SURFACE PROPERTIES OF H13 STEEL WITH DUPLEX TREATMENT

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Abstract. *In this study it was investigated the relation between nitriding and TiAlN coating thickness and their relation with mechanical and tribological properties of AISI H13 with duplex treatment. In the first part of the work gas nitriding was performed in the H13. It was produced three nitriding layer thickness: 30, 60 and 90µm. XRD characterization showed that the phases formed are practically the same for the three nitriding thicknesses. Mechanical properties probed through Vickers microhardness reveals that there was no significant difference between the 60 and 90 µm nitriding layers surface hardness. On the other hand, the 30 µm nitriding layer showed lower surface hardness. In the second part of this project, TiAlN was deposited over the H13 nitrided substrate. TiAlN was deposited with two thicknesses: 3.5 and 8 µm. It was found that the nanohardness of TiAlN decreases with the thickness of the nitriding layer; moreover the nanohardness of the samples with 8 µm was higher than the samples with 3.5 µm. The wear rate is improved by applying TiAlN coating over nitrided treated surface, even though there is no significant difference among the two coating thickness.*

Key words: *Wear rate, Nanoindentation, Duplex Treatment, PAPVD, TiAlN*

1. INTRODUCTION

Aluminum alloys are widely used to produce variety of components due to its low specific mass and good strength. Die casting is one of most common processing technology to obtain aluminum parts at low production costs. In die casting of aluminum alloys one of the most expensive item is the mold that reproduces the component geometry. The die casting tool must provide products with adequate surface finishing and tight dimensional tolerances (Mayrhofer *et al.*, 2004). Die casting tool are mostly produced with AISI H13 tool steel (Persson *et al.*, 2004). The H13 steel is firstly quenched and tempered and quite often gas or plasma nitrided. The nitriding case enhances the surface hardness and introduces compressive residual stresses which improve thermal fatigue resistance. The aluminum die casting temperature lies above the metal melting point which due to aluminum affinity with the H13 iron matrix causes soldering of aluminum pieces in the surface of dies casting tool. The other problem is erosion that arises from the high velocity that aluminum is die casted. Erosion creates small cavities in the mold that jeopardizes the product quality and often needs to be repaired by welding. Thermal fatigue, soldering and erosion are technological problems that increase the production costs because they can either require tool repair or make the mold fails (Young, 1979). To address these problems duplex modified surfaces has been proposed in the last 10 to 20 years. The duplex surface is comprised of thermochemical treatment and thin film coating deposition. In the case of H13 steel the thermochemical treatment is plasma or gas nitriding. The nitriding treatment improves the load bearing capacity, surface hardness and introduces compressive stress in the steel surface. The deposition of thin film coating over the nitrided surface can be done by either PVD or CVD processes (Bunshah, 1982). The main advantage of PVD over CVD based processes are the lower deposition temperature. The coating to be deposited must have good mechanical properties and high thermal stability around the aluminum melting point. There are a number of choices concerning the coating stoichiometry and structure. The two main family that are been investigated are the ternary CrAlN and TiAlN (Salas *et al.*, 2003).

The goal of the present work is to investigate the whole of nitriding and TiAlN layer thickness and their relation with tribological and mechanical properties of the H13 steel surface with duplex treated.

2. EXPERIMENTAL MATRIX AND MATERIALS

Firstly an AISI H13 steel bar was cut in samples with 25.4 mm diameter and 10 mm height. The samples were quenched and tempered to HRC 45. The samples were gas nitrided to a three different nitriding thicknesses: 30, 60 and 90µm. After the nitriding treatment the surface of the samples were prepared to determine the phases formed and Vickers microhardness. The phases were determined by XRD and Vickers microhardness was evaluated applying a load of 50 g. Afterwards the nitrided samples were covered with TiAlN. The TiAlN were deposited by cathodic arc in two different thicknesses: 3.5 and 8 μm. After the deposition EDS, nanohardness and wear rate were performed. The wear rate was obtained by a microtribometer by a ball-on-disk test, with an 120 minutes testing time, load:1N and rotation speed 40rpm. The nanohardness test was probed with MTS Nanoidenter XP mode, applying 50g maximum load.

