Study Of The Nickel Base Alloy For High Performance Application – A Review

L Mohanta[1], R.Sathyanarayan[2], K. Venkateswaran[3*]

[1.]Research Scholar, Department of Mechanical Engineering, B.S. Abdur Rahman University, Chennai-48
[2.]Research Scholar, B.S. Abdur Rahman University, Chennai-48
[3.]professor, Department of Mechanical Engineering, B.S. Abdur Rahman University, Chennai-48
lachhaman2002@yahoo.co.in

Abstract: Nickel-base alloy is an attractive alloy in industries for its high corrosion resistance and high strength. However, its adhesive wear resistance is not so high. Therefore, surface treatment is necessary if the alloy is used as friction materials. In nickel-base alloy micro-strain is stronger. Addition of alloying elements such as Ni has provided a thrust towards high performance in PM materials. An increase in hardness and strength occurs with increasing sintering time, which is more prominent in Ni containing compositions. On the other hand impact strength is improved by addition of Ni. A nickel-base alloy is Ni76Cr19AlTi alloy with ultra-high strength. Heavy-duty engine valve can be prepared with this alloy for its high strength even at high temperatures. Ni-rich areas are detrimental to mechanical properties such as tensile and fatigue strength. The main strengths of the nickel-based alloys are being heat-resistant, retaining their high mechanical and chemical properties at high temperatures, and having high melting temperatures, high corrosion resistance, as well as resistance to thermal fatigue, thermal shock, creep, and erosion.
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I. Introduction

Many nickel alloys are age hardenable,meaning that the hardness of the alloy increases dramatically upon heat treatment. As second phase particles form, the alloy becomes stronger and more abrasive, thus more difficult to machine. Therefore, it's preferable to perform machining in the softer state. Nickel has relatively high electrical and thermal conductivity as well as a high Curie temperature and good magnetostrictive properties. To enhance the alloy's wear-resistance, Stellite 6 powder is decided to be coated on this alloy by plasma arc This leads to use in many electrical and electronic applications. Minor variations of residual elements allow use in other specific applications, such as automotive spark plugs. Nickel-molybdenum alloys are known for their excellent resistance to nonoxidizing (reducing) media, such as hydrochloric and sulfuric acids. The original B alloy (N10001) was invented in the 1920s, and it had a nominal composition of Ni-28Mo-5Fe-0.3 V, with a maximum carbon content of 0.05 wt%. Nickel alloys are typically available wrought, forged, cast and in sintered (powder metallurgy) forms and often used in the hot sections of mission critical components in jet engines or gas turbine engines. For example, 50% weight of a jet engine is Inconel-718 (IN-718), a Ni–Fe–Cr alloy. This alloy exhibits very high strength and high temperature resistance, but it is difficult to machine this alloy due to these properties, causing low tool life for the tools to machine it . On the other hand, Inconel 100 (IN-100), a Ni–Co–Cr superalloy, is used mainly for parts operating at intermediate temperature regimes, for components such as disks, spacers and seals. Cast nickel-based alloys are also used for turbine and compression blades in hot sections of jet engines. Due to high toughness and work hardening behavior of these alloys, machining is generally extremely difficult.

II. Literature Survey

V. Umasankar1, S. Karthikeyan2*, M. Anthony Xavior [1] et al in July 2013 presented Metal matrix composites are widely used in aerospace and automotive industries owing to their outstanding specific stiffness, modulus and tensile strength coupled with abrasion resistance. Pazman and his co-workers investigated that the formation intermetallic phases between Nickel and Al-SiC composites and the sintering temperature of 580ºC favored the diffusion of Nickel into matrix. Burak Dikici1 et.al., [2] have studied the influence of Nickel on the corrosion resistance of Al-SiC composite prepared by liquid processing. Nickel coated composites have not shown significant improvement in corrosion resistance of the composite in neutral medium. According to Liang-Guang Chen and Su-Jien Lin [3], the Nickel coated SiC exhibited low interfacial strength values for Fiber reinforced 7075 Aluminium composites. L.B. Li et.al. 4,studied that electroless nickel coated Silicon carbide/Aluminium composites in alkaline medium increased the microhardness and adhesion .They have not claimed corrosion resistance in alkaline bath. However electroless coated reinforcement enhanced the adhesion and diffusibility between heavier particles, there is lack of information available on the improvement of interfacial strength and mcirohardness by coating process. Due to these facts an attempt has been made to obtain metalized reinforced composites that can be used for heavy machineries as an alternate to monolithic alloys. As far as we know no concrete investigation has been made for obtaining electroless coated Aluminium/SiC composites with superior interfacial strength and microhardness values. Due to the poor bath stability and also lack of adhesion of Nickel on composites, a special attention is to be paid to enhance the mechanical strength of composites that can be used in machineries. At present the powder processed aluminium composites are not much used on account of its inferior interface strength especially with higher percentage of reinforcement. It is well established that higher is the percentage of reinforcement lesser is the interparticle distance which resulted in inadequate sintering .Also poor bond strength promotes void propagation and increased defect density at elevated sintering temperatures. Among nickel-based alloys, IN-718 is the most widely used alloy and because of that it has been studied extensively for the analysis of surface integrity.

