# The Effect of Tool Steel Chemical Compositions on The Level of White Layers Homogeneity and the Hardness Surface

K. Astana Widi, ING. Wardana, W. Sujana

***Abstract* – The process of nitriding (the nitride layer and disability) to applied to the electronic components (hardware) besides the automotive components applied, but nowadays there are still gain no optimum result. The research of the atom diffusivity homogeneity effect to the mechanical character into the mechanical surface are yet to be done. And the factor which is affecting like the composition of the elements in the materials are needed to be done an observation. In this research we used some tool steel materials with a different chemical composition, in 550 $^0$C nitriding temperature process in 4 hours to identify the white layer which is formed on the surface and connected with their mechanical characters. The result showed that the value of the hardness materials are very affected by the stability or the homogeneity of the white layer formed in the surface. And the homogeneity is very affected by the composition elements which is contained the materials. The highest hardness level (975.5 HV) is resulted by the AISI P20 with the most homogeneity thickness surface with the most Chrom composition of 2%. The next hardness level is the AISI 4340 (751.2 HV) steel, with 1.4 % *Cr* composition and the lowest composition is the AISI 4140 (720.8 HV) with 1.07% Chrom.**

***Keywords* - chemical composition, nitriding, white layer, tool steel.**

## I. INTRODUCTION

The limitation of nitrogen atom diffusivity to produced the compound layer and diffusivity layer to forming the hard nitride layer is very low [1]-[10]. This caused the limitation applying to the nitridation products. This thin layer has a very low toughness value and easily to breaks or cracks. So this material which is hardened by the nitridation can only for an adhesive assessment. The assessment-less pressure friction. Besides the lack of efficiency in the production process (over time nitriding) with the value of hardened thickness which is produced (2.5 μm per hour) [2] make the nitridation is less effective compare with the others heating process.

Manuscript received December 28, 2012
Komang Astana Widi, is with the Brawijaya University phd student, East Java Indonesia (e-mail aswidi@yahoo.com)
Nyoman Gede Wardana, is with the Brawijaya University, East Java Indonesia (e-mail wardana@ub.ac.id)
Wayan Sujana, is with the National Istitute of Technology of Malang, East Java Indonesia (e-mail : wakilrektor1@itn.ac.id)

The value which is formed in every each layers is varied caused by inhomogeneity diffusivity from the nitrogen atom. The inhomogeneity is the one of some factors which is causing the limitation of nitrogen atom diffusivity into the materials, where the part is contained the most nitrogen atom (generally in upper layer) will form brittleness material. Reference [3] shows the compare of nitriding treatment to the mild steel where using of nitrogen gas will form the solid layer (~ 1600 HV). Whereas the using of ammonia gas causing poor mechanical character in outer rather than the layer which is formed in the inside. Reference [4] researching the use of nitriding for medical (compositon CoCrMo) where the thickness, worn-out endurance, and the hardness will be produced in double. This process using the temperature 500-800 $^0$C for 9 hours forming the $Cr_2N$ and CrN phase. Reference [5] showed the contains of nitrogen that forming ε-nitride layer in the nitridation process it is not only affected by the parameter process but the most important is the composition elements from nitriding materials. Reference [6] the role of grain limit (the rolling process) to increasing an atom diffusion on the process of nitridation. The increasing of rolling process also increased the disability of solidity. The best condition is the material with soft structure. Reference [7] showed that the increasing of temperature and nitridation plasma process will increasing the thickness of layer and their mechanical characters. The layer formed is the compound layer (δ-TiN, $\varepsilon$-$_{Ti2N}$). The sector which is rich of Al and the diffusion layer. The optimum result is from the temperature 800 $^0$C in 5 hours. Reference [8] showed that researching the paramagnetic act or ferromagnetic austenitic type material (316L) determined based on grille parameter, to change the paramagnetic act to ferromagnetic need to develop the grille parameter about 5% the way is adding 14% of concentrate nitrogen in the super-saturated nitriding process. Reference [9] showed that the use of fluidized bed to form nitride phase in the silica powder. Where the 5% of powder will not formed the β phase but adding 20% SiN /1300 $^0$C or 30% SiN /1250 $^0$C formed 21% β phase SiN. Reference [10] showed that the research has done about using the stiffening will be continued by the ion and gas nitridation process to the tool steel material and showed an early ion nitridation result. It is better the depth of white layers. It can be proved by the worn-out tested fragment model. The use of multi-

