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Study of Surface Roughness of Electronic Substrate on Abrasive Belt Grinding

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Abstract. Machining processing industries have continuously developed and improved technologies and processes to transform finished product to obtain better super finished product quality and thus increase products. Abrasive machining is one of the most important of these processes and therefore merits special attention and study. Indeed, grinding is the process of removing metal by the application of abrasives which are bonded to form a rotating wheel or belt. When the moving abrasive particles contact the workpiece, they act as tiny cutting tools, each particle cutting a tiny chip from the workpiece. The abrasive belt grinding is efficient, economic, widely used and being said “universal grinding”. It can get high machining accuracy and surface quality. Surface quality is a very important aspect of machining quality and it is the most important parameter to measure the surface quality. Many factors affect the surface roughness such as performance of abrasive belt, the amount of abrasive belt grinding, hardness of contact wheel. And the most important one is the amount of grinding. For electronic packaging, before soldering, copper substrates have to be polished by both chemical and mechanical polishing. Therefore, this article is aimed at that status so that to design and manufacture a new abrasive belt grinding machine. And then the surfaces for soldering of Cu substrates are ground and polished using the machine. Finally, the surface roughness of copper substrates polished by the abrasive belt grinding machine is evaluated and compared with other grinding machines.

1. Introduction

In mechanical machining, grinding is the one of the most important metal machining methods which is recently applied for high-tech grinders. Grinding process is typically used in the last machining process that creating a flat and smooth surface through abrasion. The process can attain accurate level 6-7, high surface smoothness (surface roughness level 7-8 and higher) and good surface quality. Up to now, grinding machines still account up to 30% of total machine tools and up to 60% in accurate mechanical industry. The principle of grinding that uses abrasive particles to cut a tiny chip from workpiece surface. Each abrasive particle coated in belt can comprehend as cutting tools like milling and turning cutter. Grinding is the multistage marching which particularly consists of coarse grinding stage and fine grinding stage [1]. In the initial stage with coarse grinding, this is preliminary machining step, metal removal takes place significantly but surface quality and accuracy level are poor.

To improve all above cons, at the next stage, machine will be used some different finer emery paper grades. In last fine grinding stage, with detailed machining process, workpiece has high-smoothness and required accuracy. Therefore, grinding is often used in last machining step in wood and metal machining industry. Recently, bench grinder is widely used in technology.
The evolution of the surface roughness has been studied from the very moment the abrasive wheel is freshly dressed until it stabilizes. A close relationship between the measured roughness and the radial wear of the wheel has been found. Furthermore, these days, with the breakthrough development of technology, machines are required to work with high accuracy and efficiency performance. In order to reduce labors and gain higher productivity, researches of improvement and innovation need to be conducted to meet those requirements [2-5].
To increase the efficiency of grinding, abrasive belt grinding machines are increasingly used. Abrasive belt grinding machines are typed of machine tools using abrasive feature of abrasive belt to grind the surface detail. The superiority of abrasive belt grinding machines is being proved more and more clearly nowadays. In addition to the obsolescence of grinding machines using flap disc due to their low productivity, flap disc is also easily unsafely breakable, changeable and requires regular adjustment. Particularly for the need of coarse grinding, workpiece processing after laser, plasma or oxygen-gas cutting, abrasive belt grinding machines show excellently preeminent metal removable performance (when using coarse abrasion belt P36, P60). Furthermore, with the large belt and significant working range, the flexibility of grinding products using this machine increases considerably comparing to the traditional grinding. Especially, regarding the plants where manipulating arms are used to operate shaping abrasion, grind and chamfer edges of huge workpiece quantity, it is such an ideal choice to apply abrasive belt grinding machines because their parameters are not affected by the impact of worn-out or shape-changing status of emery belt surface. Therefore, the operating program is simple, which needs no sensor to recognize abrasive flap rockiness and flap-fixing structure. As a result, abrasive belt grinding machines have been widely used in mechanical engineering, wood processing, furniture manufacturing and handicrafts creating, etc. Application for fine grinding, metal coarse grinding, stainless steel.
In addition, surface quality is a very important aspect of machining quality. Surface roughness is the most important parameter to measure the surface quality [6, 7]. Many factors affect the surface roughness, such as performance of abrasive belt, the amount of abrasive belt grinding, hardness of contact wheel. And the most important one is the amount of grinding. Also, in electronic packaging, lap-shear specimens that are prepared by soldering two copper (Cu) substrates using solder materials. Surface for soldering of Cu is very important for making good joints. In order to evaluate shear, creep and thermal fatigue behavior of solder joints for different solder alloys, the lap-shear technique has been widely used. The Cu substrates are previously cut with electrical discharge machining (EDM) according to a specific geometry, and then the surfaces for soldering are ground and polished using the belt grinding machine. Therefore, in this study, first, it designs abrasive belt grinding device, then uses the device for polishing Copper substrates that used in electronic packaging, and finally, analyses the surface roughness of Copper substrates to evaluate the efficiency of the device.

