The effect of mechanical deformation to the magnetic properties of stainless steel 304

N. Mubarok[1], H. A. Notonegoro[2], K. A. Zaini Thosin[3] and A. Manaf[1*]

[1]PPS Materials Science, FMIPA-Universitas Indonesia, Depok 16424, Indonesia.
[2]Mechanical Engineering Dept., FT-Universitas Sultan Ageng Tirtayasa, Cilegon 42435, Indonesia.
[3]Pusat Penelitian Fisika,LIPI, Serpong, Indonesia.

*E-mail: Azwar@sci.ui.ac.id,

Abstract. A study of a non-magnetic 304 austenitic stainless steel alloy through mechanical deformation has been done. These specimens are pipe usually used to deliver gas which contains corrosive oil fields. The metallographic observation of a 20% deformation shows the increase in the value of the magnetization, as compensation for the formation of martensite phase as a result of a mechanical treatment. Martensitic phase formed due to a shift in the structure of the z-axis due to the effects of pressure and shear from the cold rolled. The existence of martensite phase and magnetic properties conducted through x-ray diffraction and permagraf investigation. An identified x-ray diffraction pattern shows the presence of a new peak between 10^o-30^o angle indicate the mechanical deformation in crystallite structure. Furthermore, at in 20% distortion, the value of magnetization is increased above 0.2 T in small coercivity value and caused decreased the ability of corrosion resistant.

1. Introduction

The AISI 304 stainless steel pipes are important engineering materials mainly used for Oil pipe. These pipes are usually used to deliver gas which contains corrosive and erosion ingredient from oil fields [1,2]. In Several conditions, the pipes undergo the load and stress conduct the deformation which can trigger the formation of the martensite phase [3]. The previous studies found that martensite phase correlates with the appearance of the magnetic properties of the metal structure [4].

There are two types of martensite can induce the formation in austenite stainless steels while deformation process where the transformation sequence $\gamma \rightarrow \varepsilon \rightarrow \alpha'$: ε and α'. The ε martensite is paramagnetic with *hcp* structure, and the α' martensite is ferromagnetic with the *bcc* structure [5,6].

By this paper, we report the experimental process to determine the presence of martensitic phase in AISI 304 stainless steel correlated with magnetic properties at 20% under deformation by mechanical treatment.

2. Experimental procedures

The chemical composition of 304L AISI austenitic stainless steel used in this investigation as is in table 1. The specimen steel was received in pipes form with 11 mm thickness without preheat treatment.

The mechanical treatment by cold rolling was carried out in a pilot rolling machine. Different thickness reductions 0.1 mm in every rolled from 0 to 20% with the *Torsee* 71.8 kg.m were carried out at 27°C. The crystallite structure were examines using X-ray diffraction and PERMAGRAPH® L © MAGNET-PHYSIK Dr. Steingroever GmbH is use to investigate the magnetic properties of the alloy.

Table 1. Chemical composition of stainless steel 304 specimen

	C	Mn	Si	P	S	Ni	Cr	Fe
Mill certificate	0.05	1.08	0.35	0.038	0.001	8.50	18.65	-
AAS	-	1.49	-	-	-	10.6	21.20	66.44

3. Results and discussion

The mechanical treatment illustrated as in Figure 1. The specimen came under pressure from the crush of the two drum suppressor followed by the pull of a result of drum rotation simultaneously. As in Figure 2a, with the normal parallel to the axis, the martensitic plane transformation passes along the horizontal *x*-axis of the cube (Figure 2b). The macroscopic shear direction is along the horizontal *y*-axis (Figure 2c). Following the indicated habit plane and shear direction; the shape of the grain will change into the parallelepiped [7].

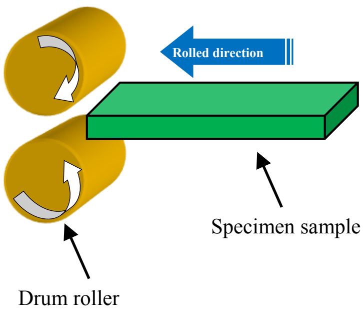

Figure 1. Illustration of mechanic treatment for deformation process

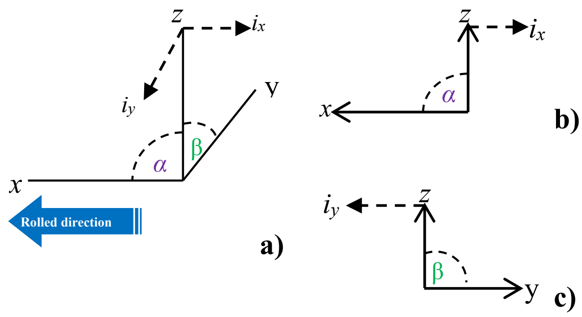

Figure 2. The orientation axis of deformation specimen sample. x-axis perpendicular to y-axis along deformation process. a) along x-axis, the angle of α widen the z-plane, b) along y-axis, the angle of β widen the z-plane.

