CHAPTER 5
CONCLUSION

Based on the experimental and optimization method of surface roughness, Tool Wear, Tool Life and Metal Removal Rate in Hot Turning and Hard Turning of AISI 316 Stainless Steel the following conclusions have been arrived at:

1. The effect of cutting speed, feed rate and depth of cut on cutting forces, surface roughness and tool wear were analyzed using ANOVA technique. The cutting forces decreases with increase in cutting speed and feed rate. The surface roughness in the range of $6\mu m$ is obtained at the high cutting speed i.e. 113.01 m/ min and at the feed rate at 0.381 mm/rev.

2. The cutting speed is the only statistically significant factor influences the tool wear and in order to minimize the tool wear, the highest level of cutting speed, 113.01 m/ min and feed rate 0.381 mm/rev should be preferred. The relationship between the factors and the performance measures are expressed by multiple linear regression equations, which can be used to estimate the expected values of the performance level for any factor levels.

3. Factorial experimentation technique is convenient to predict the main effects and interaction effects of different influential combinations of machining parameters on hard turning to investigate on work piece surface roughness and tool wear of the cutting tool insert.

4. The developed models can be used to predict the values of surface roughness of the work piece and tool wear of the cutting tool insert from any combinations within the ranges of variable studied.
5. Among the different process parameters during hard turning, the effect of cutting speed is more pronounced and combination of feed rate and depth of cut influences only to a lesser extent.

6. The experimental observations of the surface roughness (Ra) of the turned part were incorporated into ANN based Neurointelligence software package and Design Expert 8.0 evaluation package for hot turning of Stainless steels (Type 316) and the findings are follows;

a) From the ANOVA tables, the feed rate (fs) is the most significant factor for deciding the surface roughness (Ra) of the turned surface and contributes 51.3 % at 200\(^0\) C, 29 % at 400\(^0\) C and 20.1 % at 600\(^0\) C hot turning of stainless steel (Type 316). The increase of feed rate (fs) resulted in poor surface roughness.

b) The combination of cutting speed (Vc) and feed rate (fs) is the second parameter to decide the surface roughness (Ra), which contributed 11.92% at 200\(^0\) C, 15.14 % at 400\(^0\) C and 20.1 % at 600\(^0\) C hot turning. The depth of cut is of least significant parameter to predict the surface roughness of the machined surface.

c) An artificial neural network (ANN) model and response surface method (RSM) model were developed to predict the surface roughness within the wide range of cutting parameters, found to be capable of better prediction of surface roughness within the range that they had been trained. Good agreement has been observed between the predictive models and experimental results.

d) The surface roughness values of hot turned components obtained at 200 \(^0\) C is poor and when temperature raised from 400 \(^0\) C to 600 \(^0\) C, the surface finish is also improving to a desirable limit (satisfactory) showing that higher is the temperature, the material shows re crystallization characteristics.
e) The results of the artificial neural network (ANN) and response surface method (RSM) model are robust and accurate to estimate the surface roughness of the turned part in hot turning of stainless steel (Type 316).

f) Using the ANN and RSM models, saving in time and cost can be achieved for finding surface roughness (Ra) in hot turning of stainless steel (Type 316).

7. Experimental study on tool wear in hot turning of AISI 316 stainless steel with WC inserts yields the following:

a) The cutting speed and depth of cut are statistically significant factor influencing the tool wear for 200°C hot turning of 316 SS; its explain 11.765% and 16.214% of the total variation. For 400°C hot turning of 316 SS the feed rate and depth of cut are statistically significant factors and it’s explain 5.02% and 5.02% of the total variation. For 600°C hot turning of 316 SS the cutting speed and depth of cut are statistically significant factors and it’s explain 11.61% and 15.45% of the total variation.

b) Only two interactions, cutting speed - feed rate and cutting speed-depth of cut, have statistically significant to influence on the tool wear; they show 27.25% and 11.765% of the total variation for 200°C in hot turning. For 400°C hot turning of 316 SS, the interaction of cutting speed - feed rate have 45.18% influence of the total variation. For 600°C hot turning of 316 SS, the cutting speed - feed rate and cutting speed - depth of cut have statistically significant to influence on the tool wear; they explain 15.45% and 15.45% of the total variation. An analysis of the interaction plots reveals that in order to minimize the tool wear, the level of the cutting speed, 113.1 m/min, the level of the feed rate, 0.375 mm/rev and the medium depth of cut, 0.8mm.
c) The relationship between the factors and the performance measures are expressed by multiple regression equation, which can be used to estimate the expected values of the performance level for any factor levels.

d) Low levels of error in the ANOVA tables and high R-square values for 200°C and 400°C hot turning of 316 SS by WC inserts are the results of this study is to encourage the use of Taguchi parameter design for obtaining optimal cutting parameters.

8. Inferences from the Grey analysis on hot turning of stainless steel (Type 316) as follows;

a) The experimental results clearly showed that, a cutting speed (Vc) at 113.1 m/min, feed rate (fs) at 0.381mm/rev and workpiece (°C) temperature at 400°C will give the optimum results for hot turning of stainless steel (Type 316) by employing multi response optimization using Grey Relational Analysis.

b) Based on the Taguchi and ANOVA, feed rate has a dominant effect of almost 46.2% in contribution ratio, while cutting speed has 22.7% and workpiece temperature has 14.6% influence on the surface roughness, tool life and metal removal rate in hot turning of stainless steel (Type 316). The machining parameters set at their optimum levels can ensure significant improvement in the process parameters.

c) The cutting speed, feed rate and workpiece temperature are the primary factors that affect the quality of hot turning of stainless steel (Type 316), while the depth of cut is considered as a secondary factor.

d) Significant improvement in Grey Relation can be achieved by the combination of optimal hot turning parameter.
Finally, in this research work, Machining Characteristics of Hot Turning Process in AISI 316 Stainless Steel,

- Extended life span of cutting tool is established,
- Improvement in surface roughness of workpiece is achieved and
- Higher metal removal rate from workpiece is exhibited.
Scope for Future Research

- For different cutting tool inserts namely CBN and PCBN, the performance of hot turning and cost analysis can be studied.
- Workpiece metallurgical properties after hot turning can be studied throw more light on their suitability in a particular job.
- Machining characteristics of hot turning process by heating with other sources like frequency induction heating can be studied for the AISI 316 Stainless Steel. Also with the attachment for heating on a CNC turning center, a more precise study shall be conducted with different tool materials and process parameter variations.