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A Review on Appropriateness of Cobalt based Alloys and Super Alloys for Machining

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***Abstract*—Difficult to machine materials are gaining focus. Cobalt based super alloys depends on carbides formed in the Cobalt matrix and at grain boundaries for their strength and the distribution, size and shape of carbides depends on processing condition. Co-based alloys and super alloys are as categorized into difficult to machine material due to its properties such as toughness, strength, wear resistance and low thermal conductivity. This properties make delay to machinability resulting in tool wear, high temperature at tool-chip interface etc. So the tool material for super alloys should be high speed steel tools, solid carbide inserts clamped in chucks or brazed carbide tools and any nonferrous cast alloys that is it should be harder than the alloy to sustain its strength. Generally in many research studies the cutting depth, feed and cutting speed is lowered in case of super alloys for high machinability and ease of machining by lowering heat due to use of sharp cutting edges and minimization of tool-chip contact area. So in short we can say that machining of super alloys is very thought-provoking. In case of cobalt alloys appropriate coolant strategies should be made according to the need of machining. There are very small number of researches available on coolant strategies so there is a scope of research work. Thus this paper gives the review about the machinability of cobalt based alloys and super alloys and future researches are also discussed adequately.**

Keywords—Cobalt based alloys; tool wear and Coolant strategies

CONTENTS

1. INTRODUCTION

In earlier twentieth century, cobalt based alloys are discovered by Elwood Haynes as “Stellites” or cobalt chromium alloy. Cobalt-chromium alloy possesses high strength and stainless nature, tungsten and molybdenum as powerful agents [1, 2]. Cobalt based alloys are derived from cobalt-chromium-tungsten and cobalt-chromium-molybdenum possessing crystallographic properties. Cobalt alloys are considered as difficult for machining, as their strength and hardness is maintained at high temperatures [3, 4, 5]. Cobalt alloys, as a group may be designated as corrosion resistant, wear resistant, and heat resistant. Cobalt base alloys requires high speed machining. High speed machining allows to cut metals at higher speed resulting in high efficiency, high accuracy, best quality of work piece and reduced production time [6].

Applications of cobalt based alloys are shown in the Fig 1. [7]. Mainly, CoCr alloy has many applications in many fields such as aero-engine, biomedical, gas turbines etc. Researchers are focusing on improvement of properties of these alloys since two decades [8]. From the family of cobalt alloys, cobalt chromium molybdenum is an improved material specially used for biomedical purposes [1, 9]. Research on such topics are limited as compared to nickel, titanium and steel. The method used for machining for CoCr alloy are electric discharge machining (EDM), laser beam machining (LBM), milling, turning, grinding etc.

There are number of cobalt based super alloys among which FSX414 and Stellite 6 are of interest for researchers [10]. Super alloys are used above the temperature of 500oC at 70% of their melting point which may be around 1000oC and Ni or Co up to 40-50% in super alloys [6]. Cobalt based super alloys are extensively used in the applications of wear resistance, abrasion resistance, impact resistance, corrosion resistance and heat resistance [8, 10]. This machining process are widely used to manufacture geometrically complex and precision parts for aerospace, electronics and automotive industries [12]. Various industrial sectors such as chemical processing, medical application, pharmaceuticals, pulp and paper processing, gas processing and oil processing etc. [13]. Strengthening of solid solution of super alloys are provided by tantalum, columbium, chromium and molybdenum [14]. FSX414 is used specially for making of gas turbine blades due to good hot corrosion resistance. Disadvantage of FSX414 is its manufacturing cost is very high and poorer machinability [10].

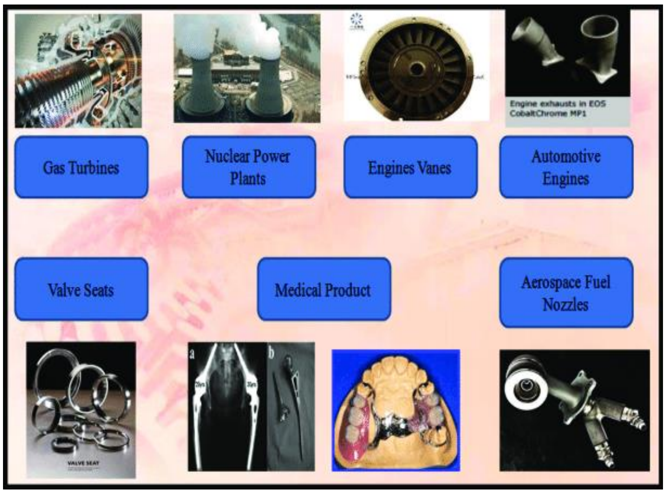

Fig 1. Applications of cobalt based alloys.