Ping ZHANG , Lin MA , Zhijie LIANG and Junjun ZHAO[4] et al in august 2011eshtablished that, nickel base alloys are selected to be electrode materials for coatings deposition. Ni398 and Ni818 alloy are both nickel base alloys with high hardness and wear resistance, and most frequently used on metal surfaces to improve surface properties. However, different chemical composition results in different properties of coatings. In this paper, two kinds of nickel base alloy coatings of Ni398 and Ni818 were achieved by ESD. Some properties of coatings were tested; the chemical compositions and metallurgical structures were analyzed. The microhardness distributions show that average microhardness of Ni818 alloy coating is a little higher than that of Ni398 alloy coating and both of them are much higher than that of the 1045 steel substrate (180{190 HV). Both coatings can improve the surface hard-ness obviously. However, the microhardness at coating margin part is lower. The reason is that the material at the surface of coating is not dense enough without the pres-sure from the next ESD step. It is shown as well that there is no dramatic change of hardness in the substrate. It means that the heat-affected zone caused by ESD is not detectible.

Meenu Srivastava*, A Srinivasan, V K William Grips[7] et al in 2011 Corrosion and wear destroy national wealth in multibillion dollar range annually. modern high performance components are subjected to extreme temperatures and mechanical stress, and thus require surface protection against high temperature and mechanical wear and tear. A highly versatile and low cost technique must be selected to apply protective coatings, one such technique is electroplating Composite electroplating involves the co-deposition of insoluble metallic or non-metallic compounds in a metal or alloy matrix. Such composite coating features the properties of both the matrix and the dispersed phase. The coatings are called as metal matrix composites (MMC) when the matrix involved is a metal. Composite coatings comprising of various dispersed phases like SiC, Si^3, N^4, Al_2O_3, CeO_2,TiO_2,YSZ etc have been developed for diverse applications. The composite system considered in the present study comprises of Ni -Co alloy as the matrix. The benefit of choosing Ni-Co alloy as matrix lies in the fact that alloying of Ni with Co strengthens it by forming a solid solution which helps to improve wear, corrosion resistance and also improves the high temperature properties. The dispersed phase chosen is zirconia ZrO_2, as it is known to possess excellent properties such as The effect of incorporation of ZrO_2 in Ni matrix has been extensively reported. Reddy et al have reinforced tetragonal ZrO_2 in Ni matrix by pulsed electro-deposition. A 16% increase in microhardness of the com-posite has been reported. The composite on annealing (50-200°C) showed an increase in the microhardness fol-lowed by a substantial decrease upto 300°C. Effect of heat treatment on the incorporation of ZrO_2 in Ni-Co matrix has not been studied much. Zhang et al have reported brush plating of Ni-Co – ZrO_2 composite coating to repair the wear surface of the die casting dies of H13.The coating improved the surface hardness, wear resistance and oxygen resistance of dies. The present study is aimed at incorporating ZrO_2 nano-particles in Ni-Co alloy matrices by electrodeposition method, and studying its influence on the thermal, me-chanical and chemical properties.

