

# Chapter 24

## GPR and RVM–Based Predictions of Surface and Hole Quality in Drilling of AISI D2 Cold Work Tool Steel

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### ABSTRACT

*This chapter examines the capability of Gaussian Process Regression (GPR) and Relevance Vector Machine (RVM) for prediction of surface and hole quality in drilling of AISI D2 cold work tool steel. This chapter uses GPR and RVM as regression techniques. The database contains information about cutting tool, feed rate, cutting speed, surface roughness, and roundness error. Cutting tool, feed rate, and cutting speed are considered inputs of GPR and RVM. The outputs of GPR and RVM are surface roughness and roundness error. In RVM, radial basis function is adopted as kernel function. GPR uses radial basis function as covariance function. The obtained variance can be used to determine uncertainty. A sensitivity analysis is also carried out. This chapter gives robust models based on RVM and GPR for prediction of surface and hole quality in drilling of AISI D2 cold work tool steel.*

### INTRODUCTION

The introduction of single/multilayer hard metal/ceramic-coated cutting tools increases productivity (Coldwell et al., 2004). So, the prediction of surface and hole quality in drilling of AISI D2 cold work tool steel with uncoated titanium nitride (TiN) and titanium aluminum nitride (TiAlN) monolayer- and TiAlN/TiN multilayer-coated-cemented carbide drills is an important task in manufacturing. There are different methods available for prediction of surface and hole quality in drilling of AISI D2 cold work tool steel with Ti, TiAlN monolayer and TiAlN/TiN multilayer-coated-cemented carbide drills (Grzesik,

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2000; Harris et al., 2001; Lee et al., 2003; Sharif and Rahim, 2007; Kurt et al., 2008; Braic et al., 2010; Xue and Chen, 2012). Akıncioğlu et al.(2013) successfully used Artificial Neural Network(ANN) for prediction of surface and hole quality in drilling of AISI D2 cold work tool steel. ANN has been successfully used to solve different problems in engineering (Penumadu, and Jean-Lou, 1997; Ural and Saka, 1998; Juang and Chen, 1999; Habibagahi and Bamdad, 2003; Shahin and Jaksa, 2004; Shang et al., 2004; Lu, 2005; Das and Basudhar, 2006; Kim and Kim, 2007; Ferentinou and Sakellariou, 2007; Bhattacharya et al., 2007; Ganesan et al., 2011; Hajabdollahi et al., 2012). However, ANN has some limitations. The limitations are listed below:

- Unlike other statistical models, ANN does not provide information about the relative importance of the various parameters (Park and Rilett, 1999).
- The knowledge acquired during the training of the model is stored in an implicit manner and it is very difficult to come up with reasonable interpretation of the overall structure of the network (Kecman, 2001).
- In addition, ANN has some inherent drawbacks such as slow convergence speed, less generalizing performance, arriving at local minimum and over-fitting problems.

This book chapter examines the capability of Relevance Vector Machine (RVM) and Gaussian Process Regression (GPR) for prediction of surface and hole quality in drilling of AISI D2 cold work tool steel with uncoated TiN and TiAlN monolayer and TiAlN/TiN multilayer-coated-cemented carbide drills. RVM is developed by Tipping (2000). It is a probabilistic model. Researchers have used RVM for solving different problems in engineering (Shen S and Liu Y, 2008; Zhang et al., 2009; Liying and Zhao, 2010; Noor et al., 2011; Wang et al., 2012; Wang, 2012; Kumar et al., 2013; Zhou et al., 2013; Hwang et al., 2014). GPR is a probabilistic non-parametric modelling approach. It determines the parameter from the given datasets. The output of GPR is a normal distribution. It has been successfully used to solve different problems in engineering (Pasolli et al. 2010; Kim et al. 2011; Heo and Zavala 2012; Zaytsev et al., 2012; Suk et al., 2012; Kongkaew and Pichitlamken, 2012; Kemmler et al., 2013; Sun et al., 2014). This study adopts the database collected from the work of Akıncioğlu et al. (2013). A comparative study has been carried out between the developed RVM and GPR models.

## **METHODOLOGY**

This article describes RVM and GPR for prediction of surface and hole quality in drilling of AISI D2 cold work tool steel with uncoated TiN and TiAlN monolayer and TiAlN/TiN multilayer-coated-cemented carbide drills. The details of RVM and GPR are given below.

## **DETAILS OF RVM**

RVM, developed by Tipping (2000) is a Bayesian form representing a generalized linear model of identical functional form of support vector machine (SVM). It differs with SVM in the case of solution which provides probabilistic interpretation of its outputs (Tipping, 2000). This section describes a brief background of RVM technique. The complete description of RVM are available in Tipping (2000). Relevance

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