of the component unlike the coatings. On the other side, the reduction in engine efficiency of an automobile is mainly due to the friction between piston ring and the liner. In this paper, a study on the wear resistance of steel piston ring materials SR 34, SR 35 and SR 10 were made before and after cryogenic treatment. The wear test was conducted as per ASTM G99-95a standards, on a pin-on-disc apparatus. The wear resistance was quantified by weight loss method. It was observed that the cryogenic treatment imparts 25%, 27% and 34% improvement of wear resistance in SR34, SR35 and SR10 rings respectively. The underlying mechanism for the improvement in wear resistance is also discussed in this study.

Keywords: Cryogenic treatment, wear resistance, piston ring.

1. INTRODUCTION

In internal combustion engines the wear between the cylinder liner and the ring has become an increasing concern over the years. In an engine it is estimated that the piston ring friction amounts to 50 to 70% of the frictional loss of piston assembly. As a whole the piston assembly is responsible for as much as 40% to 50% of total engine frictional loss. The wear of piston ring in turn affect the emission conditions also. So the emphasis is more on reducing the wear losses due to friction between piston ring and liner material. Initially the auto component manufacturers used the cast-iron materials to manufacture the piston rings and now the trend has changed towards the steel rings due to the fact the steel rings has better mechanical properties than the cast-iron rings. To further improve the mechanical properties and the wear resistance, coating techniques like chromium and molybdenum coatings were introduced. Though the coatings improve the wear resistance of rings, as soon as the coating worn out, the ring starts behaving as a base material. So it has become necessary to go for a better process, which can give a permanent solution. Deep cryogenic treatment, an add-on process over conventional heat treatment, which improves certain mechanical properties by affecting the entire section of the component. Widely used steel piston ring materials SR 34, SR 35 and SR 10 are selected for the study. These materials were procured directly from IP Rings Ltd, Maraimalainagar, as uncoated rings. The ring materials were cryotreated using standard cryogenic treatment cycle and tested for wear resistance against the liner material on a pin-on-disc wear-testing machine as per the ASTM G 99-95a standards. The wear resistance of the piston ring materials was quantified by the weight loss method. In order to understand the mechanism of wear resistance improvement, the microstructure and the Microhardness of the piston ring materials before and after cryogenic treatment were also analyzed. This study gives an overall analysis of the improvement in wear resistance and the mechanical properties in piston rings using cryogenic treatment.

2. DEEP CRYOGENIC TREATMENT

The cryogenic treatment of metals has been acknowledged for many years as an effective method of increasing the wear life of steel components. It is an inexpensive one time permanent treatment, changing the entire section of the component unlike other processes. The treatment is an add on process over conventional heat treatment in which the samples are cooled down to –196°C at the rate of 1°C per minute and soaked at that temperature for 24 hours and slowly heated back to the room temperature followed by tempering at 150°C for 2 hours. The deep cryogenic treatment have lot of benefits in a way it gives dimensional stability to the material, improves wear resistance, strength and hardness of the materials. The SR34, SR35 and SR10 piston rings are cryotreated in a standard cycle as shown in figure1, and was tempered for 2 hrs at 150°C

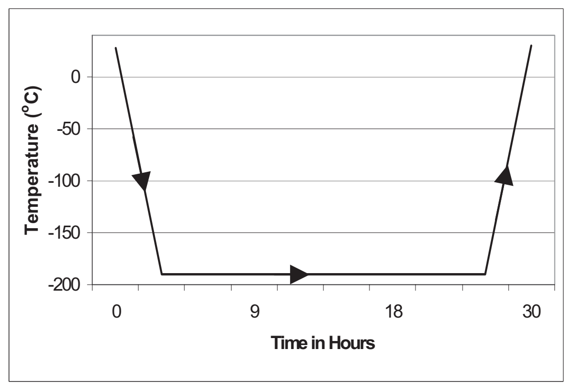


Fig. 1. Deep cryogenic treatment cycle.

3.EXPERIMENTAL INVESTIGATION

Experimental study was conducted on SR 34, SR 35 and SR 10 rings. The ring samples were subjected to deep cryogenic treatment at –196°C for 24 hours followed by tempering for 2 hours and then tested for hardness, microstructure and wear resistance. The results of the above studies were compared with that of the conventionally heat treated samples.

