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Design of electro permanent magnetic chuck for the curved surface of large workpiece

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Abstract

This paper presents a design of electro permanent magnet (EPM) chuck that adapts a mobile machine to a curved surface of a large workpiece such as parts of ship and aircraft. It is difficult to machine the large parts inside machine tools. Thus, a mobile machine is used as an alternative way, which moves on a surface of the workpiece. The mobile machine should be easily detached from and attached to the workpiece. An EPM chuck is used as a device to fix the mobile machine since that is easily attachable and detachable. The yoke connecting permanent magnet and AlNiCo magnet forms a magnetic circuit, which configuration generates the holding force of the mobile machine. However, the EPM chuck is typically customized for a flat surface, so the holding force is reduced on a curved surface due to the lack of contact area. Therefore, this study designed a different type of EPM chuck set that is specified on a curved surface. The experiments verified that it copes well to the curved surface as well as the flat surface.

EPM(Electro Permanent Magnet), Mobile machine, Curved surface

1. Introduction

In general machining, most mechanical parts are machined inside the machine tools. However, large workpieces such as parts of aircraft, ships, and wind turbines are difficult to process by traditional methods. In order to machine the mechanical parts in the machine tools, the tools must be more than twice larger than the object. Preparing such a big tool is not economical. Therefore, various mobile machines have been used to resolve such unreasonableness [1-4].

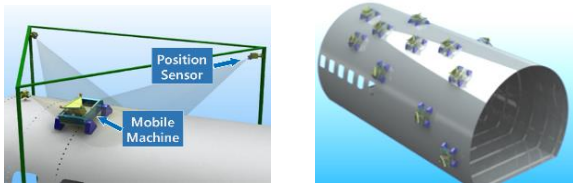

Figure 1. A mobile machine on machining on-site and multi-collaborative machining

Figure 1 shows that a mobile machine is being processed over a workpiece and several mobile machines are collaborating. A mobile machine is used for cutting, drilling, milling, welding, riveting, inspection, and cleaning, which moves on a large workpiece. The mobile machine must repeat walking and stopping on a workpiece. Then, a device for fixing the mobile machine is essential. A vacuum pad is generally used regardless of the material of the workpiece and it is also used on a curved surface. However, the horizontal stiffness is weak because the substance of the vacuum pad is rubber, which makes it difficult to hold the mobile machine in the correct position.

On the other hand, a magnetic chuck is advantageous for controlling the precise position of the moving machine. However, if the surface of the workpiece is curved, the magnetic holding force is reduced due to the lack of contact area on the curved surface. Therefore, this paper introduced a different design of electro permanent magnet (EPM) chuck set that can be flexibly adapted to a curved surface as well as a flat area. Also, the developed design showed usefulness for a curved surface adaptation by experiment.

2. Electro permanent magnet chuck

Magnet chucks consisting of only permanent magnets are inconvenient to use because it is not easy to remove that from the attached object. Therefore, electromagnets are sometimes used, but it is not preferred because electric current must be continuously applied. Instead, AlNiCo magnets are used to control the magnetic circuit. AlNiCo magnets have proper magnetization even with a small magnetic field compared to permanent magnets such as Nd magnets. These characteristics are used to convert the magnetic circuit of the permanent magnet chuck.

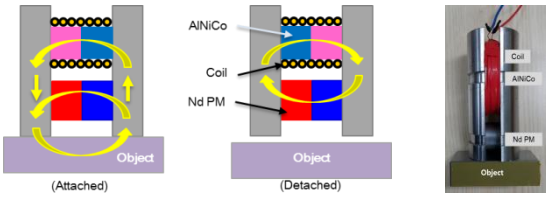

Figure 2. Magnetic circuit with AlNiCo magnet and Nd permanent magnet for attaching and detaching

Figure 2 is an example of an EPM chuck combining a permanent and an AlNiCo magnet [3]. When magnetizing the AlNiCo magnet in the same direction as the permanent magnet, the magnetic circuit is formed outside. When magnetizing in the opposite direction to the permanent magnet, the magnetic circuit is formed inside. Figure 3 is an electrically switchable commercial permanent magnet chuck. The magnetic path of the permanent magnet is switched using an electromagnet. It is not

suitable for miniaturization because it is large in size and weight by using two electromagnets and permanent magnets.

