ABSTRACT

High cutting velocities, high spindle speeds and high feed rates that could lead to increased productivity and accuracy are frequently limited by machine tool vibration and thermal growth of critical components like spindles. This is undesirable as it gives rise to problems such as poor surface finish of the machined components, damage to the cutting tool and reduced machining efficiency. The conventional materials like cast iron and steel may have the necessary strength to withstand heavy loads but they lack in damping property which is a major requirement for a machine tool. Hence, it has prompted researchers to explore alternate materials which have the capability to dampen vibrations combined with better structural rigidity, higher thermal and dimensional stability, better corrosion resistance, lesser weight and cost. Epoxy granite (EG) is an alternate material which has better damping capacity than cast iron with added advantages of good adhesion property, lower cost, better impact toughness, perfect formability and short curing time among the other polymer concrete materials. However, the inferior stiffness of EG has restricted its usage for machine tool applications. Hence, the present work focusses on overcoming the above limitation by incorporating steel reinforcements in EG structure and deriving the benefit of damping without compromising on the static stiffness.

The primary objective of the research work is to design, analyze and develop an epoxy granite column for improving the dynamic response of vertical machining centre so as to enhance the surface finish of the components manufactured with higher productivity.

A finite element model of the existing column of VMC is developed and validated against the data obtained using torsional rigidity measurement

and experimental modal analysis. The validated finite element model is used for further studies on VMC column. Moreover, the experimental results are used as performance benchmarks to design a column made of epoxy granite. Numerical investigations are performed on the existing CI column to set benchmarks for the proposed EG column, taking into consideration the worst case cutting conditions, ATC forces and weight of the spindle head. Multiple design configurations of EG column reinforced with steel were explored prior to finalizing the design configuration that satisfies both static rigidity and ease of manufacturing requirements.

A scaled down model of the finalized design configuration of EG column was fabricated to assess the improvement in damping in comparison to the existing CI column of VMC. Experimental modal analysis was performed to obtain the modal parameters of EG column. Similitude theory has been adopted for determining the modal parameters of scaled CI column and comparing the same with that of scaled EG column. The EG column is found to have higher natural frequencies and ten times higher damping ratio compared to that of CI column.

The assessment of overall dynamics of the VMC with EG column is done and compared with that of CI column. Initially, pre-stressed modal analysis of base-column-spindle head assembly is performed using FEA, where the pre-stress accounts for the loads arising from the moving and dead weights of components like spindle head, ATC, X-Y axes tables and mass of the work piece**.** Subsequently, harmonic response analysis is carried out to determine the receptance of VMC and the results show two-fold and six-fold improvements in dynamic stiffness of the VMC with EG column in X and Y directions respectively. Further, the chatter stability of the VMC is predicted by plotting stability lobe diagram. A three-fold improvement in material removal rate for the proposed VMC with EG column is observed. In view of

the above, the present study has established the superiority of the dynamic performance of VMC with EG column without compromising on the static rigidity requirements of the machine tool. Hence, steel reinforced epoxy granite can be effectively used as an alternate material for building machine tool structures for precision machine tools.