Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 55
ISSUE 1
November
2012

Investigation of the effects of various surface treatments on properties of plastic mould steels X40CrMoV5-1

C. Meran [a,*], E. Sarikaya [b]
[a] Mechanical Engineering Department, Engineering Faculty, Pamukkale University, 20070 Kinikli, Denizli, Turkey
[b] Dentas Paper Industries Inc., 20330, Denizli, Turkey
* Corresponding e-mail address: cmeran@pau.edu.tr

Received 20.09.2012; published in revised form 01.11.2012

Properties

ABSTRACT

Purpose: CrN coating, hard chrome plating and nitriding has been applied on commonly used thermoset plastic mould steel X40CrMoV5-1 (Materials number 1.2344). The effects of these surface treatments over wear behaviour, impact behaviour, hardness, tensile strength and corrosion behaviour experimentally investigated.
Design/methodology/approach: Charpy test, tensile test, hardness measurements, wear tests, salt spray tests conducted over hard chrome plated, nitrided, CrN coated and uncoated X40CrMoV5-1 specimens. Coating thickness and diffusion layers examined by Nikon Eclipse LV150 optical microscope.
Findings: Highest micro hardness was observed in CrN coating, which is followed by nitriding and hard chrome plating. In wear tests, highest wear resistance was observed in CrN coating, then nitriding. Hard chrome plated samples were exposed abrasion more than uncoated ones. CrN coating and hard chrome plating didn't affect the yield and tensile strength of material but increased the modulus of elasticity. It is observed that, nitriding decreased the tensile strength but increased the modulus of elasticity. Decrease in impact energy, and increase in brittleness was observed in descending order of nitriding, CrN coating and hard chrome plating.
Research limitations/implications: Tensile test machine with hydraulic jaws can be used in further researches.
Practical implications: Suitable surface treatment selection in X40CrMoV5-1 mold steels can be made more accurate by using spider diagrams which found in this research.
Originality/value: This study was performed in the frame of the Pamukkale University Scientific Researches Projects Coordination Unit project no 2010FBE036 „Investigation of the Effect of Various Surface Treatments on Properties of Plastic Mold Materials".
Keywords: Surface treatments; CrN coating; Nitriding; Hard chrome plating; X40CrMoV5-1

Reference to this paper should be given in the following way:
C. Meran, E. Sarikaya, Investigation of the effects of various surface treatments on properties of plastic mould steels X40CrMoV5-1, Journal of Achievements in Materials and Manufacturing Engineering 55/1 (2012) 54-58.

1. Introduction

Plastic injection moulds are the main elements of serial production. Because of the wrong material, surface treatment selections and applications in injection mould manufacturing, moulds malfunction before the targeted production cycles. Until the moulds are scrapped, moulds maintenance requirements exceeds because of corrosion, wear and difficult demolding reasons. Interruption of production because of the increased maintenance of moulds decreases the desired productivity and increases the production costs. An appropriate and optimum surface treatment selection is a key point to avoid this possible threat in injection moulding [1-21].

Surface treatments are applied to the material surface in order to increase wear resistance, corrosion resistance and mechanical properties.

With this research, an effect of surface treatments over common thermoset plastic injection mould steel with X40CrMoV5-1 chemical designation is examined.

The effects of CrN coating, nitriding and hard chrome plating over these materials are investigated. Coated sample's mechanical properties and corrosion resistance tested, compared with each other samples.

2. Materials and method

Experiments in this study were performed in the laboratory at the Department of Mechanical Engineering, Pamukkale University. The chemical composition of test materials used in experiments is given Table 1.

Table 1.
The chemical composition of X40CrMoV5-1 is given in mass %

C	Mn	Si	Cr	Mo
0.39	0.40	1	5.3	1.40

Test specimens grinded with 80-120-280-400-800 sandpaper. After grinding, X40CrMoV5-1 is heat treated. After heat treatment all specimens are polished with 10, 5 and 1 micron diamond paste. Grinded, heat treated and polished specimens shown in Fig. 1.

After polishing specimens are nitrided, hard chrome plated and CrN coated. The mechanical and chemical tests applied on surface treated and untreated specimens as hardness measurement, Charpy impact, tensile, wear, salt spray tests.