3.1. Chemical composition

The chemical composition of the steel piston rings SR 34, SR 35 and SR 10 were analyzed using OES and the chemical composition of the rings are tabulated in table1.

3.2.Wear Test

The wear test was conducted using a pin on disc apparatus as per the ASTM G 99-95a standards. Initially the conventionally treated ring specimens are cut into small pieces of length 15mm size in the automatic ring-cutting machine. The specimen ring samples are degreased on a degreasing machine to remove oil and other impurities. The weight of the specimen piece is measured on a semi-micro weighing balance having accuracy of 0.01milligrams and it is attached to the specimen holder of the pin on disc apparatus.

The wear test is conducted for 20 hrs continuously with test Parameters:

Load - 200 N
Speed - 90 rpm
Track radius - 40 mm

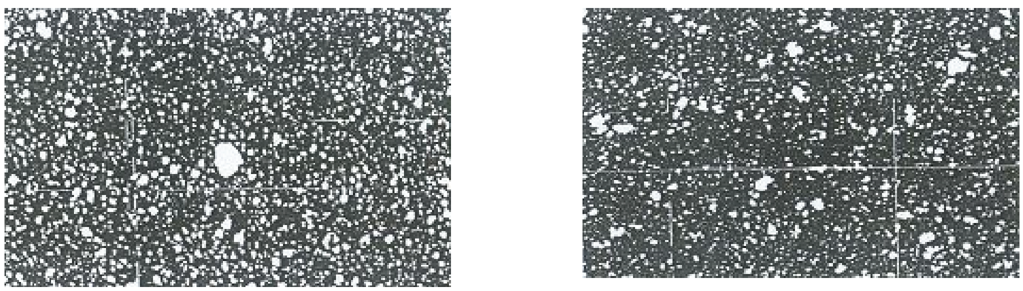
with drip lubrication against the rotating disc, for each test. After the test, the specimen is removed from the fixture, again degreased to remove the oil and other impurities. The weight of the specimen is again measured and the weight loss is calculated for all the rings separately. Next the cryogenically treated ring samples were tested for wear resistance using the pin-on-disc apparatus as per the procedure followed above, and the weight loss is calculated for all the rings separately. The results were recorded for the individual rings and shown in table 2.

3.3. Micro Hardness Study

Micro hardness test was conducted using ZWICK micro hardness tester with a load of 10N as per ASTM E 384-99$^{\varepsilon 1}$ standards. Three readings were taken on the conventionally treated ring samples at different regions. Similarly another set of three readings was taken on the cryogenic treated ring samples and the observations are tabulated in the Table 3.

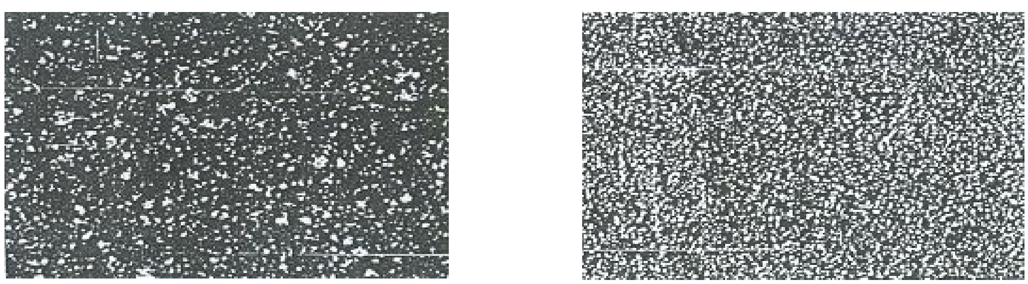
3.4. Microstructure Study

The microstructure study was conducted on all the ring specimens. The ring samples were polished as per the standard ASTM E3 using different grades of polishing papers. A set of microstructure images were taken for all the piston rings (i.e.) SR 34, SR35 and SR10 rings after the conventional treatment on the metallurgical microscope with 200X magnification. Similarly microstructure images were taken for all the piston rings after the deep cryogenic treatment also. Figure 2, Figure 3 and Figure 4 shows the microstructure images of SR 34, SR 35 & SR 10 rings respectively.