3. RESULTS AND DISCUSSION

The XRD results revealed that the phases formed in the three gas nitriding cases are practically the same. The nitriding layer is composed by iron nitrides precipitates; moreover it was not observed the presence of compound layer in any of the three nitriding cases investigated in this work. The Vickers hardness profiles for three nitriding cases are been shown in Fig. 1. The 60 and 90 μm nitriding cases shown the same surface hardness, but the hardness profiles are different. On the other hand; the 30 μm nitriding case shows a lower surface hardness than 60/90 μm nitriding layer. The hardness profile of the 30 and 60 μm is practically the same. The difference in hardness among the three nitriding cases could be due to the amount of iron nitrides precipitates formed during the gas nitriding process.

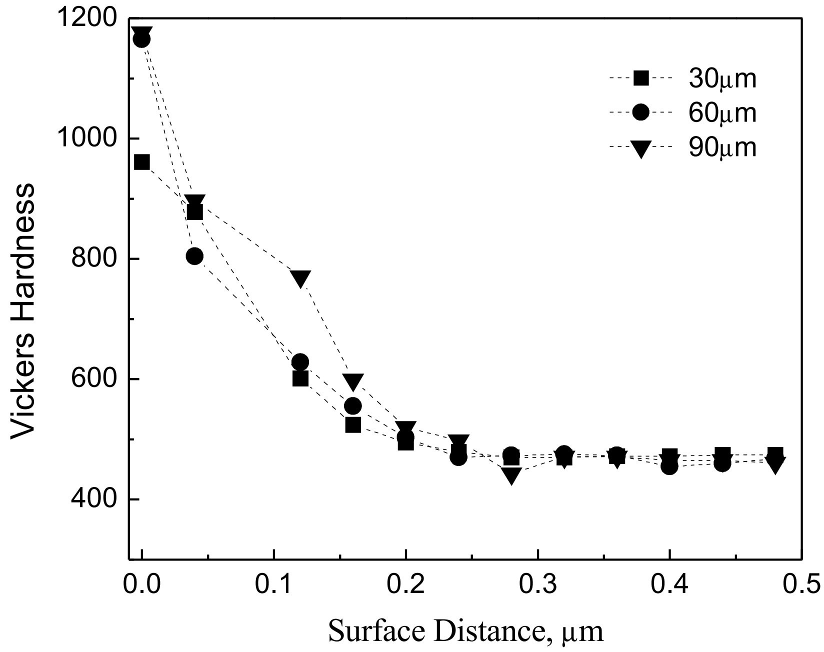

Figure 1. Hardness profile of the nitriding cases.

Identification of TiAlN coating stoichiometry was performed by EDS analysis. EDS results shown the TiAlN thin film presented 70% atomic of titanium and 30%atomic of aluminum. The coating stoichiometry was fact $Ti_{0.7}Al_{0.3}N$.

Mechanical behavior of the AISI H13 with duplex treatment was probed through nanohardness measurements. The nanohardness results for the samples nitrided treated and coated with $Ti_{0.7}Al_{0.3}N$ are been shown in Fig. 2. The nanohardness results shown that the thicker the nitriding layer the lower is the coating nanohardness; moreover the hardness of the samples with 8 μm $Ti_{0.7}Al_{0.3}N$ thickness is higher than the samples with 3.5 μm. The lowering in hardness of the coating with thickness of the nitriding layer is due to the reduction of properties mismatch that provides thermal stresses relaxation. The higher the nitriding thickness the lower is the properties mismatch. The hardness of the samples with 8 μm is higher because the residual stresses are higher due to effect of thickness of the coating layer.

The wear rate for nitrided samples are in good agreement with the hardness profile shown in Fig. 1; the nitriding case with thickness of 90 μm show the lowest wear rate comparing with 30 and 60 μm as shown in Fig. 3. The wear rate are dramatically reduced by the deposition of $Ti_{0.7}Al_{0.3}N$ coating in the nitrided samples; moreover $Ti_{0.7}Al_{0.3}N$ coating thickness does not play a important whole concerning the wear rate as can be observed in Fig. 3. The improvement in the wear rate with $Ti_{0.7}Al_{0.3}N$ is related to high hardness of the coating, which can be observed in Fig. 2.