Micro hardnesses are measured with Metkon microvickers device, macro hardnesses are measured with Meba MHT-150 Rockwell hardness. Charpy impact tests are made with Alsa 300J impact test device.

Tensile tests are conducted with Alsa tensile test device with 600 kN capacity. Wear tests are conducted with Plint friction and wear test device shown in Fig. 2. As an abrasive tool, wolfram carbide (WC) pins which have 1840 HV are used. Before and after the tests, specimen's weights measured with Precisa XT620M weight.

In wear tests, samples are rotated in 400 1/min speed, forced a wear by applying 2 kg load in 2 hours, 18864 meters dry friction.

Fig. 1. General view of tests specimens

Fig. 2. Plint friction and wear test device [22]

Salt spray tests are performed according to ASTM B117 salt spray test with using C&W Specialist Equipment, SF/200-A salt spray cabin shown in Fig. 3.

Fig. 3. SF/200-A salt spray cabin [22]

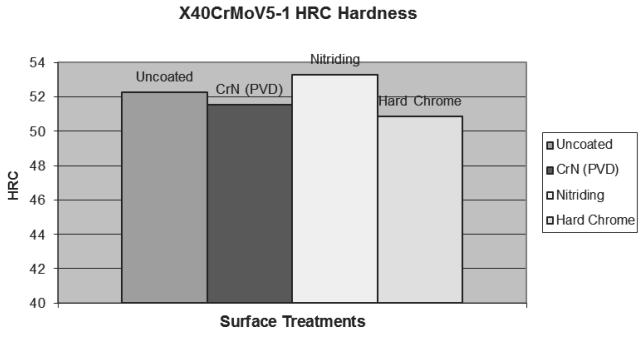
Microstructure investigations are made with Nikon Eclipse LV150 optical microscope by using bakelited and etched samples.

3. Results and discussion

3.1. The effect of the surface treatment on the physical properties of X40CrMoV5-1

The macro and micro hardness measurement results of X40CrMoV5-1 are given in Fig. 4. The results are average of 6 different measurements.

a)



b)

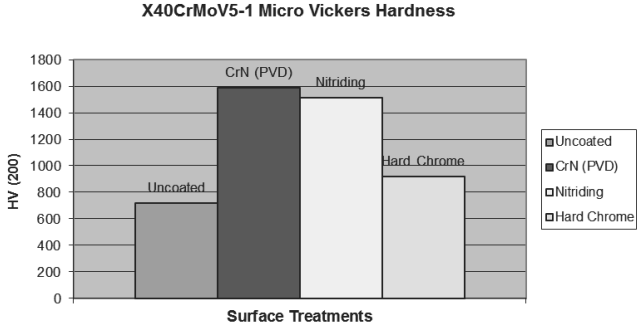


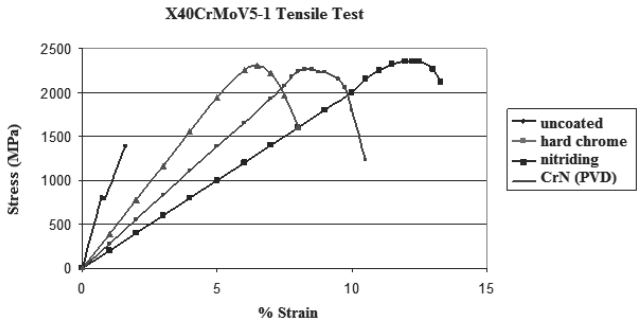
Fig. 4. Macro (a) and micro hardness (b) of X40CrMoV5-1 with different surface treatments [22]

Hard chrome plating and CrN coating do not change the materials macro hardness significantly. Because the Rockwell hardness measurement penetrated the specimen with 150 kg force, it measured the hardness of substrate material. Only nitrided specimens achieved a little more macro hardness then the untreated samples. CrN coating is around 3 µm, 1500 HV hard ceramic layer which is bounded to surface with metallic bounds. Nitride is diffused to surface and created nitride particles which is finely distributed below the surface and increased the hardness.