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2. COOLANT STRATEGIES FOR MACHINING COBALT ALLOYS

Researchers studied the effects of coolants on cutting forces, cutting temperature, and wear at tool-chip interface [1, 15]. Many researchers used dry machining as compared to minimum quantity lubrication, air cooling, flood cooling and cryogenics on cobalt based alloys as shown in fig 2. In engineering or medical applications, surface integrity is very important aspect. Karpuschewski et al. [16] stated surface integrity using ceramic tool by the effect of different cooling systems on cobalt based alloys.

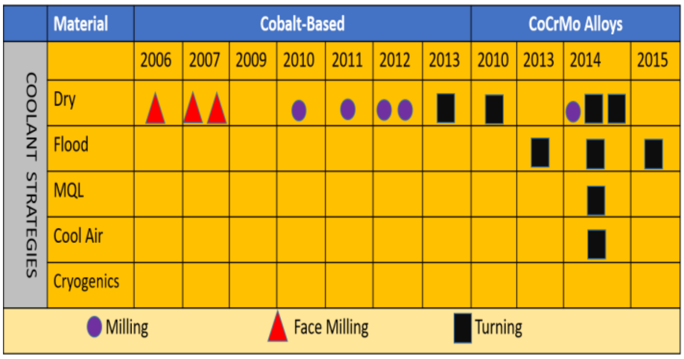

Fig 2. Coolant strategies for Co-based alloys

3. TOOL MATERIAL FOR MACHINING OF COBALT ALLOYS AND SUPER ALLOYS

In cutting processes tool material plays an important role, as formation of high thermal and mechanical stresses at the cutting edge of the tool during machining of cobalt based alloys is a major concern. Hot hardness, high toughness, thermal stability are some of the features should possessed by tool [17]. The previously used tool materials for machining of cobalt based alloys are TiCN/TiN, Al_2O_3/ TiCN/TiN and CVD coated tool [16, 18]. Tool which are used in turning or any other operation for super alloys are high speed steel tools, solid carbide inserts clamped in chucks or brazed carbide tools and any nonferrous cast alloys. Brazed carbide tool and high speed steel tools are available in variety of sizes and shapes [19]. Tool should not be allowed to wear beyond 0.015 inch. Greater wear lands cause cutting temperature in the cutting zone and produce excessive residual stresses in the work piece. When the harder cemented carbide tools are resulted in best machinability of harder alloys [19].

4. DIFFICULTIES IN MACHINING SUPERALLOYS

Short tool lives due to work hardening and attrition properties and heat generation and plastic deformation due to severe surface of machined work piece. The study of cutting forces in order to achieve adequate tool lives and surface integrity which are the criterions of selecting the reasonable machining conditions and parameters, is crucial [10]. Super alloys have poor machinability and cost is also high as of FSX414 and Stellite 6. Nowadays there is vast improvements in the field of cutting tools but machinability is not improved much as compared to cutting tools. Super alloys are machined by minimizing cutting depth, minimizing tool-chip interface, providing sharp cutting edge. In order to machine super alloys another method is to minimize the feed rate, cutting speed and minimizing heat extraction [20]. Many researchers studied the surface milling of super alloys [21, 22, 23]. These studies shows that tool life is parameter which is directly affected by cutting speed. Due to increase in cutting speed cutting forces also increases. If cutting forces are bigger then depth of cut and feed rate is also bigger. Face milling of 4140 preheated steel using coated and uncoated inserts is investigated by GU et al. [24]. Face milling of AISI 1045 steels is investigated by using four different types of cermet inserts [25]. Bhatia et al. [26] stated that, at high cutting speeds thermal cracking is the main cause of tool failure. Foot forming is the phenomenon, the cause of chipping of carbide inserts used in machining processes [27]. Aykut et al. [10] studied symmetric face milling of stellite 6 using TiN/TiCN/TiAlC PVD coated and uncoated tool hard metal inserts, chip morphology and tool wear was compared. One of the component of cutting acting in z-direction, is the highest for symmetric face milling of cutting forces. Reasoning done is that Stellite 6 has high yield strength.

5. CONCLUSION

This article concludes that the cobalt based alloys and super alloys are gaining attractiveness in engineering as well as medical applications due to their excellent properties discussed earlier. Many challenges are faced by the machining processes of Co-based alloys and super alloys due to their toughness and other strengths which makes them appropriate for aerospace and other industrial applications. Tool materials used for super alloys are generally harder in all aspects. There are many difficulties in machining of super alloys which are discussed in this paper. Coolant strategies used in previous researches were not successful. And there are very small numbers of experimentation research work done till date. Hence there are more research studies yet to be conducted, for another cooling systems available, as we had seen in fig 2 research studies to only dry machining for cobalt alloys.

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