IOP Conference Series: Materials Science and Engineering

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To cite this article: V Balasubramani *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **402** 012116

IOP Conf. Series: Materials Science and Engineering **402** (2018) 012116 doi:10.1088/1757-899X/402/1/012116

Design and fabrication of a tool changing mechanism for cylinder block in a vertical milling machine

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Abstract. In inline three cylinder engine, cylinder block is an integrated structure comprising the cylinders, coolant passages, intake and exhaust passages and ports, and crank case. The cylinder block is mostly fabricated by casting process. The surface irregularities in the top face of the casted cylinder block causes improper seating of cylinder head and surface finishing becomes essential. Hence the casted cylinder block was machined with series of operations such as rough milling, face milling, finish milling, honing, line boring, drilling, tapping and reaming operations. In face milling operation, milling machine requires special cutting tools to remove the surface irregularities of the cylinder block. In the vertical milling machine, 12.6 kg cutting tool is fitted and removed by manually and it leads safety problems to the workers. The manual tool changing method increases the idle time of the machine and hence a tool changing mechanism is required to overcome the above said problems. In this present work, tool changing mechanism is designed and fabricated for a vertical milling machine to perform top face milling operation. Hence a semi-automatic mechanism is suggested to minimize the time of tool replacement. The solid model of the semi-automatic mechanism was modelled using SOLIDWORKS and the stress analysis of the components of the tool changing mechanism was performed using ANSYS Workbench. The manual tool changing method increases the idle time of the machine and hence a tool changing mechanism is required to overcome the above said problems. The cutting tool replacement time is reduced as 4.10 minutes from 11.05 minutes.

1.Introduction

In inline three cylinder engine, cylinder block is an integrated structure comprising the cylinders, coolant passages, intake and exhaust passages and ports, and crankcase. The cylinder block is the strongest component of an engine and it provides much of the housing in a modern engine.Since it is also a relatively large component, it constitutes 20-25% of the total weight of an engine. In the basic terms of machine elements, the various main parts of an engine such as cylinder block, cylinder head, coolant passages, intake and exhaust passages, and crankcase are conceptually distinct, and these items can all be made as discrete pieces that are bolted together. This involves integrating multiple machine elements into one discrete part, and doing the making such as casting, stamping, and machining for multiple elements in one setup with one machine coordinate system of a machine tool or other piece of manufacturing machinery.Mostly engines with more than four cylinders.The cylinder block is mostly fabricated by casting process. The surface irregularities in the top face of the casted cylinder block causes improper seating of cylinder head and surface finishing becomes essential. Hence the casted cylinder block was machined with series of operations such as rough milling, face milling, finish milling, honing, line boring, drilling, tapping and reaming operations. Mostly, face milling operation is performed with the support of vertical milling machine. In face milling operation, milling machine requires special cutting tools to remove the surface irregularities of the cylinder block. In the vertical milling machine, 12.6 kg cutting tool is fitted and removed by manually and it leads safety problems to the workers. The manual tool changing method increases the idle time of the machine and hence a tool changing mechanism is required to overcome the above said problems. The cylinder block is the strongest component of an engine that provides much of the housing for the hundreds of arts found in a modern engine. The cutting tool in the milling machine consists of 16 carbon inserts and it performs for minimum 500 units. The cutting tool is changed once in a day and the manual tool replacement technique is tedious and unsafe. 12.6 kg tool is lifted manually and replaced. Hence a semi-automatic mechanism isrequired to minimize the time of tool replacement. Pneumatic cylinders are used for sliding motion with the help of a guide block and the pneumatic cylinders are utilized to attain up and down movement of the base plate. The solid model of the semi-automatic mechanism was modeled using SOLIDWORKS and the stress analysis of the components of the tool changing mechanism was performed using ANSYS Workbench. A tool changing mechanism is fabricated with the support of pneumatic cylinders and the cutting tool replacement time is reduced as 4.10 minutes from 11.05 minutes. Using this mechanism, fatigue of the workers also eliminated.In the vertical milling machine, the tool is replaced manually by three workers. Weight of the tool is about 12.6 kg, it needs to be lifted and replaced which increases the fatigue load and creating safety related issues to the worker. The manual tool changing method also increases the idle time of the machine. Hence a tool replacement mechanism is required. The objective of this work is to design and fabricate tool changing mechanism for a vertical milling machine to perform top face milling operation

2. Milling Machine

The schematic representation of the vertical milling machine is given in figure 1. Then milling the cutter is studied and it consists of 16 Cubic Boron Nitride (CBN) inserts which are fastened with the body of the cutter using wedges (Figure 2). It also consists of four slots where it can be fastened to the machine spindle.

