Available online at www.sciencedirect.com

ScienceDirect

Materials Today: ProceedingsXX (2016) XXX–XXX

materialstoday: PROCEEDINGS

www.materialstoday.com/proceedings

PMME 2016

EFFECT OF NICKEL ON MECHANICAL PROPERTIES OF ALLOY STEEL PRODUCED BY POWDER METALLURGY

Priyadarshini Tripathi[a] D.K.Behera[a*] A.K.Chaubey[b]

[a]*Department of mechanical Engineering,IGIT,Odisha,India*
[b]*Scientist,IMMT,Bhubaneswar,India*

Abstract

Nickel as we all know is used in every appliance in our everyday life. Addition of nickel has major effect in mechanical properties of alloy. The sample 2 and 3 has high hardness value which is considered suitable in applications like high corrosion resistance, shafts etc in our everyday used materials has been explored in this study through powder metallurgy techniques. The optimum weight in percentage of nickel has been taken in an alloy is 1.5 to 2 percent for sintering temperature 900-1000 ^{0}C

Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

Keywords: Powder metallurgy, Nickel, Densification, Sintering temperature

1. Introduction

Copper and copper-based alloys have at all times played an important role in development of mankind. These days, properties such as electrical and thermal conductivity, together with corrosion resistance, make copper a prominent material in numerous industrial sectors. In the case of copper-based alloys, the most significant alloying elements used are Zn, Sn, Si, Al and Ni. The first four acquire limited solubility in solid form (37, 9, 8 and 19%, at maximum), while nickel is totally soluble. Copper based alloys can increase the mechanical properties of clean copper over one or more mechanisms, such as solid solution, cold deformation, grain refinement and/or aging. Nonetheless, all these affect electrical conductivity and corrosion resistance due to micro structural changes caused by hardening [26]. The nickel can influence the mechanical properties of the alloy formed by the process of powder

* Corresponding author. Tel.: +91-9776444558; E-mail address:dkb_igit@rediffmail.com

2214-7853
Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

metallurgy. The alloy is collected of (iron, copper and carbon); nickel in the above alloy is added in different percentage along with different sintering temperature so as to find out how nickel can influence the mechanical properties, microstructure and densification of the alloy. Wilbert D. Wong-Angel et al. [1] showed us how addition of copper in an alloy can influence the mechanical properties and microstructure of the alloy .In this paper the alloy is composed of 0.6wt%C, 1.0wt%Ni, 0.3wt%Mo, 0.7wt%Mn and balance is Fe with addition of 8wt%Cu. Powder metallurgy process like milling, compacting and sintering are used to form the alloy to desired shape [21-24, 26-28]. The alloys are compacted using dual-action hydraulic press and then sintered to a temperature of 1150^0C. Various test like stress analysis, Impact test were done. SEM images shows that the alloy without copper contains high irregular pores in contrasts to alloy having copper contain has low pore concentration. The density and toughness of the alloy increases from 7.2 to 7.8 g/cm^3 and 22 to 34J

Naveen Beri et al. [2] shows that the modification of surface quality can be obtain by using powder metallurgy based CuW electrode during EDM of Inconel 718. Surface micro hardness study and XRD analysis was performed on the machined surface and then comparison was done with the conventional copper electrode. They [2] observed that micro hardness of the machined surface was improved and the XRD analysis revealed that the formation of $Fe_2W_3C_6$ phase on the machined surface has relatively increased the surface hardness.J.R.Groh et al. [3] showed us how iron, nickel and cobalt can affect the precipitation hardening of Alloy 718.Addition of either Ni or Co for half or more of the Fe in Alloy 718 eliminated the melting and the solidus temperature. The reduction of iron contain in Alloy has significantly increased the thermal exposure time which was necessary to reach the given hardness by not affecting the potential age hardenability.Bin Zou et al.[4] showed us how sintering process can affect the mechanical properties and microstructure of TiB_2-TiC+8wt% nano-Ni composite ceramic cutting tool material. Since the microstructure and mechanical properties of the composite mainly depend upon the holding time and multiple holding stages therefore the longer holding time and multiple holding stages led to coarsening of TiB2 and TiC grains, formation of pores and the brittle rupture of grains which decreased the mechanical properties. It has been accomplished that the shorter holding time of temperature 1650^0C has resulted in increasing of mechanical properties and microstructure of the composite.