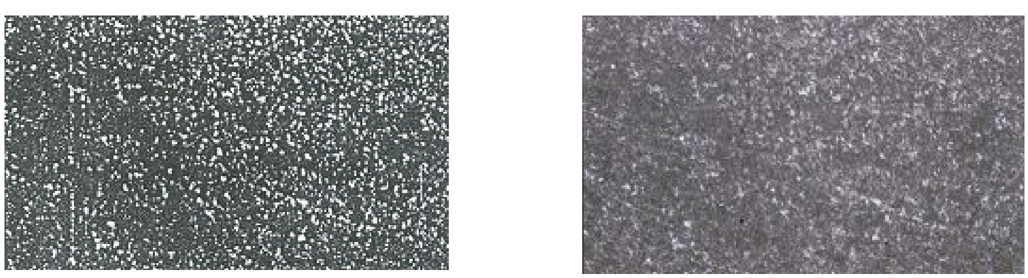
SR 34 BEFORE DCT SR 34 AFTER DCT

Fig. 2. Microstructure of SR 34 ring sample (magnification 200 X)



SR 35 BEFORE DCT SR 35 AFTER DCT

Fig. 3. Microstructure of SR 35 ring sample (magnification 200 X)



SR 10 BEFORE DCT SR 10 AFTER DCT

Fig. 4. Microstructure of SR 10 ring sample (magnification 200 X)

Table 1. Chemical Composition of ring material

Material Type	**Carbon wt %**	**Silicon wt %**	**Manganese wt %**	**Chromium wt %**	**Molybdenum wt %**	**Phosphorous wt %**	**Sulphur wt %**
SR 34 (Martenstic Stainless Steel)	0.8 – 0.95	0.35-0.5	0.25-0.4	17-18	1.00 - 1.25	0.04 max	0.04 max
SR 35 (Martenstic Stainless Steel)	0.6 – 0.7	0.25-0.5	0.2-0.5	13-14	-	0.03 max	0.03 max
SR10 (Spring Steel)	0.5 – 0.6	1.2-1.6	0.5-0.8	0.5-0.8	-	0.035 max	0.04 max

Table 2. Wear resistance improvement results of ring materials

Sl. No.	Material Type	Conventional heat treatment			Deep cryogenic treatment			Percentage improvement in wear resistance
		Weight before wear test (g) WC1	Weight after wear test (g) WC2	Weight loss (mg) (WC1-WC2)	Weight before wear test (g) WD1	Weight after wear test (g) WD2	Weight loss (mg) (WD1 – WD2)	
1.	SR 34	0.81260 0.81263	0.81238 0.81239	0.22 0.24	0.96532 0.98364	0.96515 0.98346	0.17 0.18	25.5%
2.	SR 35	0.82380 0.69330	0.82357 0.69306	0.23 0.24	0.90538 0.92376	0.90522 0.90358	0.16 0.18	27.7%
3.	SR 10	0.85931 0.85976	0.85911 0.85955	0.20 0.21	0.93215 0.97376	0.93202 0.97362	0.13 0.14	34.2%

Table 3. Micro hardness test results of ring materials

Sl. No.	Material type	Conventional treatment		Cryogenic treatment	
		HV	Average HV	HV	Average HV
1.	SR 34	383 374 386	381	387 394 392	391
2.	SR35	392 401 395	396	394 395 402	397
3.	SR10	530 534 532	532	536 531 537	534

4. RESULTS AND DISCUSSIONS

The wear test results shows that the weight loss of conventionally treated rings are 0.235mg, 0.235mg and 0.205mg in SR 34, SR 35 and SR10 rings respectively. The weight loss after the cryogenic treatment is 0.175, 0.17 and 0.135 milligrams in SR 34, SR35 and SR 10 steel piston rings respectively. It clearly shows that an increase in wear resistance was observed in all the rings. It has been quantified from the study that the wear resistance improvements were 25.53%, 27.7% and 34.2% in SR 34, SR35 and SR 10 rings respectively. The micro hardness test results shows that there was a marginal increase in hardness after the deep cryogenic treatment. In SR 34 rings it was increased from 381 to 391, in SR35 ring from 396 to 397 and in SR 10 rings from 532 to

534. There was not much drastic change in hardness after DCT. From the above wear study it has been concluded that there was an increase in wear resistance in all the steel rings after the deep cryogenic treatment. This improvement in wear resistance observed now after cryogenic treatment for the piston ring materials falls in line with the earlier research work on other materials like tool steel, die steel, etc. Even though there is a marginal increase in hardness was observed in all the three ring materials, the wear resistance improvement was significant. This confirms that the wear resistance of materials does not depend wholly on hardness alone. The possible reasons for wear resistance improvement are due to the fact that, the coarse carbides that were available in the material is fully broken and finally distributed throughout the entire structure. Apart from the above, the fine dispersement of the chromium carbides and the clustering of the chromium carbides with the iron carbides were observed throughout the structure, which is the main reason for the improvement in wear resistance after deep cryogenic treatment. Thus the cryogenic treatment is the best alternative in improving the wear resistance in steel materials.