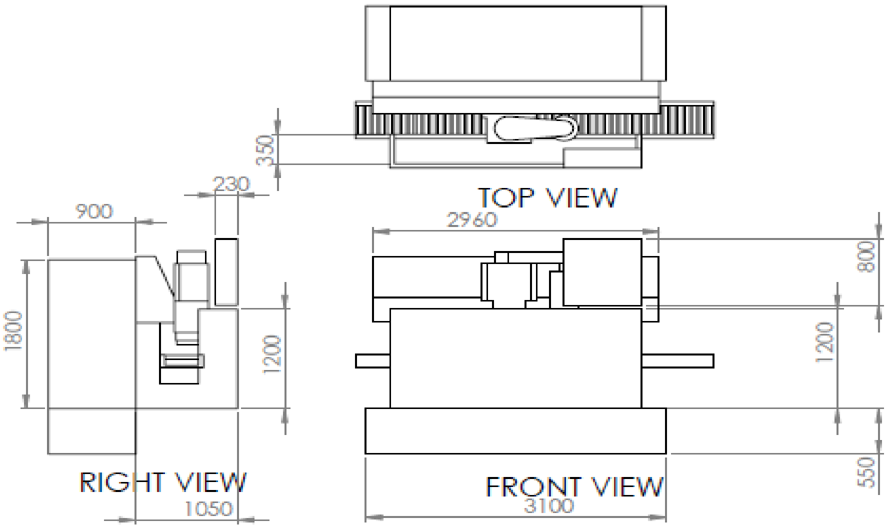

Figure 1. Schematic representation of Vertical Milling Machine.

Figure 2. Milling cutter with CBN Inserts.

2.1 Design of Tool Changing Mechanism

The initial position of the spindle is modified for the convenience of cutter replacement such thatthe cutter is 550mm away from the control box and 450 mm above the conveyor line.A breaking mechanism is needed provided for the tool to lock the spindle of the vertical milling machine and the single worker has to remove the cutter from the machine. A Tension spring which is compressed initially had been designed with the deflection of 48.24 mm is used. For the movement of cutter, two pneumatic cylinders are used, one for horizontal movement and another for the vertical movement and it is given in table 1. Pneumatic cylinders provides precision clamping and positioning of the tool during machining. In this application, pneumatics is selected for its reliability, control and easy channeling.

Table 1. Position of Pneumatic Cylinders.

Movement type	Stroke length (mm)	Bore Diameter (mm)
Horizontal	550	75
Vertical	200	50

The tool replacement mechanism is designed such that it fits into the available space nearer to the milling machine and this mechanism doesn't cause any hindrance to working space.The first pneumatic cylinder is mounted in the rear side of the control box of the milling machine and this cylinder provides horizontal motion of 550mm and it requires a thrust force of 5.006kN. The guide block is mounted in the covering of the machine. The guide and the base plate are joined using an arm. The other end of the arm hasthe second pneumatic cylinder, which provides vertical motion to the base plate for 200mm and requires thrust force of 2.17kN. The components of tool changing mechanism are given in table 2.

Table 2. Components of Tool Changing Mechanism.

Serial No	Name of the Part	Number
1.	Large Cylinder	01
2.	Guide	01
3.	Pivot	01
4.	Arm	01
5.	Small Cylinder	01
6.	Round Block	01
7.	Base Plate	01
8.	Coil Spring	01
9.	Stud M12	01

The modelled base plate and spring latchet are shown in figure 3 and 4. The tool changing mechanism with assembled components is shown in figure 5.

