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Disassembly System using an Impact Hammer for the Material Recycling

Takanobu YOSHIDA*, Yoshiomi MUNESAWA*, Hirokazu OSAKI*,
Yasuhiro KAJIHARA* and Kazuharu OHTA*

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We developed the disassembly system that uses the impulsive load and disassembly tools to disassemble used appliances economically. The main components of this system are impulse hammer, a lift table and developed disassembly tools. Several types of disassembly tools are developed to punch out fastened portion on a part and cut off the shaft of screw or connection pin of IC-chip. A simulation model is proposed to explain and formulate how the fastening point of product is broken and cut. Three kinds of disassembly tools are designed. The actual disassembly system is developed by using proposed simulation models and disassembly tools.

1. INTRODUCTION

Disassembly has been attracting worldwide attention not only for the purpose of protecting the influence in terms of the environment but also for constructing a recycling society in next century. We should pay special attention to personal computers since the amount of abandoned personal computers has drastically been increasing for the sake of frequent model changes.[1] Most of disassembly works have been executed manually by using assembly tools. These works has several problems, for instance, increment of a disassembly cost and decrement of workers' health condition by dusty and rusty parts. So, an automated disassembly system is required for solving the above-mentioned problems.

In this research, we propose a disassembly system which makes it possible to disassemble product in a short time. Firstly, a simulation model is formulated to explain how fastening point of product should be punched out and cut off. Secondly, special disassembly tools are designed for the personal computers. Finally, a disassembly system is developed, which uses an impact hammer for punching out and cutting off the fastening point in an instant.

2. PROPOSED DISASSEMBLY SYSTEM

We propose a method to break the fastening point by using disassembly tool attached to an impact hammer. An impact hammer gives an impulsive load to the fastening point such as screw and rivet, and breaks them.

2.1 Disassembly Device

The disassembly device is composed of an impact hammer and disassembly tools. This device gives an impulsive load intensively to the fastening point so that the fastening point will be broken up. Intensive impulse load

* Department of Systems Engineering

easily makes the fatigue-fracture of the fastening point with small load. As this effect is utilized, the fastening point such as screw and rivet are speedily destroyed and removed without cutting.

2.2 Simulation Model of Punching or Cutting Load at Fastening Point

Various fastening methods, such as the screw, rivet, and the solder, are used to fasten the parts and units in computer. So the punching or cutting load at the fastening point should be formulated to design disassembly tools.

2.2.1 Symbols

- ω : Distortion of fastened portion.
- Q : Shearing force generated by the load (P_B).
- D : Flexural rigidity of fastened portion.
- h : Thickness of fastened portion.
- z : Distance from surface of fastened portion to the center of thickness.
- σ_{Yp} : Yield stress of fastened portion.
- ν : The Poisson ratio.
- a : The radius of the shaft of the screw.
- b : The largest radius of the area where the head of the screw is touched.
- c : The smallest radius of the area which is not transformed by the stress.
- S_Y : The cross-sectional area of the shaft of the screw, which is cut by the load at one time.
- S : The cross-sectional area of the shaft of the screw.
- σ_{Yc} : Shearing stress of the shaft of the screw.
- C_0 : The amount of the cutting depth until last time.
- C_1 : The amount of the cutting depth of this time.
- w : The width of one connection pin of IC-chip.
- t : The thickness of one connection pin of IC-chip. Where, size (t) is less than size (w).
- σ_{Ys} : Shearing stress of one connection pin of IC-chip.
- α : The angle of tip of the disassembly tool.

2.2.2 Force to punch out fastening point

We make a model that the fastened portion under the screw is destroyed by the force (P_B) loaded at the head of the screw in **Fig.1**. The screw is punched out from fastened portion by the impulsive load. The load of thousands times per minute is loaded by the impact hammer. It is regarded as a repetition of the static load in order to simplify the calculation process. It is assumed that fastened portion is transformed plastically by the load of every one time without fail.

