Chapter 16
Machining of Poly Methyl Methacrylate (PMMA) and Other Olymeric Materials:
A Review

Fredrick Mwema
https://orcid.org/0000-0001-6116-5587
University of Johannesburg, South Africa

Job Maveke Wambua
Dedan Kimathi University of Technology, Kenya

ABSTRACT

Polymers have been adopted industrially in the manufacture of lenses for optical applications due to their attractive properties such as high hardness, high strength, high ductility, high fracture toughness, and also their low thermal and electrical conductivities. However, they have limited machinability and are therefore classified as hard-to-machine materials. This study conducts a critical review on the machining of various polymers and polymeric materials, with particular focus on poly (methyl methacrylate) (PMMA). From the review it was concluded that various machining parameters affect the output qualities of polymers and which include the spindle speed, the feed rate, vibrations, the depth of cut, and the machining environment. These parameters tend to affect the surface roughness, the cutting forces, delamination, cutting temperatures, tool wear, precision, vibrations, material removal rate, and the mechanical properties such as hardness, among others. A multi-objective optimization of these machining parameters is therefore required, especially in the machining of PMMA.

INTRODUCTION

Hard to machine materials have been categorized as materials exhibiting high hardness of above 45 HRC (Astakhov, 2011). These materials, also termed as difficult to machine materials are mainly super-alloys

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and other refractory metals including titanium, tungsten, nickel, niobium, steel, rhenium, tantalum, cobalt and chromium alloys. In addition to these, structural ceramics, composites and polymers are also considered to be hard to machine materials. The categorization of these materials is based on the production of extreme tool wear, high temperatures at the cutting points and elevated cutting forces during their machining (Shokrani, Dhokia & Newman, 2012). Polymers are chemically mixed compounds with large macromolecules made up of repetitive units, and which are created through polymerization. Such polymers are poly ethylene, poly propylene, polyvinyl chloride, polyethylene terephthalate, poly imide, polystyrene, polycarbonate, polyurethane, polytetrafluoroethylene and poly (methyl methacrylate). These polymers are often characterized as elastomers and have poor conductivity of heat, resulting in high cutting zone generation of heat, and which lead to high adhesion. This adhesive property prevents the movement of tools on the workpiece surfaces, hence limiting their machinability (Shokrani et al., 2012).

These polymers discussed above have been employed in such fields as in the making of wire and cable insulation (poly ethylene), making of plastic chairs (poly propylene), manufacture of magnetic tapes (polyethylene terephthalate), making of mechanical stress buffers (poly imide), making of license plate frames (polystyrene), manufacture of eye protection items (polycarbonate), manufacture of lenses and optical media (PMMA), and manufacture of plain bearings and gears (polytetrafluoroethylene), among others (Sohail, 2012). The materials have also found applications in the automotive, military, and aerospace industries due to their high strength-to-weight ratio. These applications owe to the chemical and mechanical properties of these materials, which include high hardness, strength, ductility, fracture toughness and also the low thermal and electrical conductivities. These properties affect the machinability of these materials, with a very reduced useful life of the tool, high surface coarseness, low accuracy in terms of dimensions and poor generation and movement of chips, which makes them hard to machine materials (Shokrani et al., 2012).

In this chapter, the theory of machining which will encompass the general machining aspects, terminology and processes will be examined. Moreover, a critical review on published materials on PMMA, other polymers, as well as other polymeric related materials and different machining and optimization methods will be discussed. This will be concluded with a summary of the review findings. Several applications of these materials in making of lightweight components will also be evaluated and presented.

BACKGROUND: THEORY OF MACHINING

Machining involves material removal in the form of chips, and which is achieved by shear deformation on the workpiece under machining. This process is characterized by the inter-relation of five machining elements, that is, the machining tool, tool holder and guiding element, the material holder, the workpiece and the machine. The cutting tools are categorized as either single or multi-edged, and may either perform the machining process in a linear or rotary direction, and these tools are designed depending on the cutting operation intended (Nee, Dufraine, Evans & Hill, 2010). The sharp edges on the machining tools allow for the chip formation as the tool interacts with the workpiece, and acts as a major determinant of tool life, the integrity of the surface finish, the shearing force required and the temperatures generated in the process. The cutting ability of a tool is dependent on the tool geometry, which is a product of the face angle, the flank, the rake angle and the clearance angle (Nee et al., 2010).

In milling, the material removal is achieved using a rotating tool which is equipped with multiple cutting edges. In the machining of composites and polymers, peripheral milling (edge trimming), which