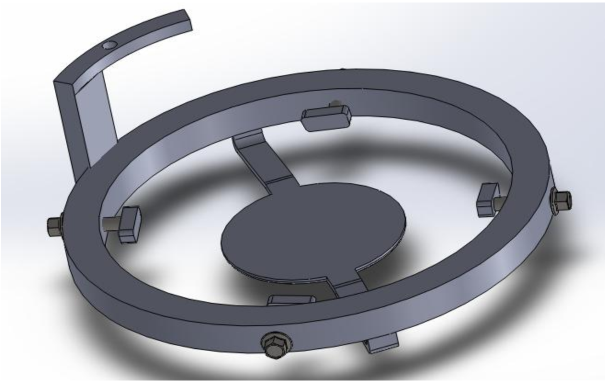

Figure 3. Base Plate.

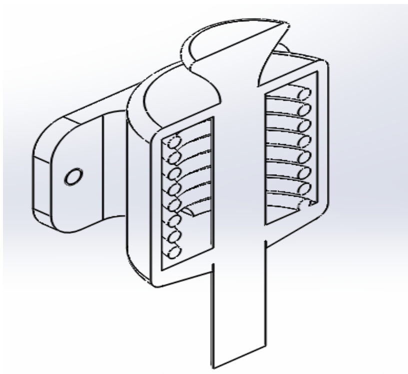

Figure 4. Spring Latchet.

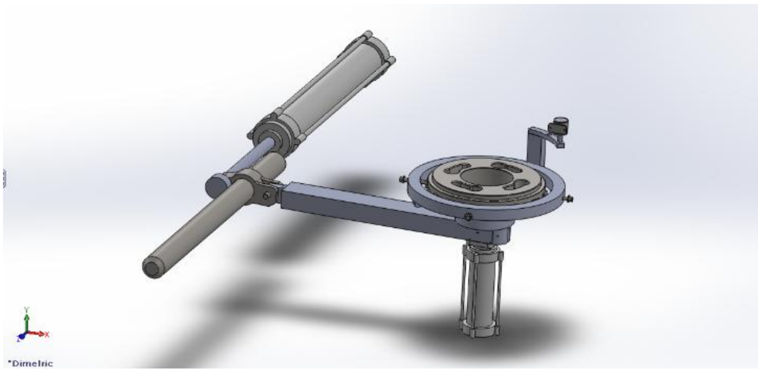

Figure 5. Tool Changing Mechanism with their components.

IOP Conf. Series: Materials Science and Engineering **402** (2018) 012116 doi:10.1088/1757-899X/402/1/012116

2.2 Finite Element Analysis of Mechanism

The finite element model of the individual components have been developed in ANSYS workbench software. The pivot, arm and stud are considered as a single linkage and the force is applied on the one end of the arm by arresting all degrees of freedom in the pivot end. Figure 6 shows the meshed model of arm and assembly in the mechanism. The weight of the cutter is applied over the centre surface of the base plate and then the lower part of the base plate is fixed and the numerical analysis is performed. Figure 7 shows the equivalent stress distribution of the base plate and it is inferred that the stress is maximum in the regions of web. Figure 8.shows the stress distribution of the base plate. The weight of the cutter is applied as load to the contacting areas of the fasteners in the rim and the flange is arrested with x, y, z and rotation about x and z movements. The equivalent stress was predicted and it was the maximum at the leading edge of the web near the rim. The predicted stress is very less compared to yield stress of the material.

3. Fabrication of the Tool Changing Mechanism.

The finite element analysis of the tool changing mechanism is performed in ANSYS workbench and the tool changing mechanism is performed. In fabricated mechanism, the pneumatic cylinders are selected with the working range of 5kN.the air discharge from the cylinder for forward stroke and return stroke is 7.33 litres. The material used for the components are Mild Steel plate of thickness 10 mm, MS plate of larger thickness was preferred because of the weight of cylinders.

