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Machinability of Cobalt-based and Cobalt Chromium Molybdenum Alloys - A Review

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Abstract

Cobalt chrome molybdenum alloy is considered as one of the advanced materials which is widely gaining popularity in various engineering and medical applications. However, it is categorized as difficult to machine material due to its unique combination of properties which include high strength, toughness, wear resistance and low thermal conductivity. These properties tend to hinder the machinability of this alloy which results in rapid tool wear and shorter tool life. This paper presents a general review of the materials' characteristics and properties together with their machinability assessment under various machining conditions. The trend of machining and future researches on cobalt-based and cobalt chromium molybdenum alloys are also discussed adequately.

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Keywords: Cobalt-based alloys; Cobalt Chromium Molybdenum alloys; Cobalt Chromium alloys; Cutting Force; Tool Wear; Tool Life.

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1. Introduction

Cobalt chromium alloy is acknowledged as an attractive material in the application of many engineering fields such as aero-engine, nuclear, biomedical and gas turbine [1-2]. It is mainly attributed to its excellent characteristics such as corrosion resistance, wear resistance, high creep resistance, heat resistance and good biocompatibility [3-6]. In biomedical application, cobalt chromium is widely consumed in the manufacture of orthopedic implants[7], especially for implants of heavy-loaded joints, such as knee and hip due to its excellent wear and corrosion resistance [8-14]. Figure 1 shows the various applications of cobalt based alloys in various engineering and medical products. The presence of molybdenum in the composition of cobalt alloys reduces the grain size thus enhances the strengthening of solid solution and subsequently improves the mechanical properties of these alloys [15]. Besides, chromium (Cr) particles will form as a protective oxide layer on the surface to provide better corrosion resistance in the body environment [16]. In machining aspect, since these alloys maintain their strength and hardness at elevated temperatures, hence machining remains difficult to perform. Low thermal conductivity, high strain hardening, high hardness at elevated temperature and high wear resistance are the reasons for the poor machinability rating of cobalt chromium molybdenum alloys. This paper discusses on the past researches in the machining of cobalt chromium molybdenum alloys.

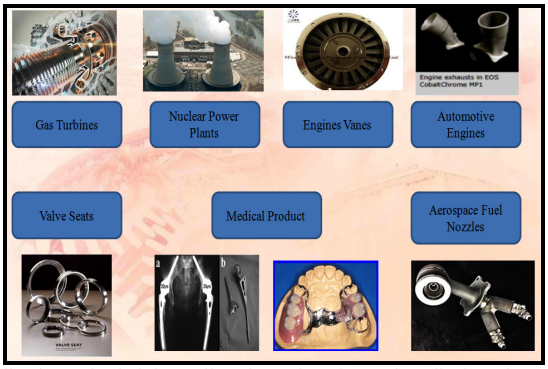

Figure 1: Applications of cobalt base alloys in engineering and medical products [8], [17], [18]

2. Classification of Cobalt Chromium Molybdenum alloys

Cobalt-based alloys were first introduced by E. Hayes as cobalt chromium or “Stellites” at the beginning of the twentieth century. The primary structures of cobalt base alloys depend on the carbide form in the Co matrix and the grain boundaries to increase the mechanical strength. The comparison of mechanicals properties between cobalt chromium molybdenum alloys and titanium are showed in Table 1. Cobalt chromium molybdenum alloys are normally manufactured by casting process (Co-Cr-Mo alloy (F75)[19], wrought and forged process (Co-Cr-W-Ni alloy (F90), Co-Ni-Cr-Mo alloy (F562), Co-Ni-Cr-Mo-W-Fe alloy (F563) [20] and powder metallurgy technique [11]. As a result, the components that are produced from casting processes exhibit better creep strength and toughness meanwhile components that are produced from wrought and forged process have higher strength, and enhanced fatigue and fracture resistance. Moreover, powder metallurgy technique is adopted when producing complicated and near-net-shaped products. The cast-able CoCrMo alloy has been widely used for many decades in dentistry field and recently, it is also used in making artificial joints. The wrought CoNiCrMo alloy is relatively new, now utilized in the fabrication of stems of prostheses for heavy-loaded joints such as knee and hip[21]. According to American Standards for Testing and Materials (ASTM), there are four types of CoCr alloys which are recommended for surgical implant applications, they are: (1) cast CoCrMo alloy (F75), (2) wrought CoCrWNi alloy (F90), (3) wrought CoNiCrMo alloy (F562), and (4) wrought CoNiCrMoWFe alloy (F563) [15], [20] .