M.C.Hardy et al. [5] describes the evaluating and characterizing the integrity of machined surfaces in a powder nickel alloy used in aircrafts engines. Techniques like nano-indentation and XRD method make us capable to understand the effects of machining processes on microstructure of the material. H.Y.Li et al. [6] showed the influence of microstructure on the dwell fatigue crack growth behavior of an advanced nickel-based super alloy at a temperature of 700^0C. The excellent crack growth resistant for coarse grain RR1000 can be achieved at temperature 700^0C in air by applying appropriate cooling rates from the super-solvus heat treatment temperature or by introducing a high temperature stabilization heat treatment.Yeon-wook Kim et al. [7] gave the characteristic of shape memory alloy prepared by the process of powder metallurgy. Ti50Ni50 shape memory alloy powder was prepared by inert gas atomization and then the powders are consolidated by using spark plasma sintering to produce dense bulk samples. During cooling and heating in the powder and consolidated sample one- step maternsite transformation of B2-b19 is observed. The Ti content is seen more in consolidated sample than the powder. J.Klower et al [8] give us how developed nickel alloy base on alloy 617 can be used as a component in 700°C power plants. The composition their alloy has a narrow tolerance of alloying elements with addition of boron as extra element in comparison to the parent alloy. The alloy 617B has a 25% higher creep strength at 700°C and higher ductility under creep conditions. Slow-strain rate tests was also which showed that the cracking under residual stresses can be prevented by a heat treatment at 700°C for 3 hours after welding and cold-working.

Josef Sedlak et al [9] shows how material can be produced by powder metallurgy using classical and modern additive laser technology. Vickers hardness test shows that the hardness of material produced by additive method is 60HV higher than classical method.

Vaclav Schornik et al. [10] shows on the influence of the work environment and value of cutting condition on tool wear in machining of nickel-based super alloys. The value of tool wear under different cutting conditions were seen and analyzed to a point that lowest tool wear is achieved in a cutting sped of 30m/min. M.M.Abou-krisha et al.[11] showed us the influence of Fe2+ concentration and deposition time on the corrosion resistance of the electrodeposited zinc-nickel-iron alloys. E.C.Hornus et al. [12] showed us how temperature can affect the crevice corrosion resistance of Ni-Cr –Mo based alloy mostly used as the engineered barrier of nuclear repositories.

T.Leitner et al. [13] showed the fatigue crack growth behavior of ultrafine-grained nickel produced by high pressure torsion. The sample from HPT deformed nickel showed significant different fatigue crack growth behavior than the other samples. B.A.Behrens et al. [14] tells us about the formation of powder metallurgical self cooling forging die with inner cavities. On applying sintering temperature, the foreign element can be be firmly bonded with or melted outside the base powder creating a defined cavity. The main purpose is of forming of forging die cavity by varying sintering temperature.J.Kumstel et al. [15] showed us how polishing of titanium and nickel-based alloy is done using cw-laser radiation. The polishing of titanium and nickel based alloy is done in two way that is using tool steel 1.2343 and laser polishing. So, it is concluded that the 3D parts formed out of the above material can easily polished with reduced time and achievable surface roughness.E.M. Francis et al. [16] showed us how the high temperature deformation mechanism in a polycrystalline nickel-based super alloy studied by neutron diffraction and electron microscopy. After comparing with the previous studies of same material and microstructure but tested at room temperature only very little difference is being found out. J.Lambarri et al. [17] showed how smoothing surface of nickel-based super alloys can be obtained by using laser technique. K.Wang et al. [18] statically analyzed to show the effect of iron precipitation upon nickel losses from synthetic atmospheric nickel laterite leach solution. The data shows that a ‘high temperature-low pH, and low temperature-high pH’ multi-step neutralizing strategy is best suited for removal of iron from the solutions. Neda Mazinanian et al. [19] states about the replacement of nickel and surface characteristics of fine powders of nickel metal and nickel oxide in media of relevance for inhalation and dermal contact. After the test it has been found out that the release of nickel is more from the metal powders than from the NiO powders. C.R.J. Herbert et al. [20] investigated the characteristics of white layers produced in a nickel-based super alloy from drilling operation. The result shown that in Nano indentation testing the white layer has 45% more hardness than the bulk material is seen.

Section 2 gives the result discussion of our work followed by section 3 with concluding remarks of the work.

