ABSTRACT

Manufacturing is the process of converting raw materials into finished products. Among various manufacturing processes, machining is considered to be quite important. In fact, majority of the finished products require machining at some stage during their production, ranging from relatively rough or nonprecision work, such as cleanup of casting or forgings, to high precision work.

In manufacturing industries, the turning and the milling are widely used metal removal processes. Turning is a primary operation in most of the production processes, used to produce components with circular cross-section. Milling is the basic machining process to produce flat surface by progressive chip removal. Both of these are used in a variety of manufacturing industries including aerospace and automotive sectors, where quality is an important factor.

Now-a-days, due to global competitiveness, manufacturing industries are more concerned about the quality of their products. The industries focus on producing high quality products in time at minimum cost. The surface roughness is considered to be a measure of the technological quality of a product. It is one of the critical performance parameters that has an appreciable effect on several mechanical properties of machined parts such as fatigue behavior, corrosion resistance, creep life, etc. It also affects other functional attributes of machined parts like friction, wear, light reflection, heat transmission, lubrication, electrical conductivity, etc. Hence, the surface quality is of great importance for the functional behavior of mechanical parts.

The quality of the machined surface is greatly influenced by the cutting conditions such as tool geometry, tool material, machining process, types of chip form, workpiece material, tool wear and vibration during machining. In order to produce parts
with the desired surface finish, the machining parameters should be selected judiciously. However, proper selection of cutting conditions and parameters for achieving a desired surface finish is very difficult task, because the mechanism behind the occurrence of surface roughness is very dynamic, complicated and process dependent.

Theoretical (analytical) models have been proposed to estimate the surface roughness in terms of feed and nose radius of cutting tool. However, these models do not include any imperfections in the process (tool vibration, chip adhesion etc.) and other process parameters (cutting speed, depth of cut etc.) on surface roughness.

Ferrous metals are widely used in manufacturing industries. The AISI-1019 and EN-353 steels are widely used as manufacturing materials in various industries such as automotive industries, aerospace industries etc. where surface finish is considered an important factor. The research on machining of these materials needs to be strengthened. Therefore, development of surface roughness prediction models along with investigation of effect of machining conditions on surface roughness for machining the AISI-1019 and EN-353 steels will be a useful research contribution.

The review of research literature reveals that the studies reported on the development of surface roughness prediction models are limited. On the other hand, a large number of studies have been carried out to investigate the effect of machining parameters on surface roughness during machining, on the basis of design of experiments (DOE). Also, various modeling approaches i.e. DOE, soft computing and hybrid techniques have been used for the development of surface roughness prediction models. The support vector machines are also useful techniques and needs to be explored.
The focus of this research is the development of surface roughness prediction models and analysis of the effect of machining conditions on surface roughness occurring during machining (turning and end milling) of AISI-1019 and EN-353 steels. The machining experiments have been performed considering cutting speed, feed, depth of cut and nose radius as machining parameters using cemented carbide tools as per the design matrix constructed on the basis of centre composite rotatable design (CCRD). The surface roughness measurements of finished workpieces have been taken in skidless mode for accuracy, using a portable surface roughness tester (Surf coder SE 1200). The repetitive measurements have been made at three different locations of the finished workpieces in the direction of the tool movement. The mean of these three values (centerline average (CLA) surface roughness values denoted by $R_a$) has been considered for each trial. After conducting experimental study, surface roughness prediction models have been developed in terms of machining parameters to identify the best combination of machining parameters. This would be helpful in obtaining the best surface finish and analysis of the effect of machining conditions on surface roughness occurring during machining. A comparison has also been made among the prediction models so obtained, to identify the best approach for the surface roughness modeling.

The present study is carried out in three stages. In the first stage, the surface roughness prediction models have been developed in terms of cutting speed, feed, depth of cut and nose radius for the turning and end milling operations on both the workpiece materials (AISI-1019 and EN-353 steels) using (a) response surface methodology (RSM) based on center composite rotatable design (CCRD), (b) feed forward back propagation neural network (FFBPNN) along with batch gradient descent with variable learning rate procedure, (c) support vector machine (SVM) with radial basis kernel
function, and (d) support vector machine (SVM) with d-degree polynomial kernel. The result reveals the cutting speed, feed and nose radius found to be the significant parameters, while the depth of cut appears to have negligible influence on surface roughness during the machining in all cases. The quadratic relationships have been observed between feed and surface roughness during the machining of AISI-1019 and EN-353 steels for both the turning and end milling operations.

In the second stage two important tasks have been attempted. (a) The investigation of the influence of machining parameters on surface roughness using different plots (interaction plot, contour plots, 3D plots and cube plot) for surface roughness, (b) identification of the best combination of the machining parameters for minimum surface roughness, in each case of machining operation for both the materials. The result shows that the surface roughness increases with increase in the feed, while it decreases with an increase in the cutting speed and nose radius during the turning and end milling operations on both the workpiece materials. The minimum surface roughness is achieved at high level of cutting speed, low level of feed and high level of nose radius during machining in all cases.

In the third stage, a comparison among the results obtained from different surface roughness prediction models has been made on the basis of statistical method based on percentage mean absolute error (MAE) to assess predictability of the empirical models. For all the cases, the SVM with radial basis kernel displays the highest accuracy for the prediction of surface roughness as compared with the RSM, ANN and SVM with d-degree polynomial kernel.

The study appears to be quite useful with regard to machining of very important and commonly used manufacturing materials (AISI-1019 and EN-353 steels), development of surface roughness prediction models, analysis of the effect of machining conditions
on surface roughness, identifying the best combination of machining conditions for obtaining minimum surface roughness, and identifying the best approach for the development of surface roughness prediction model.