2. Methodology and experimental procedure

2.1. Design of belt grinding device
The methods of using hand grinders and bench grinders are low-cost but the surface quality of products is not ideal. Moreover, these methods are prone to serious accidents due to broken flap disc as mentioned above. Therefore, abrasive belt grinding is superior to improve flexibility, surface quality and users' safety. Through the systematic approach to optimize parametric setting such as work material properties, the grit, abrasive belt type, belt speed, contact wheel hardness, grinding pressure and so forth to obtain the required output and precision in abrasive belt grinding. Currently, in the world, abrasive belt grinding machines are widely applied not only in mechanical engineering but also in construction engineering, health, hard-material processing, especially wood and furniture manufacturing industry. Many international companies have produced and sold some kinds of abrasive

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belt grinding machines in the international market, however, in general, the function and flexibility of the products are not desirable; they are also high-cost.

As discussed above, the objective of this study is to design and produce a multipurpose abrasive belt grinding machine with low costs but high precision and efficiency and then the device is used for polishing Copper substrates in electronic packaging. To meet these requirements, by changing the rotating direction of abrasive belt on grinding bracket, the machine is used as a versatile grinder. Firstly, in order to save time, human input and also fabricating materials, it is necessary to use Solidworks software which can be designing and simulating overall mechanism. This software helps us to presume machine structure before manufacturing to consider dimensions and optimization that is compatible to design requirements. The overall model of belt grinding machine is shown in figure 1. All parts of the device are building in 3D space with accuracy dimensions.

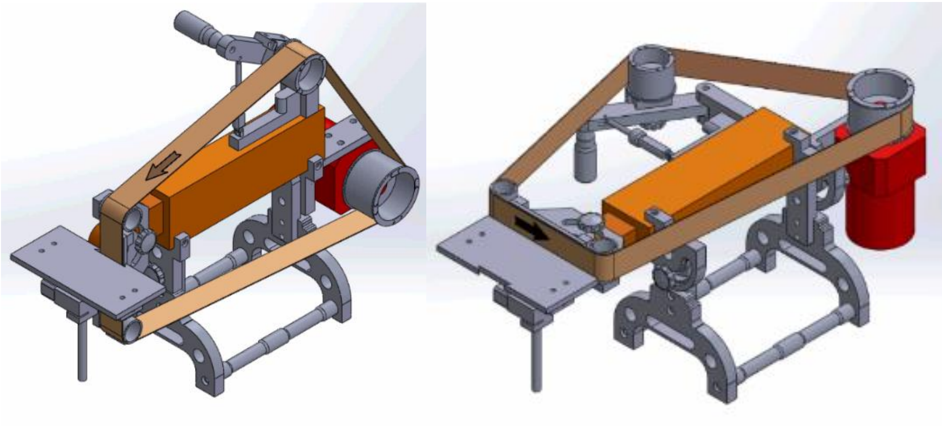


Figure 1. Belt grinding model.

The overall machine is modeling after using simulating software. The motor used in this machine is 3 phase AC motor because of low-price, simple operation and convenient maintenance. The motor shalf is mounted directly to roller. The specifications of motor are below:

- **MOTOR:** Yaskawa Electric
- Type: Induction motor
- Phase: 3, Volts: 200, Amps: 3.5/3.2 amp, HP: 1, RPM: 1420/1700, Hertz: 50/60, Poles: 4 Rating: Continuous
- Bearing No: 6205 ZZA (Max. RPM 18,000)

Roller is connected to motor shalf directly, when rotating motor shalf, this roller transmits power to other rollers through abrasive belt. To decrease the weight of machine, rollers is fabricated by aluminum material with diameter parameters alternatively which is D100, D60, 2*D40 (mm). Besides, the remaining parts of machine is fabrication by pipe and rectangular steel such as frame, tensioning part, grinding bracket.

For controller system, the controlling diagram of grinding machine is shown in figure 2. Variable frequency drive Schneider ATV12H075M2 is chosen to adjust 3 phase AC Motor speed. Up to now, VFD is applied for many machines in diverse fields, especially for industry and civil. The application of VFD is simple motor speed adjusting, low vibration boot, energy saving, overloaded motor protecting and high-performance increasing. VFD allows to adjust motor speed with the turn of knob(potentiometer). It also has an on/off power switch, start/stop switch and led signal light. Especially, it's compatible with a forward/reverse switch as an upgrade.