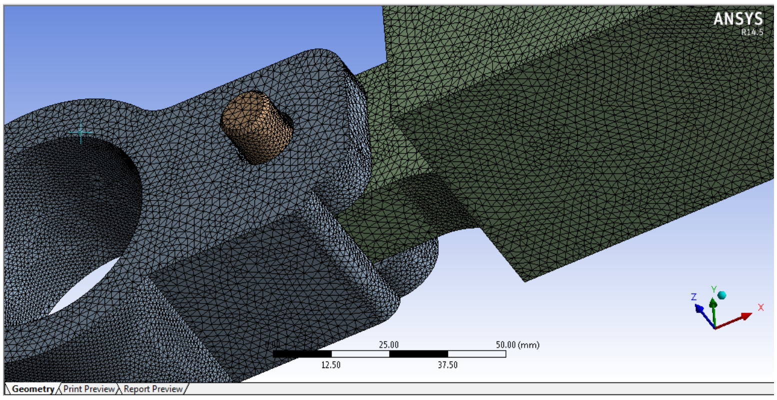

Figure 6. Meshed Model of the Pivot arm and assembly.

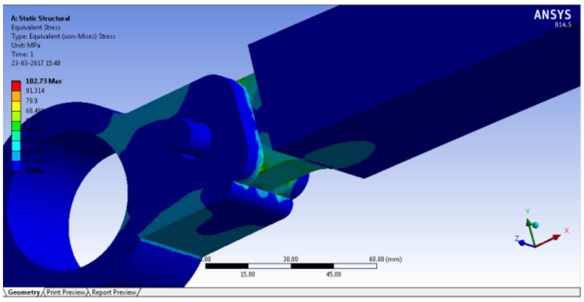

Figure 7. Equivalent stress distribution of arm assembly.

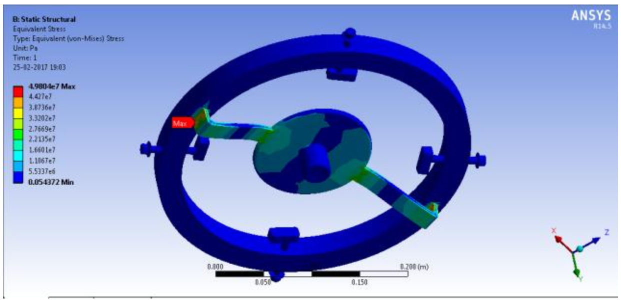

Figure 8. Equivalent stress distribution of base plate.

The operation of the tool changing mechanism is followed with the cascading sequence. It has 2 cylinders A and B and the sequence is A+, B+, B-, A- , where the cylinder A is for horizontal movement and cylinder B is for vertical movement. Figures 9 and 10 show the fabricated model of the tool changing mechanism in a vertical milling machine.

Figure 9. Fabricated Model of the fixture.

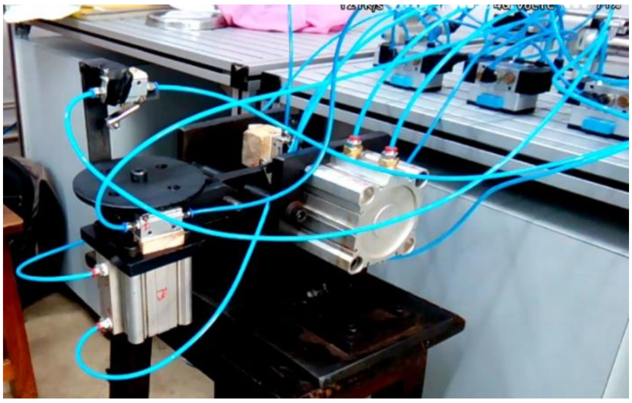

Figure 10. Tool changing Mechanism along with Pneumatic Cylinders and Limit Switches.

4. Conclusions

The tool changing mechanism for a vertical milling machine is designed and fabricated and the following advantages are attained

- The mechanism is acted as add-on module in the rear side of the milling machine and it is attached easily
- During the cutter replacement, all translatory motions are performed by pneumatic cylinders and the worker does not hold the cutter for longer time.
- The designed spring latchet locks the spindle motion and it provides the better safety to the worker.
- One worker is used for the tool replacement instead of three workers
- The cutting tool replacement time is reduced as 4.10 minutes to 11.05 minutes.

Acknowledgement

We would like to express our gratitude to Hyundai Motor India Limited for giving us permission to carry this project work in their factory.We also thank the staff in the ENG #1 department for their technical support for the completion of this project work.

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