2. Results &Discussion

The XRD pattern (λ = 1.54184 A^0) of the samples with various percentage of Ni are shown in the above figure. 2.1. Presence of two phases in the XRD pattern indicates that reaction has taken place during dry milling of the Fe-Cu-C-Ni powder for 5 hours. The peak of nickel and carbon could not be observed due to the lower percentage of Ni and C, which is below the limit of XRD system

2.1 Densification is defined as the act of becoming or making denser. Here densification is defined as sintered density by theoretical density. Theoretical density is calculated by taking the percentage weight and density of each metal powder. The formula given below is

Densification = (Sintered Density)/ (Theoretical density)

Where theoretical density (δ_d) = $100/ (m_1/\delta_1+m_2/\delta_2+m_3/\delta_3+m_4/\delta_4)$

Densifications of each sample at different sintering temperature are shown in table as given below.

Table 2.1 Densification of samples at sintering temperature 800 ^{0}C

	Sample 1	Sample 2	Sample 3	Sample 4
Serial No.	0% Ni	1.5%Ni	2%Ni	2.5%Ni
Theoretical Density	7.774	7.789	7.794	7.799
Sintered Density	4.903	5.018	5.00	4.999
Densification	64%	65%	64.15%	64.11%

Table 2.2 Densification of samples at sintering temperature 900 ^{0}C

	Sample 1	Sample 2	Sample 3	Sample 4
Serial No.	0% Ni	1.5%Ni	2%Ni	2.5%Ni
Theoretical Density	7.774	7.789	7.794	7.799
Sintered Density	5.412	6.950	6.760	6.777
Densification	70%	90%	87%	87%

Table 2.3 Densification of samples at sintering temperature 1000 ^{0}C

	Sample 1	Sample 2	Sample 3	Sample 4
Serial No.	0% Ni	1.5%Ni	2%Ni	2.5%Ni
Theoretical Density	7.774	7.789	7.794	7.799
Sintered Density	6.891	7.086	6.952	5.568
Densification	88.64	91%	90%	71%

Table 2.4 Hardness of Sample 1(contains 0%Ni)

Temperature	800 ^{0}C	900 ^{0}C	1000 ^{0}C
Hardness(HV)	70.8	160.8	170.4

Table 2.5 Hardness of Sample 2(contains 1.5%Ni)

Temperature	800 ^{0}C	900 ^{0}C	1000 ^{0}C
Hardness(HV)	87.2	228.6	230.4

Table 2.6 Hardness of Sample 3(contains 2%Ni)

Temperature	800 ^{0}C	900 ^{0}C	1000 ^{0}C
Hardness(HV)	75.3	198.6	215.4

Table 2.7 Hardness of Sample 4(contains 2.5%Ni)

Temperature	800 ^{0}C	900 ^{0}C	1000 ^{0}C
Hardness(HV)	72.5	200.8	172.7

The above results indicate that sample no 2 with 1.5 percent nickel in the alloy sintered at 900-1000 ^{0}C shows highest densification where as sample 3 is comparable within. It is known that higher the densification higher will be the resistance.

2.2 Hardness Test

The hardness test was done using Vickers hardness tester with load of 50 Kgf for a time limit of 13 sec. Several runs were taken and average hardness of each sample was calculated. The hardness of the samples is shown in the above table from 2.4 to 2.7

The below plotted graph of densification and hardness clearly shows that the densification and hardness of sample 2(containing 1.5wt%Ni) sintered at temperature 900- 1000°C is higher than the rest of the samples. But it is also seen that sample 3(containing 2.0wt%Ni) of 900-1000°C also showing almost equivalent value same as the sample 2. Further addition of nickel to the sample shows decrease in densification which ultimate leading to the low hardness value. Adding nickel above 2.5wt% is reducing the densification of the alloy as well as the hardness