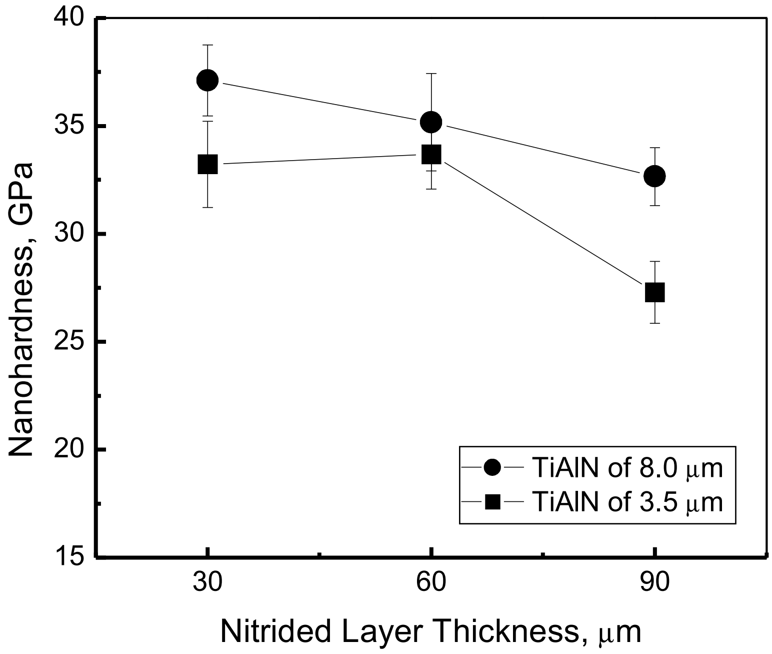

Figure 2. Nanohardness of the nitrided and TiAlN coated samples.

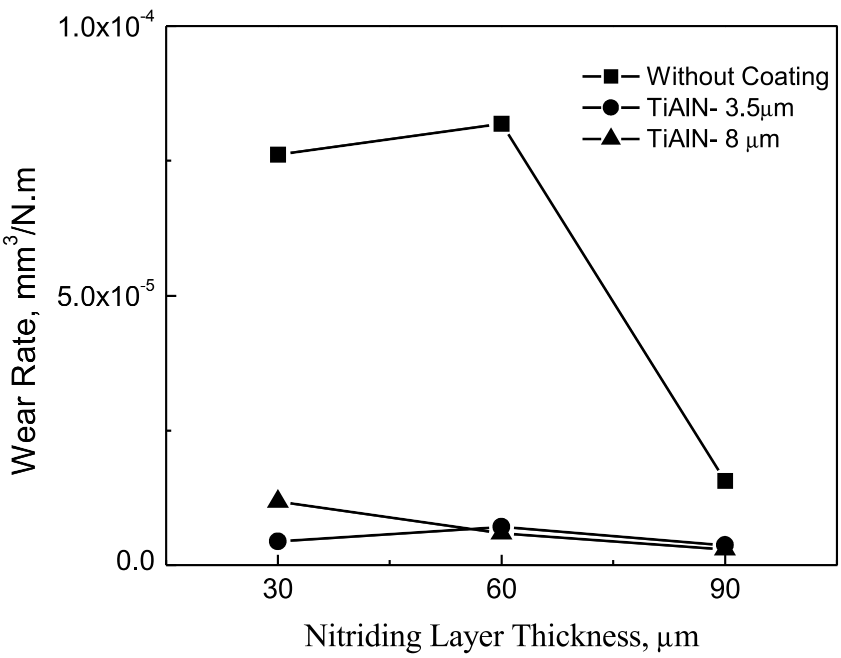

Figure 3. Wear rate of the nitrided and TiAlN coated samples.

4. CONCLUSION

The deposition of TiAlN improves the mechanical and wear properties comparing to the nitriding surface treated condition. The Hardness is higher for TiAlN with 8 μm thickness. The hardness of the TiAlN thin film decreases with the thickness of the nitriding layer. There are no significant differences in the wear rate between the two thin film thicknesses.

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