HARDNESS AND CORROSION RATE OF COCRMO

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ABSTRAK

Synthesis of bulk CoCrMo with the composition around 30% Co, 65% Cr, and 5% Mo had been done through melting, forging, and rolling processes. The material is potentially applied in orthopedic implant since it is biocompatible, strong, and has a low corrosion rate. A small portion of Nitrogen may be added to the composition in order to stabilize and improve its hardness. It is found in this investigation that Nitrogen (0,6% of the composition) results in improvement around 25% of the hardness, however it is also increase the corrosion rate from 0.0025 to 0.0329

Key words: **CoCrMo, hardness, corrosion rate**

1 INTRODUCTION

Physical accident, osteoporoses, and osteoarthritis are the major cases that increase the need of synthetic biomaterials in medical application[1]. Metal based biomaterials might be implanted in human or animal body[2]. The materials implanted should be biocompatible and do not cause any negative impact for the living body[3]. Stainless steel, Ti-Al, and Co-Cr-Mo alloys may be used as implant materials in human body to improve human bone problems[3].

The CoCrMo alloy investigated in this experiment was prepared through melting, forging and rolling processes. The composition of the material was set to accommodate the ASTM F75 (American Society for Testing and Materials)[4] requirement as shown in the Table 1. CoCrMo alloys have been widely used as implant materials in order to support human bones since it is biocompatible, have good mechanical properties and low corrosion rate[5]. The corrosion protection of the material is supported by a thin chromium oxide film on the surface as a result of oxidation process when the material in an open room[5]. Heating, forging, and cold working treatments on CoCrMo result in a strong alloy consist of small grains and low porosity which is match with a physical requirement for implant material[6].

Table 1. Composition of CoCrMo (ASTM F75 standard).[4]

Element	Wt (%)
Chromium, Cr	27 – 30
Molybdenum, Mo	5 -7
Nickel, Ni	< 2,5
Iron, Fe	< 0,75
Carbon, C	< 0,35
Silicone, Si	< 1
Manganase, Mn	< 1
Nitrogen, N	< 0,25
Cobalt, Co	63 - 65

Experimental

The elements prepared for synthesizing 10 gram CoCrMo are in the Table 2. The nitrogen element was added through Cr_2N compound. The elements were mixed and pressed under a pressure around 4000 psi in a cylindrical tube with the diameter around 1 cm. The bulks produced from this process are 4 solid disks with the thickness around 1 cm, and they are called as sample A, B, C, and D. The sample A is associated with the sample contains 0% nitrogen + 64% cobalt, The samples B, C, and D are associated with the sample contains 0.35 % N + 63.65% Co, 0.6% N + 63.4% Co, and 1% N + 63% Co respectively. The pellets then were melted at around 3000^{0}C in an electric furnace, and then cold. The forging and rolling treatments were done at the temperature around 1200^{0}C followed by quenching in water. The forging and rolling processes were done several times to produce flat samples with the thickness around 1 mm. Each sample then was cut to be 4 pieces for different characterizations (XRD, hardness, corrosion rate, and optical observation). A Surface of each sample then was ground using aluminum oxide abrasive film from 400 to 2000 mesh.

XRD observations on one sample A, B, C, and D were done in order to make sure that the CoCrMo compound had been formed. The observations were carried out using Shimidzu XRD with the wavelength λ = 1.54 angstrom. The data result from the observation were then compared with the JCPDS data for CoCrMo materials.

The hardness tests were done three times using Vickers hardness tester for a surface of sample A, B, C, and D. The average hardness data of the each surface then was calculated.

Corrosion rate values of the samples A, B, and C were also tested in a simulated body fluid (sbf) in order to know a chemical effect of the nitrogen content.

Table 2. Composition of the elements for composing 10 gram CoCrMo.

Element	Mass (gram)
Chromium (Cr)	3.00
Molybdenum (Mo)	0.50
Manganese (Mn)	0.05
Silicon (Si)	0.05
Nitrogen (N)	0
	0.035
	0.06
	0.10
Cobalt (Co)	6.40
	6.365
	6.34
	6.30

Results and Discussion

The forging, rolling, and cleaning processes result in bulk samples as shown in the Diagram 1. The Diagram shows a sample that is partly oxidized, a cracked sample, and a clean sample.

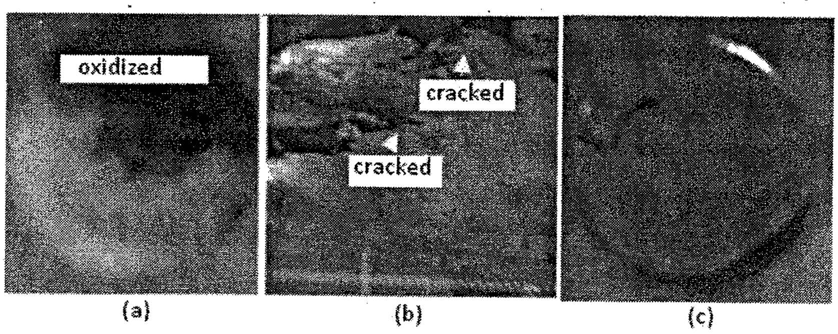

Diagram 1 (a) sample that is partly oxidized, (b) cracked sample, (c) clean sample.