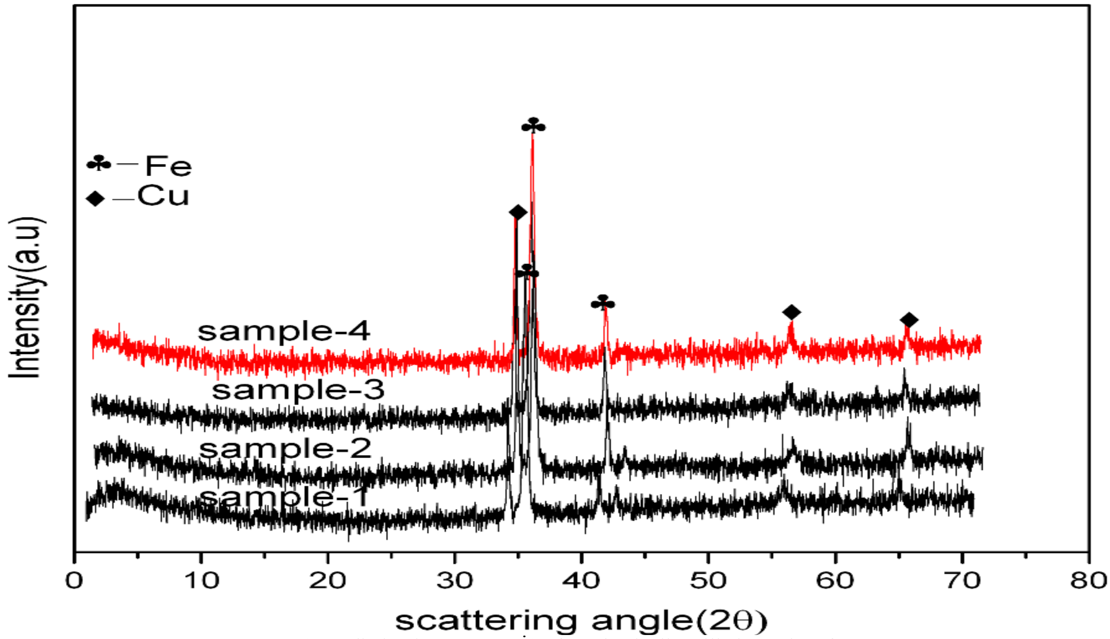
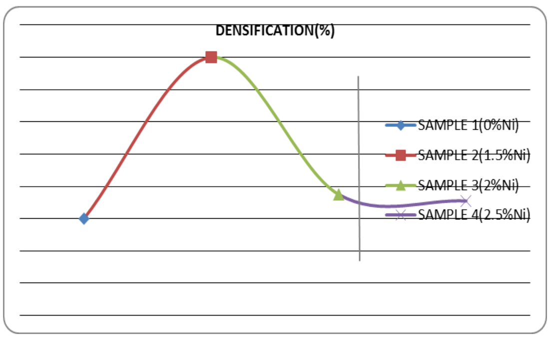


Fig 2.1 XRD pattern (Curadiation λ = 1.54184Å) of mechanically milled powder of Fe-Cu-C-Ni