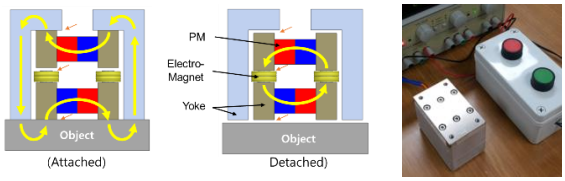

Figure 3. A commercial switchable permanent magnetic chuck

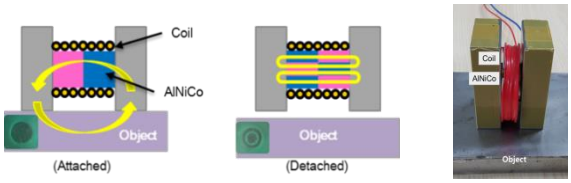

Figure 4. Magnetic circuit with only AlNiCo magnet for attaching and detaching

Figure 4 shows an EPM chuck using only one AlNiCo magnet. In general, Demagnetization is achieved by applying alternating currents several times, but here, the magnetic field corresponding to the coercive force of the AlNiCo magnet is estimated to demagnetize it with one application of current.

EPM chuck using only AlNiCo magnet

When the AlNiCo magnet is magnetized, the surface of the AlNiCo magnet is unipolar, and when demagnetized, it is bipolar. Therefore, when the magnet is magnetized, the magnetic circuit is formed externally, and when demagnetized, the magnetic circuit is formed internally.

Figure 5. Magnetic views of AlNiCo magnet attached and detached

Figure 5 shows the magnetic images of the AlNiCo magnet surface when magnetized and demagnetized. However, when the AlNiCo magnet is demagnetized, the magnet surface is bipolar. In the bottom figure, the center of the AlNiCo magnet shows the North Pole, and the edge shows the South Pole [5].

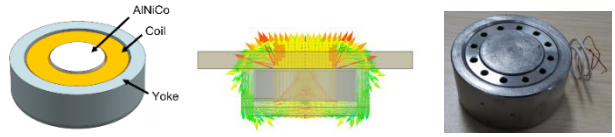

Figure 6. EPM chuck with only AlNiCo magnet for attaching and detaching

Figure 6 is an EPM chuck made using only an AlNiCo magnet. Since the EPM chuck is designed for use on a flat surface, the diameter of the EPM chuck is large, so that the fixed force may reduce and the chuck may shake on the curved surface.

3. EPM chuck set design to adapt to a curved surface

In fact, most workpieces have more curved surfaces than flat surfaces. EPM chucks made for on-plane use differ in their holding forces depending on the shape and surface conditions of the object. On curved surfaces, the holding force may be reduced and the EPM chuck may swing. Therefore, this paper designed and fabricated an EPM chuck that can adapt to a curved surface and verified its usefulness through experiments.

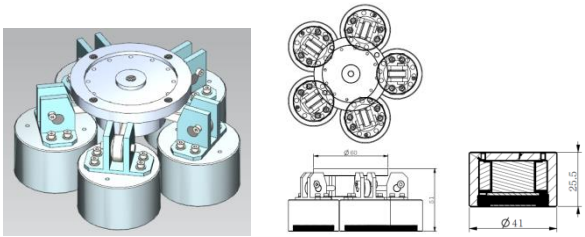

Figure 7. Design of EPM chuck set for curved surface

Figure 7 is a model of a surface adaptive EPM chuck set. In order to minimize the weight and size of the EPM chuck, the EPM chuck using only the AlNiCo magnet was made small and designed by combining them. Each EPM chuck connected to the main body in the center corresponds to the curved surface by two-way rotation in a certain range when it contacts the curved surface. When an electric current is applied to the contacted EPM chuck along the slope of the curved surface, the AlNiCo magnet is magnetized and attached to the object.

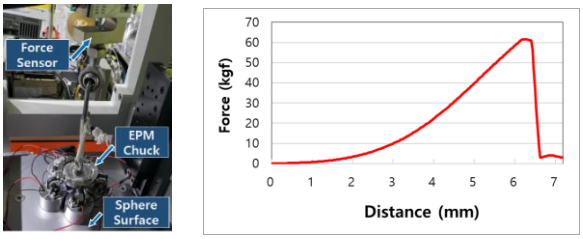

Figure 8. An experiment of the EPM chuck set on sphere surface

Figure 8 shows the curve-adaptive EPM chuck set fabricated by the proposed method and the holding force at 2.5m radius. The experimental result shows that the holding force is well maintained on the curved surface.

4. Summary

This paper designed and fabricated an EPM chuck set that can adapt a mobile machine to curved surfaces. To reduce the weight and size of the EPM chuck, several EPMs made of only AlNiCo magnets were connected. The experimental results confirmed that the proposed method is useful.

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