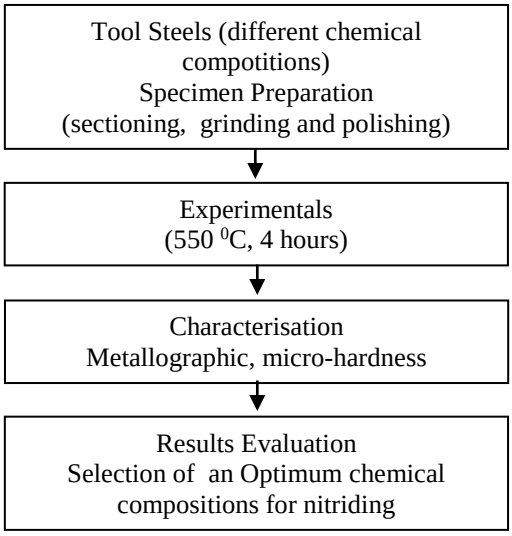
stage nitridation in the temperature 550 $^0$C and 530 $^0$C on the H13 steel showed that the white layer appear in the surface of the material (5 micron) caused by the highest nitrogen contain in that part and the diffusion layer (70-80 micron) contain precipitation nitride in the grain and the grain limit whereas in the core forming temper martensit structure. Reference [11] the experiment by *S.Zach et all* showed that the temperature of gas and steam super-saturated determined based on the Poisson equation.

In this research, the writers using the deviation of Poisson equation composition element to see the effect of the composition element to the hardness result by the view of white layer characterization which form in the surface as long as nitriding process.

## II. EKSPERIMENTAL PROCEDURE

The material include 3 specimens kind of tool steels they are AISI 618, AISI 4340 and AISI 4140 with the diameter measures 5 cm and the thickness 5 cm. Next the three kind of materials will be given a nitridation act in fluidized bed reactor within composition of 30% $NH_3$ and 70% $N_2$ (with total flow rate is 0.6 $m^3$/hours), temperature process 550 $^0$C in 4 hours. The nitridation result will be tested by using 250 times of micro structure zooming and hardness (5 points per specimen) and without specimen preparation test. The purpose will not changes the nitridation result caused by the cutting process. The realtion between the layer model to the hardened result is by analysis.

**Experimental flow chart**




## III. RESULT AND DISCUSSION

Table I. Compositions of some tool steels

| Type | Chemical Compositions | | | | | |
|---|---|---|---|---|---|---|
| | C | Si | Mn | Cr | Ni | Mo |
| P20 | 0.37 | 0.3 | 1.4 | 2.0 | 1.0 | 0.2 |
| 4340 | 0.36 | 0.25 | 0.7 | 1.4 | 1.4 | 0.2 |
| 4140 | 0.41 | 0.34 | 0.81 | 1.07 | - | 0.19 |

Tabel II. Hardness before and after nitriding

| Type Tool Steel | Before Nitriding [HVN] | After Nitriding [HVN] |
|---|---|---|
| P20 | 319,0 | 975.4 |
| 4340 | 341,0 | 751.2 |
| 4140 | 296.4 | 720.8 |

(a) (b)

Fig 1. AISI P20 Microstructure (250x) a) before, b) after nitriding

(a) (b)

Fig 2. AISI 4340 Microstructure (250x) a) before, b) after nitriding

(a) (b)

Fig 3. AISI 4140 Microstructure (250x) a) before, b) after nitriding

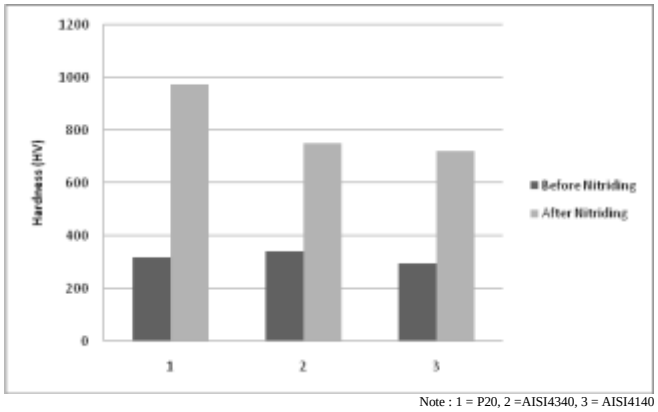



Fig 4. Hardness of some tool steels before and after nitriding process

The specimen preparation is very important to produce the layer in the surface materials with the flat surface will give a big chance to produce the homogeneity of N atom diffusion to the whole surface simultaneously. The metallographic test showed that the uneven surface result the uneven layer. The ruggedness will reduced the optimum result of an average hardness value from the materials.

The effect of composition materials has a role in the homogeneity atom diffusivity to the materials. Few things that affect the N atom diffusivity is because the low N atom

diffusivity caused by the forming super-saturated reaction from $NH_3$ gas. The form of super-saturated reaction because re-fasten N atom with N atom which is formed the $N_2$ molecule. The atoms met because there is no space available to its atom, the available space for the atoms are adapted with the composition materials capacity in time to form the nitride composition. The research shows the chrome atom material has biggest hardness value and highest contain, so that can be assumed the Cr gives the enough space for the atoms.