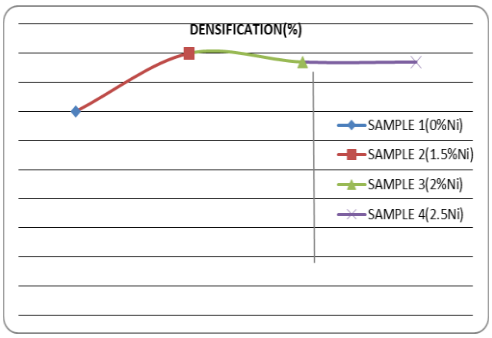


Fig. 2.2Graph of densification at 800°C

Fig.2.3 Graph of densification at 900°C

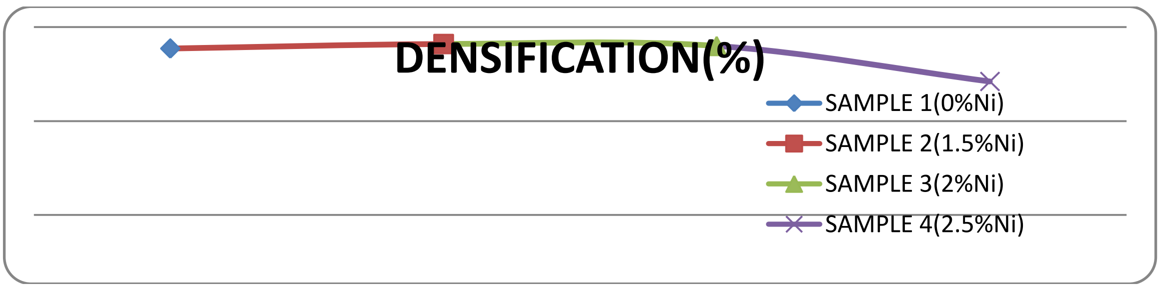


Fig.2.4 Graph of densification at 1000°C

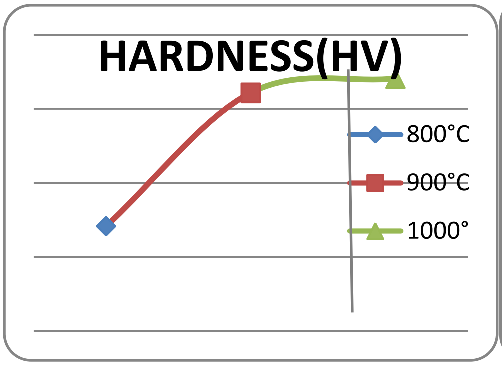


Fig 2.5 Graph of Hardness of Sample 1

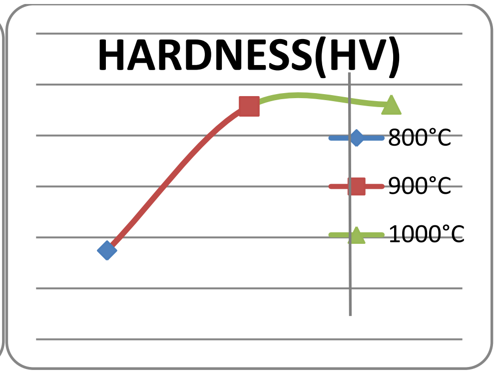


Fig 2.6 Graph of Hardness of Sample 2

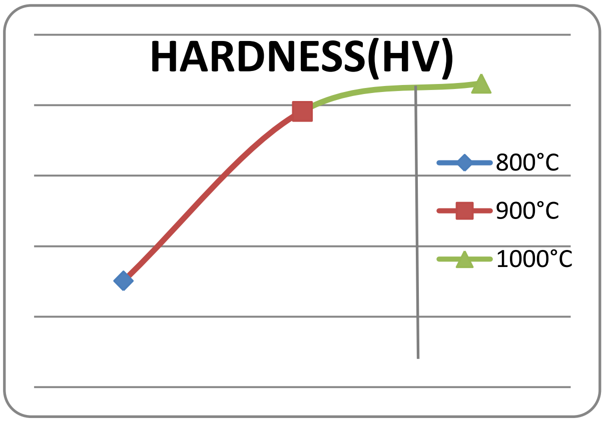


Fig 2.7 Graph of Hardness of Sample 3

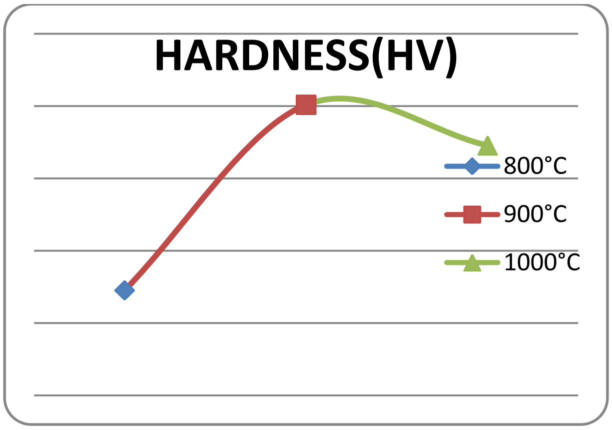


Fig 2.8 Graph of Hardness of Sample 4

3. Conclusion

The densification of sample 2(containing 1.5wt%Ni) of sintering temperature 900°C shows the best densification of 90% and hardness of 228.6 HV.The densification of sample 3(containing 2wt%Ni) of sintering temperature 900-1000°C also shows equivalent hardness to that of sample 2.Therefore the optimum wt% of Nickel to be taken in an alloy is 1.5 to 2%. For sintering temperature 900-1000°C.Nickel as we all know is used in every appliance in day to day lifetime. This work clearly shows how addition of nickel affects the mechanical properties of alloy. The sample 2 and 3 has high hardness value which is considered suitable in applications like shafts, high corrosion resistant in marine appliances etc.

Acknowledgements

The authors desire to acknowledge the help supported by department of Institute of minerals and material technology, Bhubaneswar for carrying out the experiments in their laboratory.

.

References

[1] Wilbert D. Wong-Angel et al., Effect of copper on the mechanical properties of alloys formed by powder metallurgy,Materials and Design 58(2014), page 12-18

[2] Naveen Beri et al. ,Surface quality modification using Powder Metallurgy Processed CuW Electrode during EDM of Inconel 718, Procedia material science 5(2014), page 2629-2634.

[3] J.R.Groh et al. Effects of Iron, Nickel, and Cobalt on precipaitation hardening of Alloy 718,The minerals, metals and materials society (1991), page 351-361

[4] Bin Zou et al., Effects of sintering process on mechanical properties and microstructure of TiB2-TiC+8wt% nano-Ni composite ceramic cutting tool material,Material science and engineering a 540(2012), page 235-244.