As the screw is punched out, the deflection quantity ω is given by solving the **eq. (1)**.[2]

$$\frac{d}{dr}\left[\frac{1}{r}\frac{d}{dr}\left(r\frac{d\omega}{dr}\right)\right]=\frac{Q}{D} \tag{1}$$

As the stress corresponding to the deflection quantity ω satisfies the yield condition of Mises, the fastened portion is transformed plastically. The load (P_B) is obtained considering the yield condition of Mises, which is given by **eq. (2)**.

$$P_B > \frac{h^3}{12z}\frac{\sigma_{Yp}}{\dfrac{(1+\nu)(1-\nu)\left(b^2-c^2+2c^2\ln\left(\dfrac{c}{b}\right)\right)}{8\pi\left(c^2(1-\nu)+a^2(1+\nu)\right)}\sqrt{1+3\dfrac{a^2}{r^2}}} \tag{2}$$

As the load (**PB**) is forced repeatedly to the head of screw, plastic deformation of the fastened portion is progressed, and the screw is punched out finally.

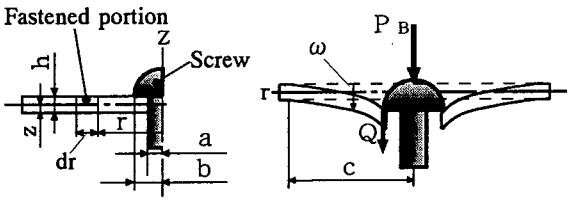

Fig.1 Model of punching out the fastened portion

2.2.3 Force to cutting off fastening point

We make a model that the shaft of screw is cut off by the force loaded from perpendicular direction of the shaft. Central axis of the screw or rivet is assumed to be parallel to **X** axis. The direction of gravity is parallel to **Z** axis. The load is given from the direction of gravity. Additionally, it is assumed that the fastened portion and the head of the screw are not transformed by the load. Under the above mentioned assumption, the head of the screw is pressed by the disassembly tool from vertical direction. The shaft of the screw is cut little by little by repetitive load. The shearing force (**PC**) is represented by **eq. (3)**.[3] **(Fig.2)**

$$P_c = \sigma_{Yc} S \tag{3}$$

As the cutting depth progresses by repetitive load, the amount of cross-sectional area (**SY**) is shown by **eq. (4)**, which is cut by the load at one try in **Fig.3**.

$$S_Y = \int_{a-c_1}^{a} 2\sqrt{a^2-y^2}\,dy - \int_{a-c_0}^{a} 2\sqrt{a^2-y^2}\,dy$$

$$= -(a-c_1)\sqrt{a^2-(a-c_1)^2} - a^2 \sin^{-1}\frac{a-c_1}{a}$$

$$+ (a-c_0)\sqrt{a^2-(a-c_0)^2} + a^2 \sin^{-1}\frac{a-c_0}{a} \tag{4}$$

The number of times (**n**) is obtained by **eq. (5)**, which is required until the shaft of screw is cut off.

$$n = \frac{S}{S_Y} \tag{5}$$

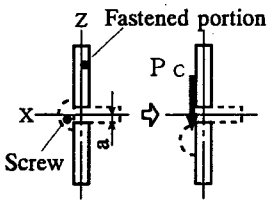

Fig.2 Model of cutting the shaft of screws

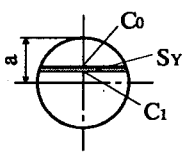

Fig.3 Cross-sectional drawing of the shaft

2.2.4 Force to separate IC-chip from a circuit board

We make a model that the IC-chip and capacitor are cut off at connection pins by the shearing force in **Fig.4**. As connection pins is pressed by the disassembly tool from perpendicular direction, the load (**Ps**) to cut off

connection pins is shown in **eq. (6)**.