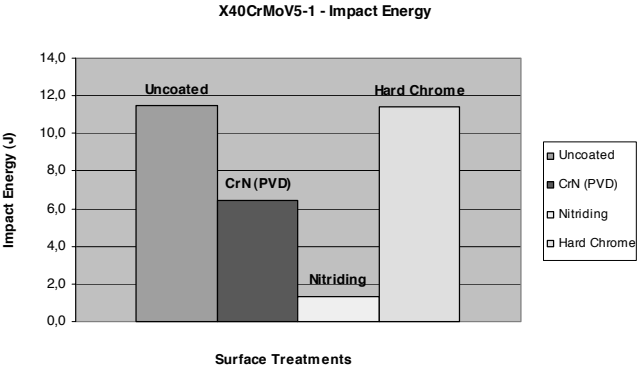
Hard chrome plating created a layer with electrolysis having around 10 µm thickness. While the layer is thin and bound is weak, this coating showed hardness related to the substrate.

The tensile, Charpy impact, and wear test results of X40CrMoV5-1 are given in Fig. 5. The results are average of 3 different measurements.

a)



b)



c)

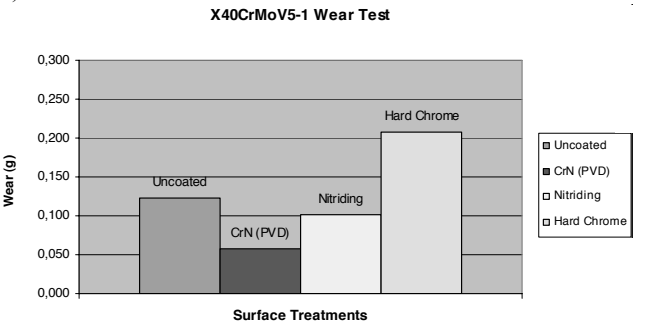


Fig. 5. Tensile (a), Charpy impact (b), and wear test (c) results of X40CrMoV5-1 with different surface treatments [22]

Because CrN coating, hard chrome plating and nitriding created a hard layer on the surface, tensile properties are changed and modulus of elasticity increased in every treated samples. In nitriding thick, hard and brittle diffusion layer increased the modulus of elasticity significantly. In CrN coating and hard chrome coating, tensile and yield stresses did not change significantly. In nitriding, yield did not observe, tensile stress is decreased, Fig. 5a.

Since the ceramic CrN coating is very brittle, crack formation had been easy and the toughness of CrN coated samples are decreased according to untreated samples, Fig. 5b. Because the nitriding layer is deeper than the other coatings, the crack propagation had been easier and thus decreased the impact energy dramatically. The hard chrome layer has the weakest bound; the toughness did not change as much as other coatings.

In X40CrMoV5-1 steel most wear observed in hard chrome plating. CrN coating wore 53% less than uncoated sample. Nitrided sample wore 18% less then uncoated sample, Fig. 5c.

3.2. The effect of the surface treatments on the corrosion behaviour of X40CrMoV5-1

The salt spray test results of X40CrMoV5-1 are given in Fig. 6. The results are average of 2 different samples.

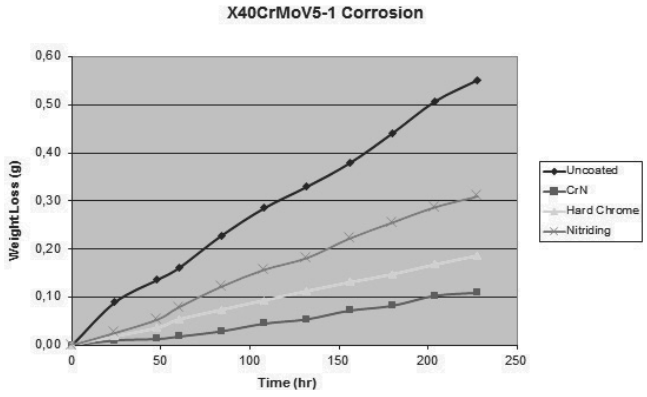


Fig. 6. Corrosion caused weight losses of X40CrMoV5-1 with different surface treatments [22]

