# ABSTRACT

Milling is a popular method of machining employed in the manufacturing industry for realizing a range of complicated features on the workpiece by removing excess material. Thin wall milling is a commonly used process in the aircraft industries to machine components such as aircraft wings, jet engine compressors, fuselage sections, turbine blades, etc. One of the most difficult operations in the aerospace industry is the thin-wall milling of flexible plate-like structures made of aluminium and titanium alloys. Chatter is a sort of self-excited vibration that imposes a most significant constraint on productivity. It results in poor surface finish, as well as damage to the cutter and machine tool. Machining stability is critical for enhancing machine tool performance and quality. Hence, many researchers incessantly put in their efforts to improve machining stability by developing various techniques and processes to reduce and control chatter. In thin wall milling, these techniques focus on improving workpiece side dynamic stability, while machine tool side stability is improved when the rigidity of the workpieces is higher.

In this research work, an attempt is made to enhance the stability of both of the above cases by using passive damping techniques to achieve better surface finish and productivity by mitigating chatter.

To enhance the chatter stability of thin-walled workpieces, the effect of rib configuration, rib curvature, aspect ratio, and material removal on the dynamic stability of the workpiece is investigated. Finite element models of thin ribs of three different configurations are developed and modal analyses

performed to investigate the effect of aspect ratio on the natural frequencies of the ribs. An expression for dimensionless frequency ratio which shows the variation of natural frequency as a function of the aspect ratio of the rib for all three configurations is derived. The effect of rib curvature on dynamic stability is investigated by considering the curved ribs of the same length with five different curvatures. It is found that the natural frequencies increase with increase in curvature of the rib. The effect of material removal on the dynamic stability of the rib is studied by considering three different radial depths of cut. The results revealed that material removal has a significant impact on the natural frequencies of the ribs since the mass and stiffness distribution of the thin-wall workpieces are altered while machining.

Subsequent to the above investigations, an attempt is made to improve the chatter stability of the thin-wall workpiece by using a tuned mass damper (TMD). The finite element model of the workpiece is developed, and the model is validated using an impact hammer test. The target mode for chatter suppression is identified from the frequency response function of the workpiece measured at one of its critical locations. A longitudinal type TMD with a single degree of freedom is designed and the effect of TMD location on chatter stability is investigated. It is found that the location of the damper has a significant impact on the chatter stability of the workpiece. Further, the optimal location of the damper that results in enhanced chatter stability is identified by using response surface optimization. The proposed methodology is validated through an impact hammer test and milling test on the workpiece with and without TMDs. The milling test and the stability lobe diagrams revealed a three-fold improvement in the chatter stability of the workpiece.

To further improve the chatter stability of the thin-wall workpiece, a beam type TMD is designed and the effect of damper location and orientation on chatter stability is investigated. The horizontal orientation of the damper is found to be superior in improving the overall chatter stability of the workpiece. The location of the damper was optimized by applying the response surface methodology. Later, the dead masses of the TMDs are replaced with permanent magnets of equal masses to convert the damper into an eddy current tuned mass damper (ETMD). Impact hammer tests carried out on the workpiece with TMD as well as on the workpiece with ETMD revealed a four-fold and fifteen-fold improvements in chatter stability of the workpiece respectively.

To improve the dynamic stability of the vertical machining centre (VMC), the column being the compliant element compared to the base, a hybrid column is designed and developed using an alternate material called epoxy granite (EG). A specimen level study was conducted on the cast iron pipe filled with EG to investigate the effect of filling on static and dynamic characteristics of filled specimens. A finite element model of the existing column is developed to investigate its static and dynamic characteristics. The results of the numerical analysis are validated by the literature. The existing column is redesigned to facilitate the filling of EG. An optimum thickness of EG filling those results in improved static and dynamic characteristics of the hybrid column is determined by performing numerical analysis. A scaled-down model of the simplified existing column was fabricated, and the experimental modal analysis was performed. The same column was filled with EG of optimal thickness found from the analysis and the EMA was repeated on the hybrid column. The results revealed a ten-fold improvement in the damping ratio of the hybrid column. To predict the chatter stability of the VMC with CI column and that with hybrid column, frequency responses in the X and Y directions of the VMC are predicted numerically. It is found from the stability lobe diagrams of the VMCs that the chatter stability of the VMC with the hybrid column improved by a factor of three.

In light of the above-mentioned outcomes, the current research has identified ways for enhancing chatter stability in milling on both the workpiece and machine tool sides. As a result, manufacturers can successfully apply the above techniques to boost their productivity while attaining the desired surface finish on the component produced.