Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 20 (2018) 283–289

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

2nd International Conference on Materials Manufacturing and Design Engineering

# Some Studies on Chip Formation Mechanism in CNC Turning of Biocompatible Co-Cr-Mo Alloy

Ketan A. Jagtap[a*], Raju S. Pawade[b]

[a]Research Scholar, Dept. of Mechanical Engineering, Dr. B. A. Tech. University, Lonere, Raigad (MS), India
[b]Associate Professor, Dept. of Mechanical Engineering, Dr. B. A. Tech. University, Lonere, Raigad (MS), India

**Abstract**

Biomanufacturing integrates life science and engineering basics to manufacture biocompatible products improving the superiority of living. Face turning is one of the important process producing the higher accuracy with surface finish on metal implants especially on sliding parts of metal-on-metal implants. Chip formation mechanism plays a vital role in manufacturing of superior quality implants. Present paper discusses the chip formation mechanism study by quantitative analysis of chip thickness ratio ($r_c$) and analysed by Response Surface Methodology (RSM). It is seen that feed rate shows dominating effect on chip thickness ratio ($r_c$) in dry face turning of Co-Cr-Mo alloy. Qualitative analysis of produced chips were analysed for study of metal mechanics in machining.


Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.

*Keywords:*Co-Cr-Mo alloy; Chip thickness ratio; RSM, Predictive modelling; Surface alterations.

## 1. Introduction

Turning process is rarely used in the manufacturing of components made of Co-Cr-Mo alloy for biomedical applications. It is, therefore, important to understand the mechanism of machining involving analysis of chip formation and the machining mechanics using assessment of cutting forces [1]. Even a minor change in the chip formation process may lead to problems related to tool life, surface topography and surface integrity after machining process. However, very few authors have reported their work in turning of Co-Cr-Mo alloy, which is not adequate for understanding the machining mechanism and mechanics.

* Corresponding author. Tel.: +91-9822645111; fax: 02140-275040.
*E-mail address:*ketanjagtap@gmail.com

2351-9789 
Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.
10.1016/j.promfg.2018.02.042

A chip thickness ratio ($t/t_c$) is a useful parameter to describe the effect of machining parameters on the chip morphology [10]. It is determined by the ratio of undeformed chip thickness ($t$) to the chip thickness ($t_c$). Face turning is one of the important process producing the higher accuracy with surface finish on metal implants especially on sliding parts of Co-Cr-Mo metal-on-metal implants. Chip formation mechanism plays a vital role in manufacturing of superior quality implants. However, very few authors have reported their work in turning of Co-Cr-Mo alloy, which is not adequate for understanding the machining mechanism and mechanics.

Co-Cr-Mo alloy is the most popular material for biomedical purposes such as dental and orthopaedic implants due to their outstanding mechanical properties, wear resistance and biocompatibility. Among them the cast alloys (ASTM-75) exhibit low ductility and higher fatigue strength evaluated to other forged alloys. These are the most popular alloys for artificial joint replacements. Artificial joint replacement (arthroplasty) is widely used and successful surgical treatment for patients experiencing from trauma and arthritis. On an average one million arthroplasties are performed annually worldwide [3]. Co-Cr-Mo alloy is the most suitable alloy often used in sliding parts, such as artificial hip and knee joints. When it is used in the head of an artificial joint, a mirrored finish is necessary to extend the life of the joint by compact abrasive wear and enhanced chemical stability. The exploration for a minimum friction surfaces has led to the progress of metal-on-metal hip implants. These devices are commonly used today in patients less than 60 years of age [6]. Retrievals of Co-Cr-Mo metal-on-metal hip implants which did not experience seizing (some serviced in patients over 25 years) revealed little to no wear of the articulating surfaces. As a result, there is novel importance on the optimization of the wear concert of Co-Cr-Mo metal-on-metal implants used in THR. To achieve the higher accuracy and surface finish using these processes, the available information of dimensional manufacturing process parameters is not adequate. Especially face turning is one of the important manufacturing process producing the higher accuracy and surface finish on metal implants. In order to enhance the machinability and hence product quality, there has been rising focus on improvement of machined surface finish by post finishing techniques such as polishing. Some of the related key publications which emphasizes on studying the Co-Cr-Mo hip implants based on laboratory as well as clinical experiences are presented below. The Co-Cr-Mo alloy is a difficult-to-cut material due to higher content of Cobalt with high hardness.

Fischer *et al.* conducted simulation study and experimental investigation of subsurface areas of retrieved metal-on-metal hip joints and laboratory specimens of worn surfaces of fcc Co-Cr-Mo alloys. Author found deposition of a nano-crystalline (nc) layer with a thickness of up to 200 nm on the specimen [3]. Ohmori *et al.* observed the surface roughness, $R_a$ of 7 nm and also reported that surface roughness achieved in ELID grinding was superior than polished surface roughness [4]. Grgazka *et al.* analyzed the influence of chosen modifiers on mechanical properties of composite materials on the base of Co-Cr-Mo alloy [5]. The effect of various burnishing parameters on grain size distribution, microstructural phases and residual stresses has been studied by Yang *et al.* [6] using pin on disc wear tests in Co-Cr-Mo alloy. The machining trials of biomedical grade stainless steel have been reported for manufacturing of femoral head. The author Uddin *et al.* [7] found significant effect of feed rate and depth of cut on the surface roughness and sphericity of femoral heads. Satyanarayana *et al.* [8] performed turning of Ti-6Al-4V biomaterial alloy and noted the optimized cutting parameters as 75 m/min cutting speed, 0.25 r/min and 0.25 mm depth of cut at $-3^0$ approach angle. In the past, authors have optimized the process parameters using RSM and DOE to achieve best surface finish. Table 1 shows some of the studies on machinability of different difficult-to-cut metals in terms of surface integrity.

In turning operation the final surface integrity depends on cutting speed, feed rate, depth of cut, tool nose radius, tool wear, machine vibrations, lubrication of the cutting tool and on mechanical and thermo physical properties of the material going to machined. Even small variation in any of the given parameters may have a significant effect on the produced surface. In machinability study, statistical design of experiment is used quite broadly. Statistical design of experiments refers to the process of scheduling the experiment so that the proper data can be analyzed by statistical techniques, resulting in applicable and objective conclusions. Design and methods such as full factorial, RSM and fractional factorial (Taguchi) methods are now generally used instead of one-factor-at-a-time experimental approach which is time consuming and absurd in cost. Present paper discusses the chip formation mechanism study by quantitative analysis of chip thickness ratio ($r_c$) and analysed by Response Surface Methodology (RSM). Qualitative analysis of produced chips were analysed for study of metal mechanics in machining.