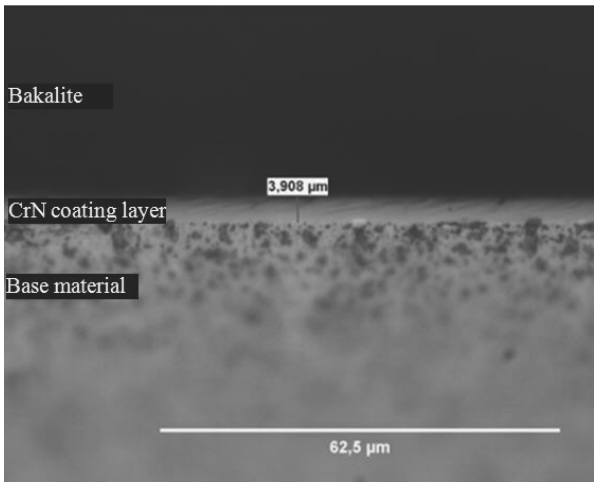
Since the CrN coating is ceramic based, in corrosive environment it behaved inert and corroded least. Because hard chrome plating is homogenous and has very less micro cracks, it prevented the corrosive substances to penetrate into substrate and increased corrosion resistance. In nitriding, formed ε-nitrur particles increased the corrosion resistance than the uncoated samples but nitrided samples corroded more than CrN coated and hard chrome plated samples, Fig. 6.

The micro structures of X40CrMoV5-1 can be seen in Fig. 7.

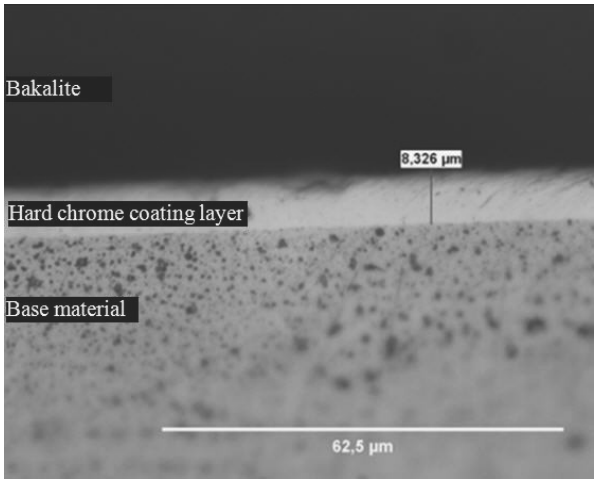
4. Conclusions

Comparing the effects of surface treatments over corrosion resistance, wear resistance, tensile strength, toughness and costs are given in Fig. 8.

a)



b)



c)

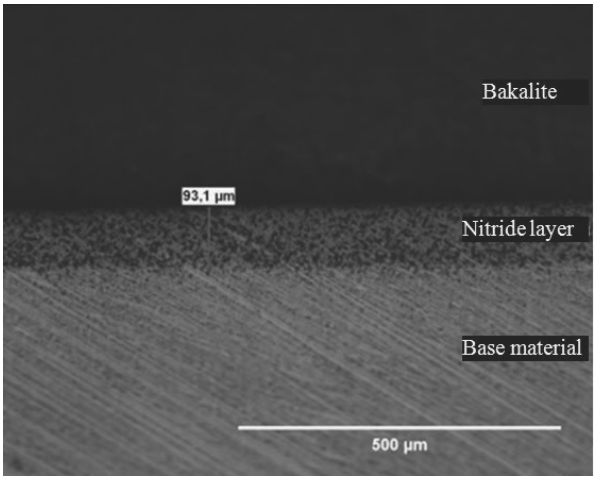


Fig. 7. Coating thickness of CrN (a), hard chromed (b), and nitrided (c) X40CrMoV5-1 steel [22]

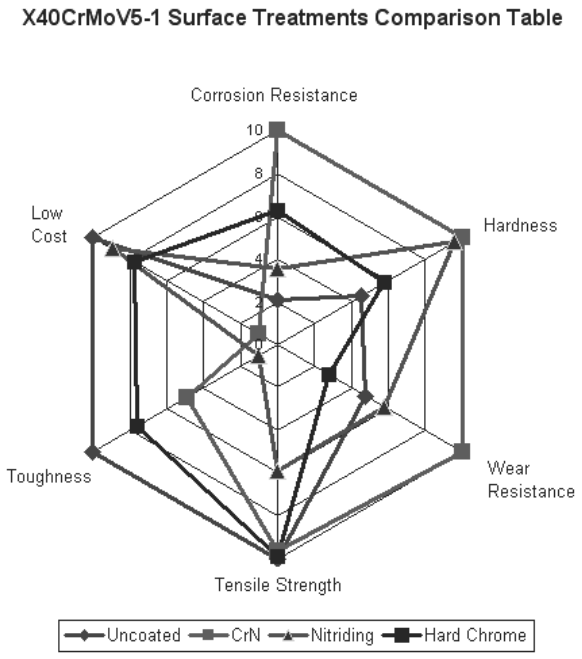


Fig. 8. Surface treatments comparison diagram of X40CrMoV5-1

Below given results obtained from the mechanical evaluation of X40CrMoV5-1 mould steel surface treatments:

