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Parallel Machin e Tool Development

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Abstract

The work done during this OURE centered on the parallel machining center that is under development by a research group led by Dr. R. Landers. The specific tasks associated with this research involved the design of several parts, documentation of the processes for assembly and operation, procurement of some materials and stock parts, and involvement with experiments with the machine tool. These various aspects are outlined in the following report, with emphasis on the design of components.

Introduction

The parallel machine tool under development in the Engineering Research Lab under the guidance of Dr. Landers was originally a three-axis computer numerically controlled (CNC) milling machine. Dr. Landers and his team have the goal of transforming it into a real-time controlled six-axis machine capable of performing both lathe-style and milling operations. Further, the goal is to have capabilities to operate two lathe tools or two milling/drilling tools with each tool moving independent of the other. This is the meaning of the parallel machining concept—to perform two independent operations simultaneously on one work piece.

Currently the hardware (with the possible exception of a few small pieces) has been procured and assembled. Nearly all this hardware was in its existing state before the beginning of this OURE project. The focus of this project was to finish the details of attaching the extra axes to the main table, devise an acceptable routing for the plethora of cables that control and monitor each device, and finish the setup of tooling and work holding equipment. A particular focus was placed on the work holding device.

Many various tasks were performed in this project, giving variety to the work. It has been an interesting project, particularly from the perspective of seeing the need for a part to be made, designing the part, and measuring the existing equipment to ensure proper fit-up.

Main Body

The research done for this project involved completing the assembly of the parallel machine tool and checking the physical compatibility of its various components. An overall view of the machine's table and extra axes can be found in Figure 1. Several small parts had to be designed and made through the machine shop. Some of the more significant of these small projects include the motor covers for the three parallel axis motors, an apparatus for locking the spindle during milling operations, hardware to hold the flexible cover for one of the parallel axes, and the parts to shorten the chuck and arbor assembly. Two parts of the project involved researching and ordering parts from industrial suppliers. The flexible cover was located at significant cost savings compared with ordering it from the spindle manufacturer. The arbor to hold the spindle was purchased from Kennametal and adapted to the application, for which there was no existing short attachment solution. The entire process of locating and ordering these parts from suppliers was quite educational. It involved many phone calls to various technical experts, explaining the desired application of the product, and determining what type of solution could be achieved compared to the cost of the solution. Another resource used in this process was the expertise of the machinists in the shop and of Randall Lewis, who teaches the manufacturing lab for mechanical engineering students.

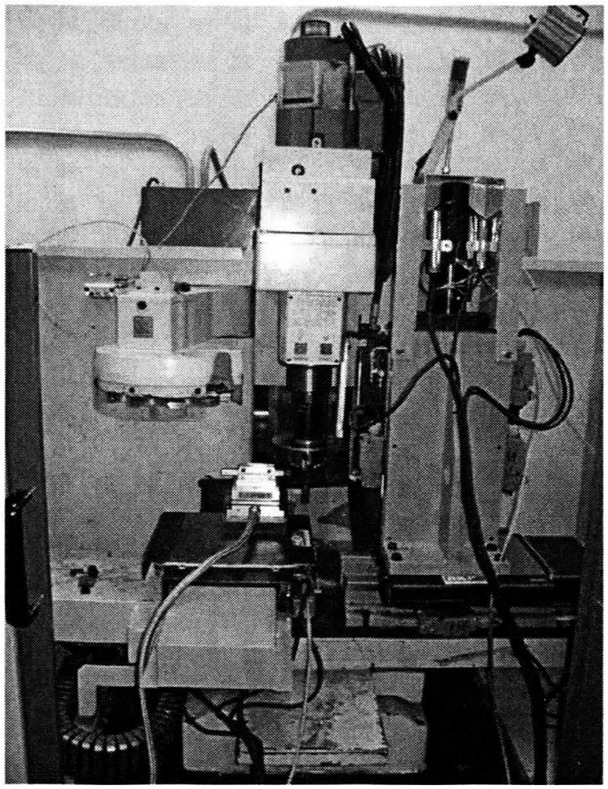
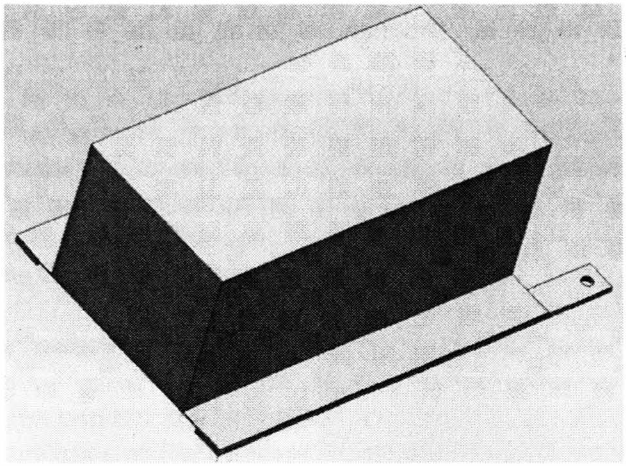


