Investigation on precision machining for CNC Milling Machine at near minimum material zone

Abstract:

Aerospace equipment manufactures constantly seek new techniques to reduce the weight of their products. Commercial aircrafts usually have more than 50,000 components and its maximum take-off weight is approximately between 250 tons to 590 tons. It has been reported that reducing 0.453 kg of mass in a commercial aircraft saves up to 1360 litres of fuel each year (Kaw 2006). Therefore, reducing the weight of a component even by a few grams could contribute a significant reduction in the weight of an aircraft. Innovations to reduce weight include replacing the conventional metallic materials by smart material or composites, which would reduce the weight of the components. However, there are few publications in improving machining processes which would ensure minimum weight in machined components. This research focuses on this aspect.

Typically, design engineers specify the tolerances for a dimension based on the functional requirements. Any component meeting the specified tolerances is accepted for assembly. If the components are machined under maximum material condition, then the total weight of the assembly will go up. To reduce the weight of a machined component, a new concept called machining near the minimum material zone conditions is proposed. For this, narrower tolerance zone is defined within the original tolerance specifications. This narrow tolerance zone is shifted close to either upper specification limit (USL) or lower specification limit (LSL). The shifting of narrow tolerance zone close to USL will be applicable for hole (internal) type of dimensions, whereas the shifting of narrow tolerance zone close to LSL will be applicable for shaft (external) type of dimensions. In normal machining, it requires considerable extra effort to machine the components within the narrow tolerance close to either USL or LSL. In order to demonstrate the concept, a typical machining situation is that of machining a rib using a new technology (cyber physical system, CPS) called precision machining for weight reduction (PMWR) system is proposed. Three main components are involved in this study. The first component is a sensor, which is in the present work is a laser detection system (LDS). It measures the thickness of the component while machining is in progress. The second component is signal processing, where new algorithm called precision machining for weight reduction (PMWR) is proposed. This algorithm shifts the narrow tolerance zone close to either USL or LSL depending on the near the minimum material zone condition. Then it determines the minimal dimensional variations of the component based on LDS and predicted dimensional variations using ANN. The feed forward back propagation neural network is used in ANN. The third component is decision making, where a potable modular fixture (PMF) moves the tool to ensure the minimal dimensional variations is zero in real-time. In other words, the PMF moves the workpiece towards the cutting tool when the dimensional variations are positive value. Similarly, the PMF moves the workpiece away from the cutting tool when the dimensional variations are negative value.

Al 6061 material widely used by aerospace industry is selected for machining in this study. A workpiece of size 100 mm length x 80 mm width x 25 mm height was chosen,

where ribs of 2 mm thickness rib are machined. A 10 mm diameter ZCC carbide tipped end mill cutter is used in this study. The machining was carried out in a high-speed Makino CNC milling machine. Cutting speed and feed rate are selected as variable cutting parameters in this study. From a preliminary study, optimum cutting parameters were determined as 188 m/min cutting speed and 0.25 mm/sec feed rate. This experimental work is carried out for finishing operation only. In other words, the workpiece is machined close to the desired thickness using a couple of rough cuts and the finish cut is machined using this PMWR system.

The experimental work carried out under this investigation is grouped under four sets of categories. The first set of experiments involves traditional machining, where the workpiece is fixed on the CNC milling machine table and the component is machined with optimum cutting parameters. This gives the current process in the defined industry. The second set of experiments consists of machining the component using PMWR system without LDS. In this, the workpiece is fixed on the PMF, which is then mounted on the CNC milling machine table. The component is machined with optimum cutting parameters. In both the experiments, the machined component is measured using digital vernier calliper. Machining the components using CPS device (PMWR system) with default ANN parameters constitute the third set of experiments. In this, the PMWR system monitors the machining condition using LDS (measures machined thickness value) and provides corrective feedback via PMF based on PMWR algorithm. The fourth experimental (complete CPS) work involves machining the components using PMWR system with optimum ANN parameter.

It was observed that the fourth experiments (complete CPS device) provided better results compared to than others though it is a simulation model. The third experiment (CPS with limited capabilities) showed promising results when compared to traditional machining. This is because of LDS, which act as a third eye in machining cycle. The results of second set of experiments are not satisfactory because the ANN prediction based on design of experiments and there is no system (like LDS) to monitor the current machining condition.

The thesis presents a comprehensive report on the theoretical/experimental basis of the proposed approach, details of the experiments, the data pertaining to the experiments and the results. The conclusions and suggestions for future work are also given.