5. CONCLUSSIONS

The present study concludes

- Cryogenically treated rings gives better wear resistance than the conventional heat-treated rings.
- The wear resistance improvements were 25.53%, 27.7% and 34.2% in SR 34, SR35 and SR 10 rings respectively after cryogenic treatment.
- A marginal increase in hardness was observed in all the piston ring materials after cryogenic treatment.
- Fine breaking of bigger chromium carbides into small carbides along with fine dispersement was observed in all the piston ring materials after cryogenic treatment on comparison with conventional heat treatment. This enhances the wear resistance properties.
- The reciprocatory type wear tester with temperature effects and actual liner ring profile will enable to simulate the actual wear pattern in laboratory conditions.

ACKNOWLEDGMENTS

The authors acknowledge the help rendered by M/S. IP Rings Ltd, Maraimalai Nager for having given the materials required for the study. The technical advises given by Mr.I.Jeyakrishnan, DGM, IP Rings and Mr.K.Sevugarajan, Metallurgist, IP Rings are also highly appreciable.

REFERENCES

[1] B.J. Taylor and T.S. Eyre, A review of piston ring and cylinder liner materials, Tribology international, (1979) 79-89.

[2] Masahiko Nakada, Trends in engine technology and tribology, Tribology international**,** Volume 27 Number 1.

[3] P. C. Nautiyal et al, Friction and wear processes in piston rings, Tribology international, February 1983.

[4] Mitsuhiro Soejima et al, Studies on the measuring method of the total friction loss of internal combustion engines, JSAE 9430680.

[5] Yukio Tateishi, Tribological issues in reducing piston ring friction losses, Tribology international, 1994 Volume 27 Number 1.

[6] Peter Anderson, Piston ring tribology-A literature survey, Helsinki University of Technology, Internal Combustion Engine Laboratory.

[7] Y. Wakuri et al, Piston ring friction in internal combustion engines, Tribology International, 1992 Vol 25.

[8] R. L. Mehau et al, Evaluation of piston ring materials in oil containing an abrasive using a ring-on-block test machine, *Wear, 147* (1991) 41-57.

[9] D. Scott et al, Material and metallurgical aspects of piston ring scuffing - A literature survey, *Wear.33 (1975) 293 –* 315

[10] D.MohanLal, S.Renganarayanan, A.Kalanidhi, Deep cryogenic treatment to augment wear resistance of tool and die steels, Cryogenics 41 (2001) 149-155.

[11] J.Y. Huang, Y.T. Zhu, X.Z. Liao, I.J. Beyerlein, M.A. Bourke, T.E. Mitchell, Microstructure of cryogenic treated M2 tool steel, Materials Science and Engineering A339 (2003) 241- 244.

[12] Fanju Meng, Kohsuke Tagashira and Hideaki Sohma, Wear Resistance and microstructure of cryogenic treated Fe-I.4Cr-IC bearing steel, Scripta Mctallugica et Materiallia Vol. 31, No. 7, pp. 865-868, 1994.

[13] Fanju Meng et al, Role of Eta-carbide Precipitations in the Wear Resistance Improvements of Fe-12Cr-Mo-V-1.4C Tool - Steel by Cryogenic Treatment, ISIJ International. Vol. 34 (1994), No. 2, pp. 205-210.

[14] Ding C. The development of metal material's deep cryogenic treatment. Heat Process Technol 2001, 54-57.

[15] Wu Zhisheng et al, Effect of deep cryogenic treatment on electrode life and microstructure for spot welding hot dip galvanized steel, Materials and Design 24 (2003) 687–692.

CONTACT

J.D.Darwin, Department Of Mechanical Engineering, Noorul Islam College Of Engineering, Thuckalay-629175, India.
Email: jdarwa@yahoo. Com

ABBREVIATIONS

SR	Steel Rolled
ASTM	American Society for Testing of Materials
OES	Optical Emission Spectroscope