CHAPTER 7

CONCLUSION

The orthogonal turning of the Aluminium 6061-T6 alloy was carried out under dry cutting and cryogenic cooling on main cutting edge. The experiments on the turning of four different work-tool combinations were carried out under wet and cryogenic environments. They were: i) Aluminium 6061-T6 alloy - Uncoated carbide tool (CNMG 120408-THM), ii) AISI 1045 steel - Multi-coated carbide tool (CNMG 120412-5-TN2000), iii) AISI 304 stainless steel - PVD TiAlN coated carbide tool (CNMG 120412 MP - KC5010) and iv) Ti-6Al-4V alloy - PVD TiAlN coated carbide tool (CNMG 120408 MP1 - KC5010). Three types of cooling approaches have been used in the turning studies and they were: i) Wet machining, ii) Cryogenic cooling on rake surface (Cryo I) and iii) Cryogenic cooling on rake, main and auxiliary flank surfaces (Cryo II). In the cryo II, the cutting tool inserts were modified using Electrical Discharge Machining (EDM), for the supply of liquid nitrogen to the heat generation zones in the turning process. The cutting temperature, cutting forces, surface roughness, chip thickness, shear angle, chip form, chip morphology and tool wear were evaluated to study the performance of cryogenic cooling. The following conclusions are drawn from the research work.

1. Cryogenic cooling approach is an alternative method for reduction in cutting temperature at different work-tool combinations.
2. Cryogenic cooling provides substantial improvement in tool life and surface finish over wet machining.

3. Cutting force decreases with cryogenic cooling approaches (Cryo I and Cryo II) for all the work-tool combinations.

4. The machinability characteristics in the turning of the different work-tool combinations have shown better results in cryogenic cooling over wet machining.

5. Cryogenic cooling with a modified cutting tool (Cryo II) approach is more advantageous at high speed-feed combinations besides meeting the eco-friendly requirements.

6. Cryogenic cooling with a modified cutting tool (Cryo II) promotes favorable chip-tool and work-tool interactions.

7. Cryogenic cooling with a modified cutting tool (Cryo II) exhibit better performance than cryo I for all work-tool combinations.

7.1 ORTHOGONAL TURNING OF THE ALUMINIUM 6061-T6 ALLOY UNDER CRYOGENIC COOLING ON MAIN CUTTING EDGE

The orthogonal cutting of the Aluminium 6061-T6 alloy was carried out using an uncoated carbide tool under dry cutting and cryogenic cooling on main cutting edge. The major conclusions from this investigation can be summarized as follows:

1. The cutting temperature was reduced by 29 - 39% in cryogenic cooling on main cutting edge over dry machining.
2. Cryogenic cooling on main cutting edge increased the cutting force by 9 - 13% over dry machining.

3. Cryogenic cooling on main cutting edge reduced the chip thickness by 6 - 25% over dry machining.

4. Cryogenic cooling on main cutting edge produced well and adequately broken chips in the orthogonal turning of the Aluminium 6061-T6 alloy.

7.2 TURNING PERFORMANCE OF ALUMINIUM 6061-T6 ALLOY, AISI 1045 STEEL AND AISI 304 STAINLESS STEEL UNDER CRYOGENIC COOLING

1. The cutting temperature was reduced by 60 - 74% under cryo II and 40 - 58% under cryo I in the turning of the Aluminium 6061-T6 alloy over wet machining. In turning of AISI 1045 steel under cryo II, the cutting temperature was reduced by 50 - 65% over wet machining. The cutting temperature was reduced by 44 - 60% and 29 - 45% under cryo II and cryo I in the turning of AISI 304 stainless steel over wet machining respectively. The substantial reduction in cutting temperature attributes due to its high thermal conductivity of work material.

2. The main cutting force was decreased by 30 - 55% in the turning of the Aluminium 6061-T6 alloy under cryo II over wet machining. In turning of AISI 1045 steel under cryo II, the main cutting force was decreased by 14 - 29% over wet machining. In cryo II, the main cutting force was decreased by 15 - 35% over wet machining in the turning of AISI 304 stainless steel. In cryo II, the liquid nitrogen was supplied to
all heat generations, which increase the heat dissipation capacity and reduce the adhesion between the interactions. Thus reduce cutting force in cryogenic cooling.

3. In cryo II, the surface roughness was reduced by 34 - 43% in the turning of the Aluminium 6061-T6 alloy over wet machining. The surface roughness was reduced by 25 - 38% in the turning of AISI 1045 steel under cryo II over wet machining. In the turning of AISI 304 stainless steel under cryo II, the surface roughness was reduced by 19 - 36% over wet machining.

4. The chip thickness was decreased by 14 - 29% in cryo II over wet machining. The shear angle was increased by 16 - 29% under cryo II in the turning of the Aluminium 6061-T6 alloy over wet machining. In cryo II, the shear angle was increased by 15 - 26% in case of AISI 1045 steel over wet machining. The shear angle was increased by 11 - 26% in the turning of AISI 304 stainless steel under cryo II over wet machining.

5. Cryogenic cooling with a modified cutting tool (Cryo II) provided broken chips in the turning of Aluminium 6061-T6 alloy, AISI 1045 steel and AISI 304 stainless steel.

7.3 TURNING PERFORMANCE OF Ti-6Al-4V ALLOY UNDER CRYOGENIC COOLING WITH A MODIFIED CUTTING TOOL

1. Cryogenic cooling with a modified cutting tool (Cryo II) reduced the cutting temperature by 62 - 69% over wet machining.
2. The main cutting force decreased by 33 - 49% in cryogenic cooling with a modified cutting tool over wet machining.

3. Cryogenic cooling with a modified cutting tool reduced the surface roughness by 25 - 43% over wet machining.

4. Cryogenic cooling with a modified cutting tool decreased the chip thickness by 12 - 20% and increased the shear angle by 9 - 19% over wet machining.

5. Small sized serrated teeth were formed in cryogenic cooling with a modified cutting tool. This may be attributed due to control of cutting zone temperature and favorable chip-tool interaction.

7.4 TOOL WEAR UNDER CRYOGENIC COOLING

1. In cryo II, lesser flaking was observed for all work-tool combinations over wet machining.

2. The main and auxiliary flank wear was reduced by 37 - 38% and 28 - 47% in the turning of Aluminium 6061-T6 alloy under cryo II over wet machining respectively.

3. In turning of AISI 1045 steel under cryo II, the main flank wear was reduced by 27 - 37% and the auxiliary flank wear was reduced by 24 - 29% over wet machining.

4. In turning of AISI 304 stainless steel, the main and auxiliary flank wear was reduced by 25 - 30% and 30 - 33% in cryo II over wet machining.

5. The main and auxiliary flank wear was reduced by 28 - 39% and 29 - 42% in turning of the Ti-6Al-4V alloy under cryo II over wet machining.
7.5 SUGGESTIONS FOR FURTHER STUDY

1. Machining parameters like speed, feed and depth of cut can be optimized for a maximum material removal rate and minimum cost for machining.

2. In the development of the cryogenic cooling setup, a detailed study can be conducted for varying the pressure when liquid nitrogen is applied on the cutting zone.

3. In the modification of the cutting tool, the size of holes can be optimized for the effective use of liquid nitrogen in the turning process.

4. In cryogenic cooling, a detailed study can be conducted for varying the stand-off distance between the nozzle and the cutting tool.