Finite element method of milling operations.

The aim of this work is the investigation of the finite element method of milling operations. Milling operations are very common in several industrial sectors, like aeronautic, aerospatial, medical, race, etc. The prediction of the performances of cutting process and the influence of the process parameters on the product quality is important for tool and process design. The Finite Element Method (FEM), applied to machining, is able to predict the cutting forces, stresses and temperatures of the process. These physical quantities are useful to design the cutting tool and determine the best cutting parameters.

The increasing productivity challenge together to the increasing cost pressures and changing environmental awareness has led manufacturing industry to give critical considerations to the strategy of machining and the use of conventional coolant in machining process. For materials difficult to cut, like nickel based alloys and titanium alloys, the adoption of High Speed Milling strategy is limited to the milling tool capability. It is crucial to know the mechanical and thermal load acting on the insert changing cutting parameters. The FEM method turns out to be suitable to know the milling tool condition, in term of stresses, temperatures and chip morphology.

The objective of this research is to provide a powerful analysis tool to design and optimize the cutting process. Milling operations have been considered and different materials have been used.

The idea is to be a support for high –value added machining operations, like hard to cutting materials and green cutting.

The general problem is referred to the prediction of the interaction between work piece and tool during machining. This interaction is very complex, because several physical phenomena are concerned, from micro to macro scale. The workpiece and the tool are in contact due to the relative movement, at determined cutting speed, depth of cut, feed rate and cooling fluid. During the operation the wear of insert causes a modification of its geometry, and then the interaction tool-workpiece changes.

In addition the chip removal and dynamic performances of the machine is linked each other. The machine tool structure vibrates and then influences the cutting process and so on. In some circumstances the dynamic characteristics of the machine tool can be relevant and influences the chip removal. This produces big cutting force and then a high wear of the insert.

It is opinion of the author that the FEM tool can be suitable in the explanation of the lack of prediction of the theory of chatter, analyzing the process damping.

The simulation of milling operations should be a support to the milling tool design and useful to the optimization of cutting process.

From top management point of view the increasing productivity together with high quality level are the principal challenges.

Who makes milling tool bodies, inserts and coatings must put in the market new products with improved performances, in terms of long tool life and increased productivity, and able to cut “new” materials. This means a big experimental effort where several variables are concerned, with the consequence of large development time. The FEM tool can be useful for the analyst to design appropriately the cutting process and reduce the development time of new products.

Who is production responsible is interested to select the right cutting parameters with the aim to increase the productivity maintaining the same quality level or better. Another issue is to avoid defects during the machining. This is very important in the production of a single piece of an expensive material. The FEM tool can be useful for the production analyst to design appropriately the cutting process, so to know the impact of cutting parameters.

Today the reduction of machining production pollution is an important issue for the actual society. Increasing cost pressures and changing environmental awareness has led manufacturing industry to give critical considerations to the use of conventional coolants and traditional cooling techniques in machining processes. This means new challenges to the modeling, in terms of capability of the method of analysis, and in terms of analysis of new machining configurations.

In this work the FEM simulation is carried out using explicit and implicit formulation. First milling tests using single tooth milling tool (Fig. 1) have been carried out. Two materials have been selected, continuous chip one and segmented chip the other one. Then the material law has been calibrated using two approaches, using the OXCUT software, developed at the ERC/NSM (Ohio State University), and the 2D FEM approach. The calibration method was performed in collaboration with the lab. ERC/NCM in Ohio State University, that in the 1980 developed the finite element method applied to machining.
Sensitivity analyses about friction model and geometrical model have been performed. The measured cutting forces are compared to finite element modeling.
The results show a good agreement between simulation and experimental results (Fig. 2).

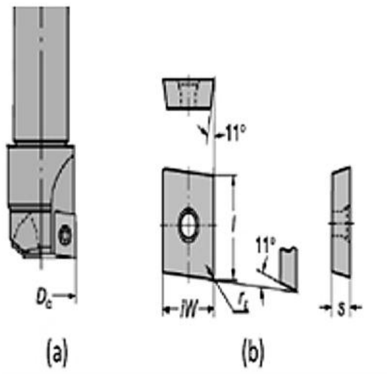

Fig. 1 – Single tooth milling tool

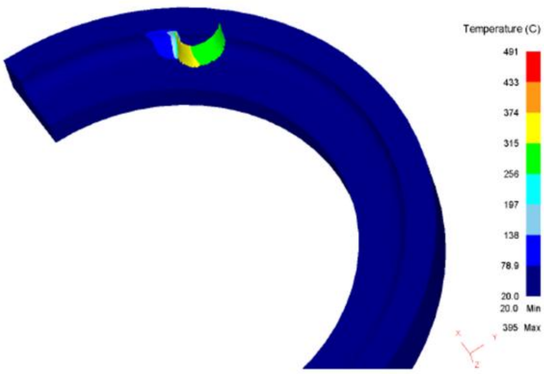

Fig. 2 – Milling simulation of titanium alloy, for cutting speed of 157 m/min, feedrate of 0.1 mm/tooth and depth of cut of 1mm

Milling tests using multi tooth milling tool have been performed (Fig. 3). New inserts and chipped inserts were used. In this case 2D FEM simulation have executed, and the results show an acceptable agreement, also regard to chipped inserts.


Fig. 3 – Multi tooth milling tool