國立交通大學

機械工程學系

碩士論文

可攜式印表機列印模組設計

Design of Print Module on Mobile Printer

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中華民國九十四年六月

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摘要

本論文主要在研究使用熱轉印技術的可攜式印表機。近年來因為數位相機的普及，所以相片印表機的需求也日益增多。加上行動通訊的發達，市面上有愈來愈多的行動輸入裝置，例如手機或 PDA 等。然而小型印表機此種行動的輸出裝置，相對於輸入裝置則相當地少。現今愈來愈多廠商開始投入可攜式印表機的研發，由此看來可攜式印表機是未來直得發展的方向之一。

當設計可攜式印表機時，印表機體積及列印時間是兩個主要可攜式印表機的消費者使用需求。經由市場商品調查及專利分析後，可確定較符合以上設計需求的規格。在本篇論文中會提出幾個新的概念，這些概念將藉由一些機構的設計來減少使用的馬達，進而達到以上兩個需求。本文最後提供一個創新的列印模組機構設計，分析其此機構之可行性，並藉由原型的製作將此概念設計具體化實施。

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ABSTRACT

This study focuses on a mobile printer using thermal transfer printing technology. In recent years, since digital cameras are more and more common, the requirement of photo printer is increasing. In addition, because of the development of mobile communication, there are more and more mobile input devices such as PDA and cell phone on the market. However, the mobile output devices, such as small printer, are much fewer than input devices. Now there are more and more companies beginning to develop mobile printers. Therefore, it is worth to develop in the future.

When design mobile printer, size and printing time are the two main requirements of mobile printer for users. After product research and patent analysis, the objectives which are satisfied the requirements above can be confirmed. In the thesis, several new concepts are proposed, and these concepts use some mechanism design to reduce the number of motors used for achieving these two requirements. Finally, the thesis proposes one innovative mechanism design of the print module. Analyze the feasibility of the mechanism and embody the concept by prototype.

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Chapter 1 Introduction

1.1 Printers

Printer is one kind of output devices for computers. It can transfer the information in computer or the images in digital camera to documents or photos for people to read or preserve. Now there are many kinds of printing technologies, such as inkjet and laser, etc. In addition, the developing directions of printer are various. Besides the developments of higher image quality printing and the faster printing speed for general printers, mobile printer is also one important direction of printer developments in the future [1].

1.2 Motivation

Mobile communication is vastly growing recently. Obviously the information input devices, such as digital camera and cell phone, are more and more common [2]. Because the digital cameras are popular, traditional photograph is superseded by digital image gradually. Therefore, users need a display device to view the images. However, it still can not take the place of traditional photograph completely because people are used to view images by photographs for a long time [3]. As shown in Fig.1.1, the sales volume of photo printer is growing year by year. Therefore, users can print the images by themselves instead of go to the photograph store.

However, the development of output end of the mobile information transmission is slower than input devices. The proper printer with lightweight, compact, convenient, and mobile characteristics is harder to seem than general printer on market. At present, there are more and more companies noticing this market and more mobile printers are made.

Because the mobile communication is more and more popular, the demand of such a mobile printer is brewing and will be booming very soon. Therefore, people can carry a mobile printer with digital cameras. After take pictures by digital cameras, people can just print the photos outside to share the enjoyment right away.

As mentioned above, there are several popular full color printing technologies which can implement the photo printing purpose. However, when considering lightweight, lower power consumption and simple configuration among those technologies, thermal transfer printing technologies are applicable to reach the aim most. The reason will be illustrated in Chapter 2. Therefore, thermal transfer printing technologies are taken as the technology used in the print module of mobile printer in the thesis.

Most of the printers are very big and can just be put on the desk at home or office. Producing a mobile printer is harder than a printer for home or office use because the element size on mobile printer is smaller and it is necessary to reduce the number of motors for size reduction. Most of the motors in thermal transfer printer are used on the print module to drive the paper, ink ribbon and thermal print head. Therefore, the problem, how to reduce the number of motors in print module, has to be solved.

According to the reasons above, the purpose of this research is to reduce the number of motors used in print module and provide a new patentable design of print module on the mobile printer.

1.3 Thesis Organization

In this study, Chapter 2 is the literatures review which includes brief introduction of general printing technologies, the comparison of these printing technologies, marketing research and the configuration of thermal transfer printer. Chapter 3 introduces the requirements and the theory of “TRIZ” when designing the print module on mobile printer. Conceptual designs are introduced in Chapter 4. Chapter 5 presents the embodiment design of the chosen concept and the prototype. Chapter 6 shows the analysis of the final design to test the feasibility. Chapter 7 is conclusions and works.

