Optimisation of the Bauer Equation Using the Least Squares Method for Thermoplastics Turning

János Farkas, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Jozsef Cziraki Doctoral School of Wood Sciences and Technologies, University of West Hungary, Sopron, Hungary
Etele Csanády, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Institute of Woodworking Machinery, University of West Hungary, Sopron, Hungary
Levente Csóka, Simonyi Karoly Faculty of Engineering, Wood Sciences and Applied Arts, Institute of Wood and Paper Technology, University of West Hungary, Sopron, Hungary

ABSTRACT

A number of equations are available for predicting the output of machining processes. These equations are most commonly used for the prediction of surface roughness after tooling. Surface roughness can be influenced by many factors, including cutting parameters, tool geometry and environmental factors such as the coolant used. It is difficult to create a universally applicable equation for all machining because of the variations in different materials’ behaviours (e.g. metal, wood, plastic, composite, ceramic). There are also many differences between the various types of machining process such as the machining tools, rotational or translational movements, cutting speeds, cutting methods, etc. The large number of parameters required would make such an equation unusable, and difficult to apply quickly. The goal is thus to create a simple formulation with three or four inputs to predict the final surface roughness of the machined part within adequate tolerances. The two main equations used for this purpose are the Bauer and Brammertz formulas, both of which need to be optimised for a given material. In this paper, the turning of thermoplastics was investigated, with the aim of tuning the Bauer formula for use with thermoplastics. Eleven different plastics were used to develop a material-dependent surface roughness equation. Only new tooling inserts were used to eliminate the effects of tool wear.

KEYWORDS

Least Squares, Nose Radius, Plastic Machining, Plastic Turning, Roughness Measurement, Surface Roughness

1. INTRODUCTION

Manufactured surfaces are mainly characterised by their surface roughness. The roughness value gives an indication of the form and depth of the micro-geometrical topography of the surface. The amplitude of the roughness, for all types of material such as wood, metal, plastic, etc., is influenced by the material of the machined part, the geometry and the material of the cutting tool, the cutting parameters and the cutting environment (e.g. presence and type of cutting fluid). According to the most of researches in this topic (for example: Suresh and Basavarajappa (2014), Rao et al. (2014), Mahamani (2014), or Agrawal et al. (2015)), of the cutting parameters, the feed rate has the greatest influence on surface roughness in metal cutting. Factors related to the machined part would include,
International Journal of Manufacturing, Materials, and Mechanical Engineering
Volume 8 • Issue 1 • January-March 2018

for example, hardness, and it has been found that for metals, the hardness strongly affects the roughness of the finished surface. Roughness can be characterised using a variety of parameters; in this paper the \( R_z \) value is used which is calculated by averaging the heights of the deepest five, and highest five surface points.

In this paper the effect on \( R_z \) of various cutting parameters and cutting tools was investigated for the turning of thermoplastics. In turning, the correlations between machining parameters – mainly the feed rate and cutting speed – and the surface roughness are described using two main formulas.

The Bauer formula, equation (1), is relatively simple. Using this formula, the theoretical surface roughness \( (R_{th}) \) can be calculated based on the feed rate \( (f) \), and the cutting tool’s nose radius \( (r_c) \) as follows:

\[
R_{th} = \frac{f^2}{8 \cdot r_c} \quad (1)
\]

The other prevalent formula is the Brammertz formula, equation (2). This formula gives a more precise expression for the theoretical roughness \( (R_{th, BR}) \) as it includes the effects of cutting speed \( (v_c) \) and edge radius \( (r_n) \). This formula is more useful in cases where the cutting speed strongly affects the results.

\[
R_{th, BR} = \frac{f^2}{8 \cdot r_c} + \frac{h_{min}}{2 \cdot r_c} \left( 1 + \frac{r_c \cdot h_{min}}{f^2} \right) \quad (2)
\]

Where: \( h_{min} = 84 \cdot v_c^{-0.7} \cdot r_n^{0.25} \quad (3) \)

These two formulas highlight the most significant parameters which affect surface roughness and provide reasonable approximations, but they cannot by universally applied. In some cases, the predictions can differ significantly from measured values due to the effects of other machining parameters (depth of cut) and factors such as cutting fluid and tool wear.

Palásti-Kovács et al. (2014) investigated the applicability of these formulas for the machining of two types of steel. Their study focused on the effect of tool wear on metal turning and concluded that the formulas are not sufficiently precise, because of the many other parameters which can affect roughness. Because of easier and comfortable application, and the less input factors, in further experiments the Bauer equation will be used. For Brammertz formula, tool geometry, DOC and cutting speed also needed for calculation.

At the start of this study, a literature review was carried out examining the effect of cutting parameters on the machining of various materials. The aim was to identify the most important parameters which determine the surface roughness. Suresh and Basavarajappa (2014) examined the effects of a number of process parameters on the turning of hardened steel (hardness of 55 HRC). In their study, the feed rate proved to be the most significant parameter influencing surface roughness; the second most important parameter was the depth of cut (DOC), and the least important parameter was the cutting speed. These authors also monitored tool wear and found that worn tools generated higher surface roughnesses than new tools. Rao et al. (2014) machined aluminium fly ash composites with various filler contents. They found that as the cutting speed increased, the surface roughness decreased, and as the feed rate increased, the surface roughness increased for all filler contents. It is clear from their data that the feed rate had a more significant effect on surface roughness than the
Experimental Investigation of Machining Characteristics for the WEDM of Al/ZrO2(p)–PRMMC
www.igi-global.com/article/experimental-investigation-machining-characteristics-wedm/73926?camid=4v1a

Optimization of Process Parameters Using Taguchi Coupled Genetic Algorithm: Machining in CNC Lathe
www.igi-global.com/chapter/optimization-process-parameters-using-taguchi/170152?camid=4v1a