The nitrogen atom movements into the material and the fasten prevention between the atoms are need to be done by increasing the composition elements can promote the nitride form where the composition element have bigger holding capacity to the N atom compare with the fasten between the atoms. Nitrogen atom releases beside the internal material effects also affected by the external factor which is too much N atom diffused to the materials caused the N atom have not had fasten with the atom of composition elements. It is possible to be uneven spread of the passive material layer. It can be affected the nitrogen atom homogeneity diffusivity into the material. As we know in general the material that used is the composition material which is has a good passive layer in terms of corrosion endurance.

The heating which is gave to the heat act does not affect the atoms breakdown. But it just stretch the atom fasten. The energy needed only 1/25 from the total energy to breakdown the fasten. In nitridation act, how is the effect of low flow rate to increasing energy result from heating process to energy needed to stretch the atom material fasten.

As we know, the energy need to release 1 nearest fasten atom is not equal. The factors who affect the disequality of fasten between nearest atom are internal material factor and environment process factor. Knowing the factor so that can be easy to understand about the weakest fasten characterization with the purpose to increase the nitro atom diffusivity to the materials.

The effect of material composition compiler to the 2 solid phase interface (austenite to perlite) has bigger chance to facilitate the nitrogen atom diffusion or vice versa. This thing can be observed by analyzing the grain model which is formed. If the grain limit morphology showed the growth of the grain limit it means the atom with an empty position (moving) will be easy diffuse by the other atoms in that phase.

## IV. CONCLUSION

The hardness value from the nitriding process is affected by the homogeneity of white layer in the whole material surface. More flat the layer more betters the hardness value. So the hardness value is not only affected by the thickness of white layer formed. The homogeneity of white layer affected by the contains of Cr where all of tool steel showed that the AISI P20 steel has the highest composition element with better white layer homogeneity. The other composition element in the tools steel has a less of role to the white layer homogeneity level. Its homogeneity surface layers is important for wear and corrosion resistant applications.

## V. REFERENCES


1. J. Hay, *Mechanical evaluation of titanium-nitride-coated tool steel*, Agilent Technologies, USA, 2010
2. Ş. Polat, Ş. Hakan Atapek, F. Gümüs,"Gas Nitriding Of A Hot Work Tool Steel And Its Characterization," presented at the International Iron & Steel Symposium, Karabük, Türkiye, April 02-04, 2012
3. V. vitry,Abdoul-F. Kanta, F. Delaunois, "Application of nitriding to electroless Ni-Cr Coatings : Chemical and structural effects ; mechanical characterization ; corrosion resistance", *Elsevier. Materials and Design Journal*, 39 pp.269-278, Feb. 2012
4. Q. Wang, L. Zhang, J. dong, "Effects of plasma ntriding on microstructur and tribological properties of CoCrMo Alloy Implat Materials," *Science Direct. Journal of bionic engineering*, 7 pp.337-344, 2010
5. S.R. Hosseini, A Ahmadi, "Evaluation of the effects of plasma nitriding temperature and time on the characterization of Ti 6Al 4V Alloy,' *Elsevier. vacum* 87 pp.30-39, 2013
6. D. Wu, "Ferromagnetism in interstitially hardened austenitic stainless stel induced by low-temperature gas-phase nitriding", *Elsevier. scripta materiala*, 2011
7. Y.D. liu, S. Kimura, "Fluidised-bed nitriding of fine silicon powder," *Elsevier. powder technology*, 109 pp.160-167, 1999
8. P. Kula, E. Woloweic, R. Pietrasik, K. Dybowski, B. Januszewicz, "Non-steady state approach to the vacuum nitriding for tools" *Elsevier. Vacum*, 88 pp.1-7, 2013
9. S. Fare, N Lecis, E. Brescia, M. Mazolal, "Role of grain boundaries in diffusional phenomena during gas nitriding of pure iron ," *Elsevier. Procedia Engineering*, 10 pp.2943-2948, 2011
10. S. Ben Slima, "Ion and Gas Nitriding Applied to Steel Tool for Hot Work X38CrMoV5 Nitriding Type: Impact on the Wear Resistance," *Materials Sciences and Applications*, pp. 640-644, Sept. 2012
11. S. Zach, "How Well Are Supersaturation and Temperature in Expansion Chambers Predicted by the Poisson-Equation?, Nucleation and Atmospheric Aerosols," *American Institute of Physics*, 2000.


## VI. BIOGRAPHY

Komang Astana Widi, ST, MT, born in Denpasar, Bali, June 25th 1976 I am a lecturer in the mechanical major study with the specify of material study of Institut Nasional Malang. And now I am studying the doctoral program on Brawijaya University with the same major study.

My recent research concentration is about the material field. The last research that I attend is the International Conference on Sustainable Development [ ICSD] on March 6th 2012, Bali, Indonesia.

Mr. Widi is the member of ACE Bali and received honors and patents as the best lecturer in Koperti sector VII in east java, and the patent of HKI [*hak kekayaan intelktual*/ intellectual property rights] and received patent arrangement fund from DIKTI