Durul Ulutan, Tugrul Ozel[2] et al November 2010 described nickel alloys (Ni–Co–Cr, Ni–Fe–Cr or Ni–Co–Fe) have the ability to retain most of their strength even after long exposures to extremely high temperatures and are the only material of choice for turbine sections of the jet engines. Nickel alloys are typically available wrought, forged, cast and in sintered (powder metallurgy) forms and often used in the hot sections of mission critical components in jet engines or gas turbine engines. For example, 50% weight of a jet engine is Inconel-718 (IN-718), a Ni–Fe–Cr alloy. This alloy exhibits very high strength and high temperature resistance, but it is difficult to machine this alloy due to these properties, causing low tool life for the tools to machine it . On the other hand, Inconel 100 (IN-100), a Ni–Co–Cr superalloy, is used mainly for parts operating at intermediate temperature regimes, for components such as disks, spacers and seals. Cast nickel-based alloys are also used for turbine and compression blades in hot sections of jet engines. Due to high toughness and work hardening behavior of these alloys, machining is generally extremely difficult. During the machining operations, the workpiece material is exposed to thermal, mechanical, and chemical energy that can lead to strain aging and recrystallization of the material. Due to the strain aging process, the material might become harder but less ductile, and recrystallization might cause the material to become less hard but more ductile. These thermal (high temperature and rapid quenching) and mechanical (high stress and strain) effects are the main reasons for the microstructural alterations in the material, as well as phase transformations and plastic deformations.

BASIM A. KHIDHIR*, BASHIR MOHAMED [3] in 2010 presented that, Due to their high temperature strength and high corrosion resistance, nickel alloys are used for engines for commercial and military aircraft and space engines. It is considered by machinists one of the most challenging areas. This is due to a complex of material properties , namely low thermal conductivity leading to increased temperatures at the tool point/rake face; work-hardening tendency during machining; high thermal affinity to tool materials resulting in welding/adhesion of workpiece material to the cutting edge; presence of hard abrasive particles (e.g. carbides, oxides) resulting in intense tool wear . The heat generated during a cutting operation is the summation of plastic deformation involved in chip formation and the friction between tool and workpiece and between the tool and the chip, metallurgical changes, that have improved superalloys making the metal stronger, tougher or more resistant to oxidation or corrosion, have also made these metals more difficult to machine. For the nickelbased superalloys, high temperature characteristics translate directly to machining challenges. The combination of high cutting force and high temperature when machining these materials leads to edge breakdown of the tool through chipping or deformation. In addition, for the majority of these metals, work hardening takes place rapidly. A hardened surface created during machining can result in depthof-cut-line notching of the tool and may also compromise the fatigue strength and geometric accuracy of the part. Many nickel alloys are age hardenable,meaning that the hardness of the alloy increases dramatically upon heat treatment. As second phase particles form, the alloy becomes stronger and more abrasive, thus more difficult to machine. Therefore, it's preferable to perform machining in the softer state. Typically, it is best to machine parts to near finish dimensions in the solution-treated condition. After age hardening, only a final finishing operation is performed, providing the desired surface finish while minimizing the risk of distortion caused by heat treatment. The geometry of the tool plays a big part in controlling heat. The geometry of the cutting tool must allow for chip removal in order to take the heat out with the chip. Tool geometry should allow for smoother cutting and less vibration and better chip evacuation. In addition, higher rpm and feed rates with shallow depth-of-cut are typically required to maintain chip flow and heat. This study intends to investigate the effect of tool holder geometry on cutting performance in terms of tool life and tool wear when machining of nickel-based alloys - 276. Increasing the productivity and the quality of the machined parts are the main challenges of manufacturing industry. Modern cutting tools allow cutting at high speeds, thus increasing the volume of chips removed per unit time and this objective requires better management of the machining system corresponding to cutting tool-machine tool-workpiece combination to go towards more rapid metal removal rate.

Pavel NOVÁK, David ŠOTKA, Michal NOVÁK, Alena MICHALCOVÁ, Jan ŠERÁK, Dalibor VOJTĚCH[6] in 2010 presented that Nickel aluminide (Ni_3Al) is a structural component of common nickel-base high temperature alloys. In special cases, nickel aluminides (Ni3Al, NiAl) can be applied as bulk structural materials. High aluminium content reduces the density (5.86 g.cm-3 for NiAl) and protects against high-temperature oxidation by the formation of Al_2O_3 and $NiAl_2O_4$ protective layers during the oxidation. In many applications, where common metallic materials fail, metal-matrix composites can be applied. Addition of the reinforcement can increase elastic modulus, strength, hardness or wear resistance. In this work, production of NiAl-matrix composites by reactive sintering was tested. Various ceramic reinforcement types (oxide, silicide, carbides) were tested. The best chemical compatibility and the highest hardness and wear resistance increase were achieved by Al_2O_3 fibres. Electroless nickel plating pretreatment of Al_2O_3 fibres improves both the distribution of fibres and the hardness of the composite. However, it strongly degrades the wear resistance, probably due to the phosphorus content. Similar effect can be obtained when particles or fibres of suitable reinforcement are added to intermetallic phase,thus producing intermetallic-matrix composites. In metal-matrix composites, the ceramic particles (SiC,Al_2O_3) are commonly applied as reinforcement. These particles can be possibly applied to reinforce bulk intermetallics as well. However, high melting points of intermetallics and high reactivity of the melts can cause dissolution or even melting of the reinforcement particles when conventional melt metallurgy is used.Therefore, powder metallurgy processes are developed for production of these materials.

