ABSTRACT

In this study, a series of implant material containing molybdenum of different weight percentages were fabricated via high temperature vertical vacuum casting induction furnace and examined their physical, mechanical and wear properties. The mechanical properties were tested by the micro-hardness tester and the compression testing machine, while the wear performance was analyzed through a pin-on-disc tribometer under different operating conditions at room temperature. Density, hardness, compressive strength and sliding wear were considered as criterions for this study. The proportions of alternatives consist of Co-30Cr as a base material and molybdenum as an alloying element which was varied from 0 to 4wt.%. Due to the conflict between the properties obtained, the Grey relational analysis method (GRA) was applied to choose the best material among the set of alternatives. From the results obtained, it was found that Co-30Cr implant material containing 4wt.% molybdenum provides the best combination of the properties for a given application (i.e. hip femoral head).
INTRODUCTION

Nowadays, the real challenges faced by a researcher in the field of biomaterial material are the selection of apposite constituents with appropriate weight percentage and design of formulation for optimized physical, mechanical and wear properties. Metallic implants are the leading biomaterials used for hip joint replacement and are becoming progressively significant. The metallic implants generally used for orthopaedic applications include stainless steel, cobalt-chromium alloys, and Titanium and Titanium alloys. These metallic materials have numerous properties such as high strength, high fracture toughness, hardness, corrosion resistance and biocompatibility, which make them excellent choice for total joint replacement (Aherwar, Singh & Patnaik, 2016). Currently, cobalt-based alloys are among the safest biomaterials for hip implants, because of their excellent corrosion properties and mechanical strength (Granchi et al., 1999). The main attribute of cobalt-based alloys are their corrosion resistance in chloride environments, which is due to the additions of alloying elements and the formation of the chromium oxide Cr2O3 passive layer (Yildiz, Chang & Goodman, 1998). Usually, Co-based alloys comprise of a cobalt-rich solid-solution matrix including carbides (e.g. Cr7C3, and M23C6) within the grains and at grain boundaries, where tungsten (W), chromium (Cr), silicon (Si), tantalum (Ta), zirconium (Zr), nickel (Ni), and cobalt (Co), may present in a single carbide particle (Budzynski, Youssef & Sielanko, 2006; Ramsden et al., 2007). Addition of molybdenum content in the modified cobalt-chromium alloy may provide further strength to the matrix (Kauser, 2007; Zhang, Xiao & Zhou, 2012; Abedini, Ghasemi, & Ahmadabadi, 2012; Brodner et al., 2003) (as a result of their fine grain structure and large atomic size) and excellent resistance to heat, which is the influential parameter in wear rate. Wear is a prime factor for aseptic loosening that is the most common failure mode of femoral head material. Therefore, this study mostly concentrates on improvement of wear performance of a modified Co-Cr alloy (Co-30Cr).

However, other vital properties of the fabricated materials for orthopedic applications to be improved are density, hardness and compressive strength. A few of the properties such as hardness and compressive strength are desired to be as high as possible while the other characteristics including coefficient of friction and wear rate are preferred to be as low as possible. On the other hand, the fabricated materials possess distinct performance for each individual property. It is needed, therefore, to decide on the best alternative that has the utmost level of satisfaction for all the relevant properties. This can be done by applying systematically approaches that logically identify the importance of the performance defining criteria i.e. material properties for a given engineering application and decide on the most relevant alternative and eradicate the improper candidate materials. In this view, numerous multi-criteria decision making (MCDM) methods such as AHP, GRA, TOPSIS, PROMETHEE, VIKOR, PSI, ELECTRE, ROVM and many others have been proposed to assist in selecting the best compromise alternatives (Griza, Reguly & Strohaeker, 2010; Chatterjee, Athawale & Chakraborty, 2009; Majumdar, 2010; Huant et al., 2010; Tripathy & Tripathy, 2016; Sriранgan & Paulraj, 2016; Cicek & Celik, 2010; Fayazbakhsh & Abedian, 2010). Among all, the GRA (Grey relational Multi-criteria Optimization and Compromise Solution) technique is quite an efficient ranking method because of its simple mathematical calculations and amiability of the use compared with other MCDM methods (Jahan & Bahraminasab, 2015). In the biomedical field, the majority of the authors used a computer simulation tool known as finite element analysis (FEA) for optimal selection of material (El-Sheikh et al, 2002; Fagan & Lee, 1986) and few have employed MCDM techniques in material selection for orthopaedic applications (Jahan & Bahraminasab, 2015; Grujicic et al, 2010; Rai, 2006; Singh, Patnaik & Chauhan, 2016; Aherwar, Singh, & Patnaik, 2016; Jahan et al., 2011; Quigley et al., 2002; Bahraminasab & Jahan, 2011).
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