X-ray pattern by *Cu-Kα* diffraction analysis performed over the *2θ* range from 10° to 90°. The results of the XRD analysis done on the surfaces of AISI 304 stainless steel presented in Figure 3. The XRD pattern shows 0% deformation (blue line) and 20% deformation (red line). The symbol of *α* shows the disappearance of a part of austenite peak and *β* show of the reveal of martensite phase in deformation sample. As seen, at 20% deformation as unconstrained transformation the peak has consisted the presence of austenite and *α'martensite*, respectively [8]. In fact, the strain energy was mainly consumed for production of *α' martensite* during deformation.

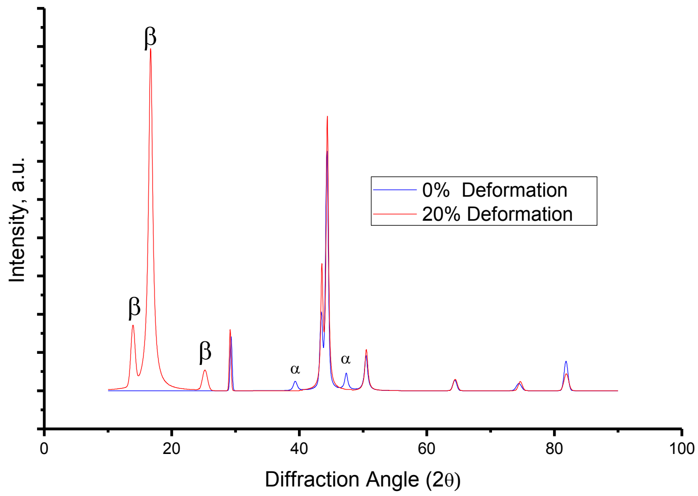

Figure 3. XRD of 0% deformation (blue line) and 20% deformation (red line). symbol of α indent the disappearance a part of austenite peak and β indent the reveal of martensite phase in deformation sample.

The magnetic hysteresis of AISI 304 stainless steel by Permagraf has shown in Figure 4. At in 0% deformation, the magnetic saturation has zero value indicating that specimens are nonmagnetic without deformation. Furthermore, at in 20% distortion, the value of magnetization is increased above 0.2 T and presence their coercivity value on its magnetic properties. This magnetic property indicates the formed of magnetic moments in the sample due to the influence of unconstrained transformations. The impact of the rise of the magnetic properties of the samples of AISI 304 stainless steel deformed caused decreased ability of corrosion resistant [9].

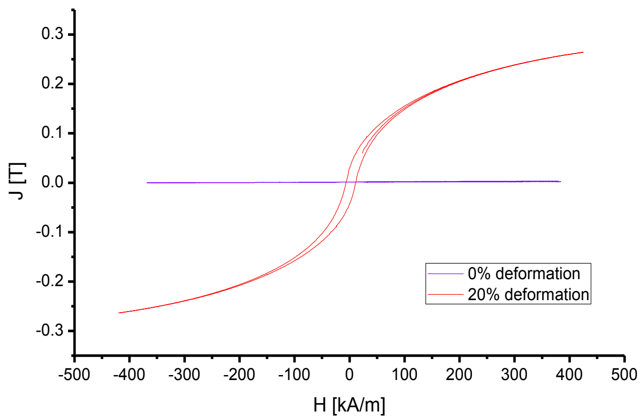

Figure 4. Magnetic hysteresis of 304 stainless steel at 0% deformation (blue line) and 20% deformation (red line) at 22 °C.

4. Conclusion

The emergence of martensitic phase conducted 20% deformed by mechanical treatment identified the presence of new pattern at 2θ = 10° - 30°. The existence of this produce martensite phase changes magnetic properties which have saturation value above 0.2T in small coercivity and caused decreased the ability of corrosion resistant.

5. Acknowledgement

The authors gratefully acknowledge the support of Department of Physics, University of Indonesia for the research facilities.

6. References

[1] Ex N, Electrical NHP, Products E, Nhp NHP. Solutions for the oil and gas industry n.d.
[2] Chawla V, Chawla A, Puri D, Prakash S, Gurbuxani PG. *Corrosion* 2011;**10**:367–85.
[3] Dryzek E, Sarnek M, Wróbel M *J Mater Sci* 2014;**49**:8449–58. doi:10.1007/s10853-014-8555-y.
[4] Surkialiabad R, Hedayati A, Alam AS *Transformation* 2013;**2**:11.
[5] Mubarok N, Notonegoro HA, Thosin KAZ, Manaf A *AIP Conf Proc* 2016;**020022**:020022. doi:10.1063/1.4953947.
[6] Abreu HFG De, Carvalho SS De, Lima Neto P De, Santos RP Dos, Freire VN, Silva PMDO, et al *Mater Res* 2007;**10**:359–66. doi:10.1590/S1516-14392007000400007.
[7] Sade M, de Castro Bubani F, Lovey FC, Torra V *Mater Sci Eng A* 2014;**609**:300–9. doi:10.1016/j.msea.2014.05.018.
[8] Character D. Martensite in Steels 2002:1–12.
[9] Shalash L, Nasher L *ResearchgateNet* 2010;**9**:30–8.