[5] M.C.Hardy et al. ,Characterising the integrity of machined surfaces in a Powder Nickel Alloy used in Aircraft engines,ProcediaCIRP13(2014), page 411-416.

[6] H.Y.Li et al. ,Effects of microstructure on high temperature dwell fatique crack growth in a coarse grain PM nickel based superalloy, ActaMaterialia 90(2015). page 355-369.

[7]Yeon-wook Kim et al. ,Shape memory characteristic of powder metallurgy processed Ti50Ni50 alloy, Physics Procedia 10(2010), page 17-21.

[8] J.Klower et al.” Development of Nickel Alloys Based on Alloy 617 for Components in 700oC Power Plants”. Procedia Engineering 55(2013), page 226-231

[9] Josef Sedlak et al., Study of materials Produced by Powder Metallurgy Using Classical and Mordern Additive Laser Technology.,Procedia Engineering 100(2015), page 1232-1241.

[10]Vaclav Schornik et al., The influence of working environment and cutting conditions onmilling Nickel=Based Super Alloys with carbide tools,procedia engineering (2015), page 1262-1269.

[11]M.M. Abou-Krisha et al.,The influence of Fe2+ concentration and deposition time on the corrosion resistance of the electrodeposited zinc-nickel-iron alloys,Arabian Journal Of Chemistry (2012), page 1-8.

[12]E.C.Hornus et al. ,Effect of temperature on the crevice corrosion resistance of Ni-Cr-Mo alloys as engineered barriers of nuclear repositories.,Procedia Materials Science 1(2012), page 251-258.

[13]T.Leitner et al.,Fatigue crack growth behavior of ultrafine – grain nickel produced by high pressure torsion.,Procdia materials science 3(2014), page 1044-1049.

[14]B.-A.Behrens et al. ,Development of a powder metallurgically self cooling forging die with inner cavities.,Procedia Technology 15(2014), page 456-464.

[15] J. Kumstel et al. ,Polishing titanium- and nickel-based alloys using cw-laser radiation.,Physics Procedia 41(2013), page 362-371.

[16] E.M.Francis et al., High –temperature deformation mechanism in a polycrystalline nickel-base superalloy studied by neutron diffraction and electron microscopy.,ActaMaterialia 74(2014), page 18-29.

[17] J.Lambarri et al. ,Laser surface smoothing of nickel- based superalloys. ,Physics Procedia 41 (2013), page 255-265.

[18] K.Wang et al.,The effect of iron precipitation upon nickel losses from synthetic atmospheric nickel laterite leach solutions: Statistical analysis and modeling, Hydrometallurgy 109(2011), page 140-152.

[19] Neda Mazinanian et al ,Nickel release and surface characteristic of fine powders of nickel metal and nickel oxide in media of relevance for inhalation and dermal contact., Regulatory Toxicology and Pharmacology 65(2013), page 135-146 .

[20] Herbert, C.R.J, Axinte, D.A., Hardy, M.C., and Brown, P.D.,,Investigation into the characteristics of white layers produced in a nickel-based superalloy from drilling operations, Procedia Engineering, 19(2011) pp. 138.

[21] G.S.Upadhaya ,Powder Metallurgy Technology., Cambridge International Science Publishing(2002)

[22] P.C. Angelo et.al. ,Powder metallurgy: Science,Technology and Applications.,PHI Learning Private Limited (2008).

[23] www.google.com

[24] R.M. German, Powder Metallurgy of Iron and Steel, John Willey and Sons, USA, 1998.

[25] R. Yilmaz, M.R. Ekici, Microstructural and hardness characterisation of sintered low alloyed steel,Journal of of Achievements in Materials and Manufacturing Engineering, VOLUME 31,ISSUE 1,November,2008

[26] Paula Rojas, Rosa Vera, Carola Martínez, María Villarroel,,Effect of the Powder Metallurgy Manufacture Process on the Electrochemical Behaviour of Copper, Nickel and Copper-Nickel Alloys in Hydrochloric Acid , Int. J. Electrochem. Sci., 11 (2016) 4701 – 4711, doi: 10.20964/2016.06.40.

[27] Nickel in powder metallurgy steels, A Nickel development institute,Refernce book , series N0 11OO6.

[28] W. Brian James, Hoeganaes Corporation, retired,’’ Powder Metallurgy Methods and Applications’’, ASM Handbook, Volume 7, Powder Metallurgy ,P. Samal and J. Newkirk, editors