Figure 1: The machine tool, with old work holding system and lathe tooling.

The cutting coolant pumping system for the machine tool had been believed to be dysfunctional, so it had been removed. Upon closer inspection, it was determined that the coolant had been poured directly into the coolant tank, rather than being diluted to approximately five to ten percent concentration, as was specified in the design. Thus, most of the coolant had to be recovered from the tank, screened to remove debris that had been collected, and stored in a container for future use. The correct concentration of coolant was then mixed in the tank. The pump, which was removed because it would not circulate the thick, concentrated coolant, was reinstalled, primed, and tested. It produced a volume flow rate approximately equal to the desired rate, so it was determined to be sufficient.

A project related to protecting the equipment from damage was the design of motor covers for the motors on the three extra axes. Since the cutting experiments will use a coolant that will have considerable spray, it was desirable to protect the motor housings from coolant splash as well as chips. An image from the NX3 program used to draw up these and other parts can be found in Figure 2, below. These motor covers were designed such that no additional holes or modifications to the parallel axes were necessary. Another protective device that was designed was the flexible accordion cover for one of the horizontal axes. It can be seen in Figure 3, along with the high speed spindles and their mill tooling.



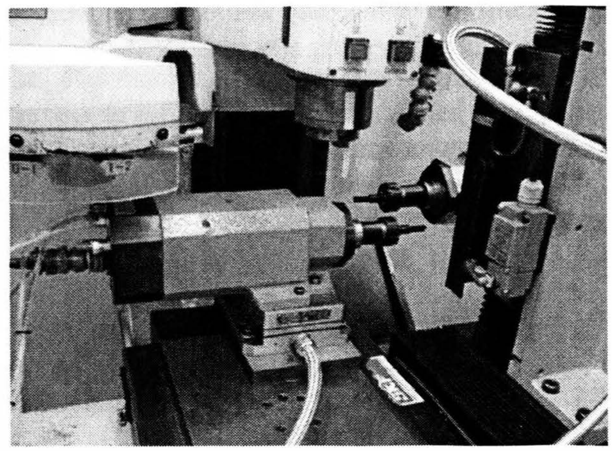


Figure 2: Motor cover drawing. Figure 3: High speed spindles and mill tooling.

One important facet of the project was the modification of the work holding system. In order to perform both lathe and milling operations, the work (in the case of the picture above, a blue wax cylinder) is held in a four-jaw chuck in the main spindle. Because of the length of the chuck and the fact that this is an innovative work-holding setup, the original design had the work protruding several inches from the end of the main spindle. This caused concern that there would be excessive vibration issues, so a goal was set to reduce the length of the work holding system. Several solutions for this problem were considered, including the use of square and round collets, but the conclusion was that it was necessary to retain the four-jaw chuck to keep the work size and shape flexible. The shortening, therefore, had to come from the part between the chuck and the spindle. After researching available styles of adapters (which connect the main spindle to whatever is being held by it), it was determined that the most appropriate style of holder was a shell mill adapter, which combines significant holding strength with a much shorter length. This part was then researched and the final order was placed with Kennametal. A picture of this type of holder from another company can be found in Figure 5. The part of the adapter from the black surface down will replace the large black cylinder seen in the old work holding system. Although the adaptation of the shell mill adapter from its original purpose to the new, unique configuration needed for the parallel machine system is not yet complete, it is believed that this new design will reduce the length of the entire holding system by nearly 50%.