$$P_s > m\sigma_{Ys}wt \tag{6}$$

The load becomes large, as the number of connection pin (**m**) of the IC-chip increase. So, the shearing angle (**α**) of tip of disassembly tool is sharpened in order to protect the loss of the shearing force. In the case, the cutting load (**P α**) is given by **eq. (7)**.

$$P_\alpha > \sigma_{Ys}\frac{t^2}{2\cos^2\alpha\sin\alpha} \tag{7}$$

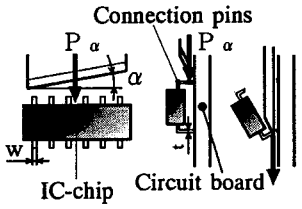

Fig.4 Model of separating the IC-chip

2.3 Design of Disassembly Tool

2.3.1 Design of disassembly tool to punch out fastened portion

The head of the screw is pressed by the disassembly tool from perpendicular direction, and fastened portion is destroyed. It is important that the tip of the disassembly tool should not slip from the head of screw. Moreover, it is necessary to adjust easily to the head of screw. Then, the shape of the disassembly tool is designed as follows.

The semicircular hole is bored at the tip of the cylindrical disassembly tool. The size of hole is enough to cover the head of screw. As the fastened portion is punched out, the disassembly tool is inserted deeply into the broken portion. There is a case that the destruction of fastened portion progresses more than necessary. So, the tool should be pulled up with the large force. Therefore, a cylindrical supplementary rim is attached to the disassembly tool as a stopper in **Fig.5**.

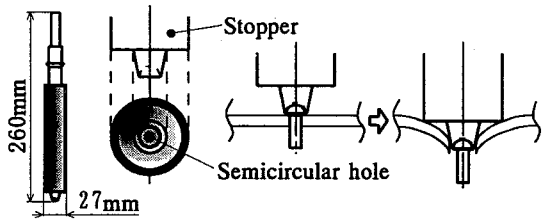

Fig.5 Shape of disassembly tool to punch out fastened portion

2.3.2 Design of disassembly tool to cut off shaft of screw or rivet

The slippage of disassembly tool from the screw might occur during an operation to cut off the shaft of screw. As the slippage is occurred, the load might not be efficiently transmitted to the shaft of screw. So, the hollow is made at the tip of the disassembly tool considering the shape of the head of screw. As the shearing force is not dependent on the thickness of the disassembly tool, the thickness is equivalent to the height of the head of screw. As the tip of the disassembly tool enters between the head of screw and fastened portion, the shearing power is dispersed. So the thickness of the disassembly tool is made not to be too thin in **Fig.6**.

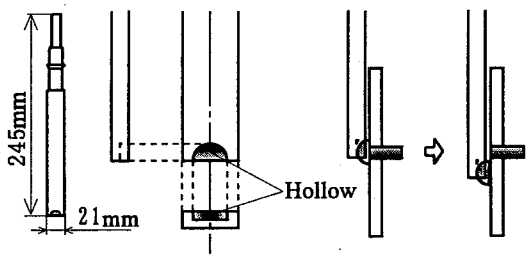

Fig.6 Shape of disassembly tool to cut off the shaft of screw or rivet

2.3.3 Design of disassembly tool to cut off connection pin of IC-chip on circuit board

The load should be given to connection pin as much as possible along the board so that the part of conductor should not be bent. Shearing angle of the tip of the disassembly tool is determined as follows. The cutting edge does not contact to large number of connection pin at one time, and give the impulsive load at the nearest point on the circuit board. **(Fig.7)**

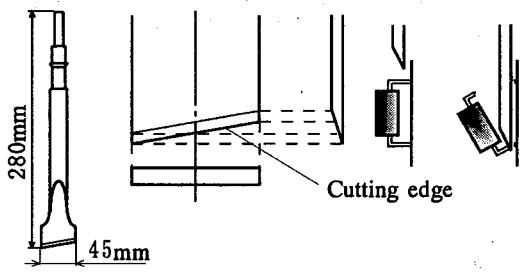

Fig.7 Shape of disassembly tool to cut off connection pin of IC-chip

2.4 Proposed Disassembly System Using Designed Disassembly Tool

The disassembly system is composed of following units in **Fig.8**. This system is composed an industrial robot with 6 D.O.F.[4]

(1) **Impact hammer and lift table**

The designed disassembly tool are attached to an impact hammer, which moves parallel to Z axis. This unit is named as the disassembly unit. This unit is set on a lift table, and the stroke in Z axial is extended by moving it.