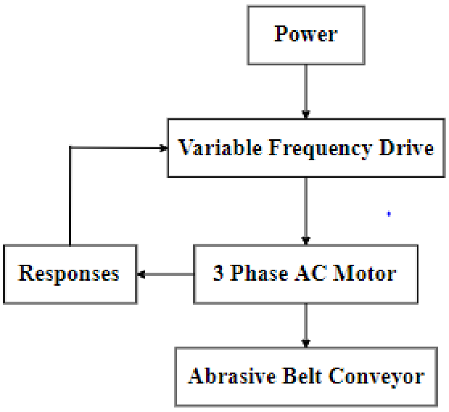
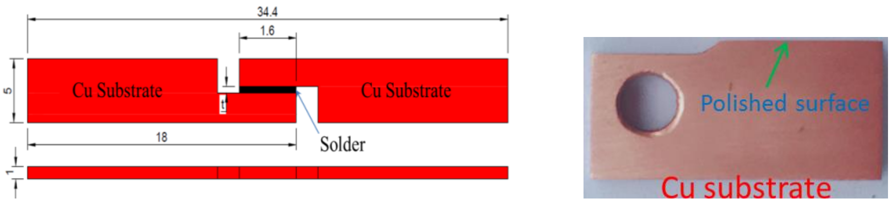


Figure 2. Grinding machine controlling system diagram.

2.2. Copper substrates for electronic packaging

In the study, the grinding device is used to polishing Copper substrates that used for lap-shear experiment as shown in figure 3. The lap-shear technique has been widely used to evaluate shear, creep and thermal fatigue behavior of solder joints for different solder alloys. A lap shear specimen is prepared by soldering two Cu substrates using solder materials. The Cu substrates are previously cut with EDM according to a specific geometry, and then the surfaces for soldering are ground and polished using the belt grinding machine. Finally, the impurities on the Cu substrates are removed by dipping them into 50% nitric acid for 20s and then quickly in acetone.



(a) (b)

Figure 3. The lap-shear joint specimen and Cu substrate for polishing.

3. Results and discussion

This research takes into account the effect of some process parameters of surface grinding process i.e. belt speed (rpm), and depth of cut on surface roughness with reference to copper as workpiece material. All other process parameters of surface grinding operation are kept constant. Due to its wide usage as a substrate material in electronic packages and scientific experiments, copper was chosen as the substrates. Therefore, this analysis is done to study the effect of input parameters on surface finish of copper in surface grinding operation. A variable frequency drive is used to vary the rpm (belt speed) of the grinding belt to three different values. A total of 9 experiments are done on each material by varying belt speed (rpm) and feed rate (mm/r). Later surface roughness of each specimen is checked using Mitutoyo Surface roughness tester with cut-off length as 0.25cm. Table 1 shows the experimental results for surface roughness of copper material at different technological parameters.

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Table1. The surface roughness of copper material after different technological parameters.

Exp. No.	Material	Speed n_w (rpm)	Depth of cut f (mm/r)	Surface Roughness Ra (μm)
1	Copper	1400	0.01	0.177
2	Copper	1400	0.02	0.185
3	Copper	1400	0.03	0.250
4	Copper	2000	0.01	0.145
5	Copper	2000	0.02	0.160
6	Copper	2000	0.03	0.173
7	Copper	2500	0.01	0.130
8	Copper	2500	0.02	0.147
9	Copper	2500	0.03	0.156

We can be seen from the table that with the improvement of workpiece rotate speed n_w, amount of metal into the cutting zone in unit time increases. Material removal rate increases, debris becomes thicken and grinding grooves increases, which leads to decrease of surface roughness. Indeed, when the speed increases from 1400 to 2000 (rpm) and the feed rate keeps constant at 0.01 (mm/r), the surface roughness decreases around 18% from 0.177 to 0.145 μm.

With increase in depth of cut, there is a proportional increase in the normal pressure at the point of contact of wheel and workpiece. Very less depth of cut will lead to less cutting and more rubbing due to small shear pressure or good toughness value of material. Large depth of cut will also lead to less cutting and more rubbing due to more wear, abnormal fracture and completely break-off of wheel grains. Thus, an optimum value needs to be determined depending upon material and machine/process parameters.

4. Conclusion

In this study, the belt grinding machine was designed and built. Then, some copper substrates that used in lap-shear joint specimen, were tested at different technological parameters of the machine to evaluate the surface roughness. The effects on work piece surface roughness brought by performance of abrasive belt work piece rotate speeds grinding depth and feed hardness of contact wheel and so on are studied in experiments. The results indicate that using the abrasive belt grinding can reduce the surface roughness of work pieces effectively and increase the efficiency of grinding process.

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