Chapter-10

Conclusions and Scope for Future Work

10.1 Conclusions

The experimental investigation and analysis was carried out using cutting forces and acoustic emission during turning of three different types of specimens and the flank wear measured during the experimental work was analyzed. Subsequently, simulation and modeling for flank wear analysis was tried out using Adaptive Neuro fuzzy inference system (ANFIS) and Artificial Neural Network techniques. The investigation has been carried out for a various changed cutting conditions using three work materials (EN24, EN31 and EN8) and three tool materials (uncoated carbide, coated carbide and ceramic).

The observations drawn while machining using uncoated carbide tool inserts on EN24, EN31 and EN8 materials are summarized below:

- Machining using uncoated carbide tool inserts showed a range of flank wear as 0.05mm – 0.67 mm for the changes in the operating conditions in EN24.
- The machining of the entire work specimen with uncoated carbide tool inserts at different cutting conditions generated short and continuous chips in EN31 and EN8 and long continuous chips in EN24.
- Uncoated carbide tool inserts developed maximum wear when EN24 materials were machined under varied cutting conditions.
- Also, the flank wear in uncoated turning tool inserts have been found to be higher in machining of EN24 material than in machining other two materials.
- The machining of EN31 with uncoated tool inserts generated chips that were continuous and short and lead to develop flank wear.
- Maximum flank wear was recorded in machining EN24 (0.67 mm) while other two materials recorded from EN31-0.64 and EN8-0.46 mm when machined in the high speed and high feed condition.
Chapter 10 Conclusions And Scope For Future Work

• In most of the cases the cutting forces showed an upward trend with the increase in the tool wear rate and tool wear followed the standard wear pattern in all the cases.

• Experimental results also showed that as the feed increased, the flank wear also increased significantly.

• Further, with change in cutting speed, the wear increased in most of the cases.

• The tangential components (Fz) of force are found to be more sensitive to tool wear as compared to axial component (Fx) and radial component (Fy).

• The acoustic emissions parameters AE (RDC)_{avg} and AE (EG)_{avg} show a significant increase with tool wear. All the above AE parameters also show gradual rise in their values after tool wear of about 0.2 mm.

• The burst emissions could interfere with the actual wear state.

• AE (RDC)_{avg} showed best results with tool wear as compared to other acoustic emission parameters.

• It is also difficult to comment on weather the AE is due to crater wear or flank wear when both wears occur simultaneously.

The observations drawn while machining using coated carbide tool inserts on EN24, EN31 and EN8 materials are summarized below:

• Machining using uncoated carbide tool inserts showed a range of flank wear as 0.05 - 0.37 mm for the changes in the operating conditions in EN24.

• The machining of the entire work specimen with coated carbide tool inserts at different cutting conditions generated short and continuous chips in EN31 and EN8 and long continuous chips in EN24 which gave rise to flank wear.

• Coated carbide tool inserts developed almost similar flank wear when EN24, EN31 and EN8 materials were machined under varied cutting conditions.

• Also, the flank wear in coated turning tool inserts have been found to be higher in machining of EN8 compared to EN24 and EN31 materials.

• Maximum wear in machining three materials showed that 0.40 mm from EN8, 0.37 mm from EN24 and EN31 respectively which were found to be in the high speed and high feed condition.
Chapter 10 Conclusions And Scope For Future Work

- In most of the cases the cutting forces showed an upward trend with the increase in the tool wear rate and tool wear followed the standard wear pattern in all the cases.
- The tangential components (Fz) of force are more sensitive to tool wear as compared to axial component (Fx) and radial component (Fy). The values of the cutting forces start to increase gradually after tool wear range of about 0.11 - 0.18 mm.
- The acoustic emissions parameters AE (RDC)avg and AE (EG)avg show a significant increase with tool wear. All the above AE parameters show gradual rise in their values after tool wear of about 0.18mm.