Paul Crook[5] et al in 2005 presented that Commercially pure wrought nickel has good corrosion resistance and mechanical properties. A combination of good ductility and malleability, low hardness, a low work-hardening rate, and good weldability make the metal highly fabricable. Good low-temperature ductility and impact strength make it a useful material at cryogenic temperatures. Nickel is also noted for very good resistance to aqueous corrosion in certain environments. The most common product is nickel 200 (N02200). It contains 99.6% Ni with small amounts of iron, copper, manganese, silicon, and carbon. It has found a wide variety of applications involving caustic soda, water, nonoxidizing acids, alkaline salt solutions, chlorine, hydrogen chloride, fluorine, and molten salts molten salts. Nickel has relatively high electrical and thermal conductivity as well as a high Curie temperature and good magnetostrictive properties. This leads to use in many electrical and electronic applications. Minor variations of residual elements allow use in other specific applications, such as automotive spark plugs Nickel: This element is an ideal base because it not only possesses moderate corrosion resistance by itself, but it also can be alloyed with significant quantities of copper, molybdenum, chromium, iron, and tungsten, while retaining its ductile fcc structure. Some inherent properties imparted by nickel to its alloys are resistance to stress-corrosion cracking, resistance to caustic compounds, and resistance to hydrofluoric acid.The nickel alloys designed to resist aqueous corrosion can be categorized according to their major alloying elements. In addition to commercially pure nickel, which possesses high resistance to caustic soda and caustic potash, there are six important nickel alloy families: Ni-Cu, Ni-Mo, Ni-Cr, Ni-Cr-Mo, Ni-Cr-Fe, and Ni-Fe-Cr. Some of these families are strongly associated with certain trademarks. The nickelcopper materials, which are commonly used in seawater applications and in hydrofluoric acid,for example, are known as the Monel alloys. Likewise, the nickel-molybdenum materials are known as the Hastelloy B-type alloys, and the versatile Ni-Cr-Mo materials are known as the Hastelloy C-type alloys. The Inconel trademark is used for several Ni-Cr and Ni-Cr-Fe alloys, and the Incoloy name is associated with Ni-Fe-Cr materials. While these trademarks are still used by the companies that own them, Nickel-molybdenum alloys are known for their excellent resistance to nonoxidizing (reducing) media, such as hydrochloric and sulfuric acids. The original B alloy (N10001) was invented in the 1920s, and it had a nominal composition of Ni-28Mo-5Fe-0.3 V, with a maximum carbon content of 0.05 wt% and a maximum silicon content of 1 wt%. Nickel alloys are used extensively in the hot sections of land-based gas turbines for power generation. As compared with aircraft gas turbines, those based on land are more robust, due to fewer weight constraints. However, the material requirements are generally the same for both types of turbine. Materials commonly used in gas turbine applications include the solid-solution strengthened 230 (N06230), 617 (N06617), and 625 LCF (N06626) alloys and the age-hardenable Nimonic 80A (N07080), 263 (N07263), 706 (N09706), 718 (N07718), and X-750 (N07750) alloys.

III. Conclusion

Therefore, we have concluded from the reviewed article related to the nickel base alloy that addition of nickel increases the impact strength and hardness. Nickel is added to its alloy because of its vital properties such as resistance to stress-corrosion cracking, resistance to caustic compounds, and resistance to hydrofluoric acid. Due to their high temperature strength and high corrosion resistance, nickel alloys are used for engines for commercial and military aircraft and space engines. Since Nickel alloys have very high wear and corrosion resistance they are mostly used in jet engines and gas turbines.

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