(2) **Disassembly tools**

This is personally a part which contacts with fastening point. We designed three kind of disassembly tools. Disassembly works are executed by changing those tools, that is, punching out fastened portion, cutting off the shaft of screw or rivet, and connection pin of IC-chip on circuit board.

(3) **Robot with a Powerful Hand**

A disassembly subject is carried to the fixture by this robot. And the fastening point on disassembly subject is positioned to the tip of disassembly tool as this robot moves the fixture.

(4) **Fixture**

This unit is used to fix the disassembly subject for decreasing the loss of disassembly force and securing the safety of operators. The top and side of a subject is fixed by using the air clamping. And, this device can be moved parallel to X axis and Y axis.

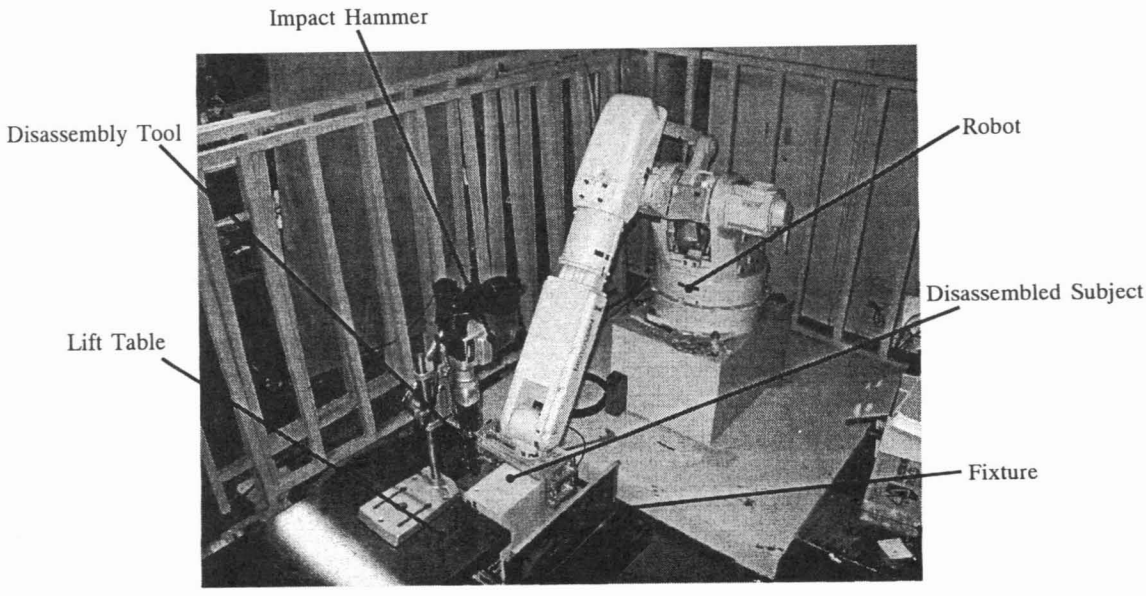

Fig.8 Proposed disassembly system using the designed disassembly tool

3. CONCLUSION

This research proposed a disassembly system using an impact hammer for the material recycling. Force to punch out the fastened portion and cut off shaft of screw and connection pin of IC-chip on circuit board are formulated by simulation models. And, three kind of disassembly tools are designed by using the simulation models. The disassembly system is constructed by using the proposed disassembly method.

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[4] YASKAWA Co., "MOTOMAN YR-K10" operating manual (1984)