The observations drawn while machining using ceramic tool inserts on EN24, EN31 and EN8 materials are summarized below:

- Machining using ceramic tool inserts showed a range of flank wear as 0.05 - 0.25 mm for the changes in the operating conditions in EN24, 0.06mm – 0.26 mm in EN31 and 0.05 – 0.27 mm in EN8.
- The machining of the entire work specimen with ceramic tool inserts at different cutting conditions generated short and continuous chips in EN31 and EN8 and long continuous chips in EN24 which gave rise to flank wear.
- Ceramic tool inserts offered maximum resistance to flank wear and developed almost similar flank wear when EN24, EN31 and EN8 materials were machined under varied cutting conditions.
- Also, the flank wear in ceramic turning tool inserts have been found to be higher in machining of EN31 compared to EN24 and EN8 materials.
- Maximum wear in machining three materials showed that 0.27 mm from EN8, 0.26 mm from EN31 and 0.22 mm from EN24 respectively which were found to be in the high speed and high feed condition.
- The tangential components (Fz) of force are more sensitive to tool wear as compared to axial component (Fx) and radial component (Fy). The values of the cutting forces start to increase gradually after tool wear of about 0.11mm.
- The acoustic emissions parameters AE (RDC)avg and AE (EG)avg showed significant increase with tool wear. All the above AE parameters showed gradual rise in their values after tool wear range of about 0.08 - 0.11mm.
In comparison machining of EN24, EN31 and EN8 using ceramic tool inserts developed flank wear of almost same magnitude in all the experiments.

The following observations were obtained from the modeling and simulation of flank wear using ANFIS. In this modeling a new approach namely combined machining parameter approach has been tried out. This approach involved combining of data obtained from all the experiments together and used for modeling. For training the system combined data are used. Testing and validation of the system response was also carried out with data identified from the sets. The test and validation was also given in their respective groups of speed and feed and checked for average relative and absolute % error. In both the approaches, the accuracy of the system to predict results is satisfactory.

- The model based on Adaptive Neuro Fuzzy Inference System (ANFIS) was capable of predicting the tool wear rate for particular cutting parameters (for which it has been trained).
- The model did not require a mathematical model to be developed for wear mechanisms.
- The model performed quite satisfactory results with the actual and predicted tool wear values with almost all the trials using tool material combinations.
- Off line training of the system is a must for making reasonable tool wear predictions.

The following observations were obtained from the system modeling using ANN. In this modeling a new approach namely combined machining data approach (CMDA) has been tried out. This approach involved combining of data obtained from all the experiments together and used for modeling. For training the system combined data are used. Testing and validation of the system response was also carried out with data identified from the sets. The test and validation was also given in their respective groups of speed and feed and checked for average relative and absolute % error. In both the approaches, the accuracy of the system to predict results is satisfactory.

- The model based on Artificial Neural Network (ANN) was capable of predicting the tool wear rate for particular cutting parameters (for which it has been trained).
- The model did require relatively small mathematical model and routine error computation for training network.
Chapter 10 Conclusions And Scope For Future Work

- Optimization was carried out using design of experiments’ routine.
- The model performed quite satisfactory results with the actual and predicted tool wear values.
- Off line training of the system is must for making reasonable tool wear predictions.

10.2 Scope for Future Work

Finally, it could be stated that the following statement is still valid today “though a lot of work has been done there is still a demand for a reliable and universal monitoring system”. Such a system would involve two inherent components: Hardware and Software. Presently, the hardware component is more developed and many sensors and transducers have been applied in industrial conditions. However, the software component requires improvement, as there are more difficult and complex tasks yet to be solved.

It is recommended that the work reported in this thesis may be extended by considering the following:

- The wear analysis may also be tried out on multi-point cutting tools like twist drills and milling cutters on the similar lines.
- In this thesis the investigation was focused on ferrous materials, similarly the investigation may be done for non-ferrous materials also.
- Investigation may also be extended to new generation tools like Cubic born nitride (CBN) and Diamond (PCD).
- Materials used in this investigation were not application specific but more general. The scope of this work may also be made more pragmatic and meaningful in identifying actual components for wear analysis for adoption of on line monitoring programs.
- Materials may also be heat treated based on application specific conditions and machining may be tried out and analysis conducted for the results.
- Flank wear analysis may also be tried out on very hard steels using the same tool inserts and other new inserts.
- For analysis other AI techniques (genetic algorithms etc.) could also be applied and compared with the current model results.