It is shown from the XRD observations that the CoCrMo alloys had been formed, though they are less homogeneous than that were expected.

The average hardness data result from the experiment are presented in the Table 3.

Table 3. Average hardness of CoCrMo surfaces

Sample composition	Sample code	Average hardness (N/mm^2)
CoCrMo (N=0%)	A	492
CoCrMo (N=0.35%)	B	599.67
CoCrMo (N=0.6%)	C	633.67
CoCrMo (N=1%)	D	689.33

It is clearly seen from the data above that an addition of nitrogen (0,6%) to the CoCrMo compound results in increasing of its hardness around 25% from 492 to 633.67 N/mm^2. Weaver[7]. had found that the hardness values of adult human bones are in between 50 to 85 $grams/mm^2$. This means that the CoCrMo samples produced in this experiment are much harder than the human bones. It is also found in our investigation that increasing nitrogen content in the CoCrMo samples has increased its corrosion rate (Table 4) when the samples were tested in a simulated body fluid.

Table 4. Corrosion rate of the CoCrMo samples.

Sample	Nitrogen Content (%)	Corrosion Rate (mpy)
A	0	0.0025
B	0.35	0.0254
C	0.60	0.0329

1 mpy (mils/year) = 0.0254 mm/year [8]

The data in the Table 4 show an unexpected result. The nitrogen content that increases the mass density should reduce the corrosion rate since it reduces the porosity of the samples. Lutz et al[9] suggested that increasing of the corrosion rate of the CoCrMo samples might be associated with the lack of Cr_2O_3 compound covering the sample surfaces. Since the nitrogen addition was carried out through adding Cr_2N, it is expected that some of the Cr might be oxidized to produce Cr_2O_3 layer on the surface.

Conclusion

Melting process followed by forging and rolling might be carried out to develop CoCrMo plats which are much harder than human bones. The processes should be improved to find more homogenous samples. The CoCrMo samples are having a low corrosion rate that may be a good quality implant material. An addition of nitrogen (0,6%) to the CoCrMo compound results in increasing of its hardness around 25%. Adding nitrogen through Cr_2N is a proper way since it caused a formation of Cr_2O_3 layer which may improve the corrosion protection.

References

[1] Ismayadi. (2004). *Asuhan keperawatan degan reumatik (artitistreumatoid) padalansi.*[skripsi]. Sumatera Utara: FakultasKedokteran, Universitas Sumatera Utara.

[2] Junaidi, S .(2009). *Biomaterial BerbasisLogam.* Aplikasi Teknologi, Featured, Material Sains, Agustus 2009. 15 April 2011

[3] http://www.infometrik.com/biomaterial-berbasis-logam/

[4] Nasab, M.B., Hassan, M.R., (2010). Metallic biomaterials of knee and hip.*Trends Biomater Artif. Organs* 24:69-82).

[5] Joseph, D.B. (1995). *Biomedical enginering handbook.* ISBN 0-8493-8346-3: IEEE Press.

[6] Turkan,U., Orhan O, Eroglu, A.E. (2006). Metal ion release from nitrogen ion implanted CoCrMo orthopedic implant material. *Surface & Coatings Technology* 200:5687–5697.

[7] Prasetyo A. (2010). *Pengaruh Variasi Kandungan Silikon terhadap Korosi Paduan Kobalt (ASTM F 75) Hasil Metalurgi Serbuk dalam Larutan Artificial Blood Plasma dengan Teknik Polarisasi Potensiodinamik dan Teknik Exposure* [tesis]. FakultasTeknik, Universitas Indonesia.

[8] Weaver, J.,K. (1966). Microscopic Hardness of Bones, Journal of Bone and Joint Surgery, volume 48, issue 2. (http://jbjs.org/article.aspx?articleid=14474).

[9] Mudali, U.K., Sridar, T.M., and Baldev, R. (2003), Corrosion of Bioimplants, Sadhana, vol. 28, part 3&4.

[10] Lutz et al. (2011). Corrosion Behavior of CoCr Alloy after Nitrogen Immersion, Journal of Surface and Coatings Technology, vol.205, no.8, pp. 3043-3049. http://libra.msra.cn/Publication/49258121/corrosion-behaviour-of-medical-cocr-alloy-after-nitrogen-plasma-immersion.

[11] Pramanik, S., Agarawal, A.K., and Rai, K.N. (2005). Development of high strength hydroxyapatite for hardtissue replacemen. *Trends Biomater artif oragans* 19(1):46-51.