Another project related to the work-holding system was a setup to hold stationary the main spindle. This spindle locker was required so that prismatic parts can be held stationary while the high-speed spindles perform milling or drilling operations on them. Since the main spindle speed is controlled by the real-time controller and the electric motor that runs the spindle is unable to hold a set position without allowing significant movement, a mechanical locker was necessary. An innovative design was chosen, involving a disc that attaches to the four-jaw chuck in the main spindle and an arm that bolts to the disc at four discrete radial locations. The device can be seen in Figures 4 and 6, where it unlocked and retracted for turning operations. With this design, it was possible to lock the spindle for milling and unlock it for turning, with only minimal operator effort.

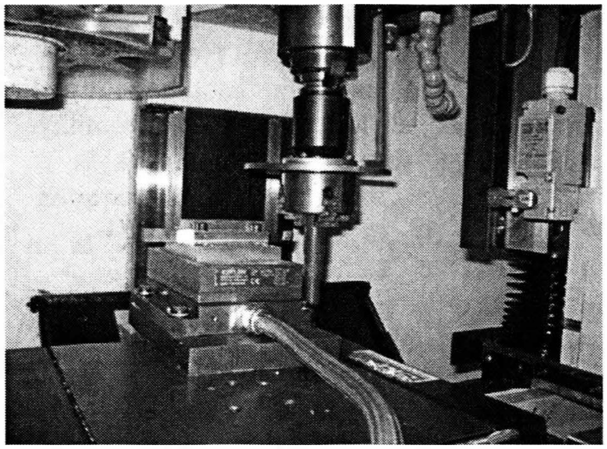


Figure 4: The old work holding system.

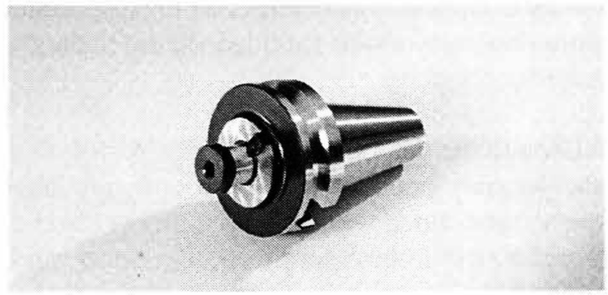


Figure 5: The new adapter.

Figure 6: Back view of the setup.

Another part of this research project was performing cutting experiments. For this portion, machining wax had to be located and machined to the appropriate dimensions. Additionally, the process for centering the work in the four-jaw chuck had to be written and performed with a dial indicator. Once the work was held properly in the chuck, the machine was tested to determine whether the hardware and code that move the main spindle and axes were functioning correctly. Two significant results were discovered through this testing, which was performed with the aid of Tang Lie, another research assistant for Dr. Landers. First, it was determined that the lathe tool needed to be rotated ninety degrees from its current position in order to cut properly. This discovery aided in the design of the second lathe tool holder. The realization that the tooling needed to be turned also forced a reversal of the main spindle's direction of rotation. Secondly, the main spindle was determined to have a malfunction through which it received a "noisy" signal because of non-shielded wiring in the machine tool and thus did not perform its required motions correctly.

Although the machine tool was first tested on machining wax, there are plans to cut aluminum and possibly steel parts once the hardware and software of the control system are proven. The speeds associated with cutting aluminum and the appropriate tooling for these operations therefore had to be determined. Research was done using the Machinist's Handbook and by contacting the tooling company to check compatibility of the tooling with the operation.

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