- CrN coating gives the best performance in wear, hardness and corrosion resistance but its cost is high compared to other surface treatments.
- Whether nitriding doesn't improved corrosion resistance much, it increases the wear resistance, hardness significantly and it becomes a cheap alternative to CrN coating in non-corrosive operation conditions.
- In the moulding of very plain and corrosive parts hard chrome plating could be a good alternative.

Acknowledgements

This study was performed in the frame of the Pamukkale University Scientific researches Projects Coordination Unit project no 2010FBE036. The authors would express their thanks to Pamukkale University for their kindly support.

References

[1] M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Inc., Oxford, 2004, 5.
[2] D.R. Askeland, The Science and Engineering of Materials, PWS Publishing Company, Boston, 1995, 511-519.
[3] H. Bennighoff, Beschichten von Werkzeugen, K. Plast Kautsch, Zurich, 1988, 13.
[4] Boehler Brochure Boehler Company, Publication, Dusseldorf, 1997.
[5] M. De La Puenta, Products Finishing, 2000/1 (2000) 19-20.
[6] A. Dittrich, W. Kortmann, Werkstoffauswahl und Obernachenbearbeitung von Kunststoffstahlen, Thyssen Edelstahl Technical Report, Dusseldorf, 1981, 190-192.
[7] H. Gastrow, Injection Molds: 130 Proven Designs, Carl Hanser Verlag, Cincinnati, 2002, 8-10.
[8] B. Genath, Die Mikroerosion erzielt hohe Genauigkeiten, VDI-Nachr. (1973) 17-18.
[9] P. Jones, The Mould Design Guide, Smithers Rapra Technology Limited, Shawbury, 2008, 321-323.
[10] W. Konig, E. Klocke, Fertigungsverfahren, Vol. 3, Springer Verlag, Berlin, 1997, 78-79.
[11] W. Kortmann, Vergleichende Betrachtungen der Gebrauchlichsten Oberflachenbehandlungsverfahren, Thyssen Edelstahl Publication, Berlin, 1985, 163-199.
[12] J.H. Ludwig, Werkzeugwerkstoffe Ihre Oberflachenbehandlung, Verschmutzung und Reinigung. Munich, 1982, 72-78.
[13] K. Malle, Von der HSC-Produktidee zum Bearbeitungszentrum, VDI-Z, Aachen, 1996, 138.
[14] G. Menges, W. Michaeli, P. Mohren, How to Make Injection Molds, Hanser Publishers, Munich, 2001, 105-109.
[15] G. Mennig, Mold Making Handbook, Carl Hanser Verlag, Munich, 1998, 79-80.
[16] W. Michaeli, H. Greg, G. Kretzschmar, F. Ehrig, Training in Injection Molding, Carl Hanser Verlag, Munich, 2001, 1-24.
[17] K. Onaran, Malzeme Bilimi, Bilim Teknik Yayınevi, İstanbul, 2000, 328-341.
[18] H. Rees, Mold Engineering, Hanser Gardner Publication, New York, 2002, 353.
[19] D.V. Rosato, M.G. Rosato, Injection Molding Handbook, Kluwer Academic Publishers, London, 2000, 479-481.
[20] J.F. Shackelford, Introduction to Materials Science for Engineers, Prentice Hall International Inc., New York, 2004, 6-7.
[21] J. Steiner, Senkerodieren von Stahl im Werkzeubau, Kunststoffe, Berlin, 1986, 1193-1194.
[22] E. Sarikaya, Investigation of the Effect of Various Surface Treatments on Properties of Plastic Mold Materials, Graduate Thesis, Pamukkale University, Institute of Natural Science, Denizli, Turkey, 2011.