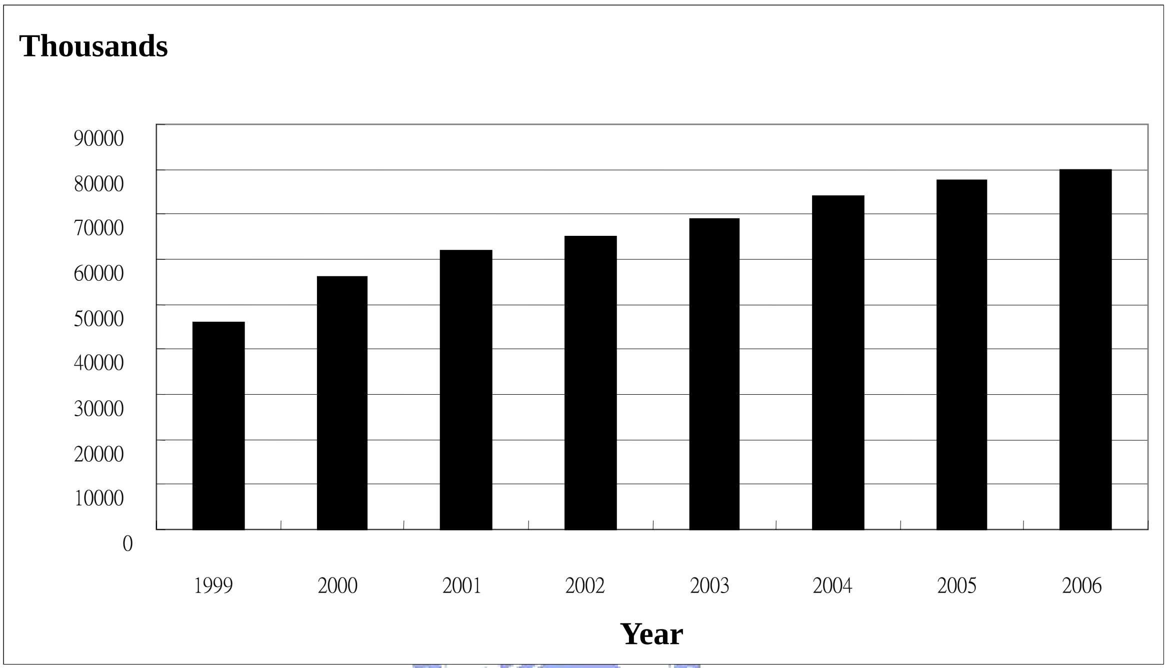


Fig.1.1 The trend of sales volume of photo printer [4]

Chapter 2 Literature Reviews

2.1 Printing Technologies

Now there are many kinds of printing technologies on market and the way to form images on paper is different to each other. Here are some introductions about these printing technologies.

2.1.1 Inkjet Print

Inkjet is the most common printing technology now. There are two different types, thermal bubble and piezoelectric, on inkjet printer. Different types of inkjet printers form droplets of ink in different ways.

Thermal bubble - Used by manufacturers such as Canon and Hewlett Packard, this method is commonly referred to as bubble jet. As shown in Fig.2.1, in a thermal inkjet printer, tiny resistors create heat, and this heat vaporizes ink to create a bubble. As the bubble expands, some of the ink is pushed out of a nozzle onto the paper. When the bubble pops (collapses), a vacuum is created. This pulls more ink into the print head from the cartridge. A typical bubble jet print head has 300 or 600 tiny nozzles, and all of them can fire a droplet simultaneously.

Piezoelectric - Patented by Epson, this technology uses piezo crystals. As shown in Fig.2.2, a crystal is located at the back of the ink reservoir of each nozzle. The crystal receives a tiny electric charge that causes it to vibrate. When the crystal vibrates inward, it forces a tiny amount of ink out of the nozzle. When it vibrates out, it pulls some more ink into the reservoir to replace the ink sprayed out [5].

2.1.2 Laser Print

The process of forming images in laser printer can be divided into six steps.

Step 1: Drum preparation - In preparation for printing, the drum must be cleaned to remove any traces of previous pages. First, a rubber blade wipes the excess toner from the drum, and then erase lamps (in older models) or a charged drum (in newer models) electrostatically clean it by neutralizing residual electrical charges on it.

Step 2: Drum writing - The data in the printer's memory is written to the drum using a laser. Rather than writing it with ink or toner, however, it writes by shining a very precise laser on the photosensitive drum in certain spots, changing the electrical charge in those spots. As the drum cylinder rotates past the laser, it sweeps across the surface, turning on and off to neutralize certain areas to about -100V. These neutralized areas will be the spots where toner adheres to the drum later in the process and then transfers to the paper.

Step 3: Paper feed - Feed rollers draw the paper into the printer from the paper tray. Registration rollers hold the paper until it's time for it to be released.

Step 4: Toner pickup - Steps 3 and 4 occur more or less simultaneously. As the paper is being drawn in, the toner is being applied to the drum.

The toner cartridge contains a rotating, magnetic, metal-developing cylinder, a toner reservoir, and a height control mechanism that limits the amount of toner the cylinder can pick up at a time. Toner consists of plastic resin particles (the particles that melt to produce the image on paper) and iron oxide (the particles that are affected by magnetic attraction and electrical charges). The toner's metal particles adhere to the magnetic cylinder, and the cylinder presents the toner to the drum as it passes by.

Step 5: Toner transfer to paper - At this point, the image exists on the drum, complete with toner. As the paper feeds into the printer, the transfer corona applies a positive charge to the paper. When the paper passes by the drum, the -100V charged toner on the drum jumps off onto the positively charged paper. Then, the paper runs past a static charge eliminator, which is a row of teeth with a negative charge that reduces the paper's highly positive charge.

Step 6: Fusing the toner to the paper - The image is on the paper, but it's not secure there; it's just loose toner held in place by gravity and a weak electrostatic charge. For permanent application, it must be fused. Fusing is basically melting the toner's particles so that they stick, or fuse, to the fibers in the paper.

Fig.2.3 and Fig.2.4 show the components of laser printer and the paper path while printing [6].

2.1.3 Dye Diffusion Thermal Transfer

Dye diffusion thermal transfer (D2T2) is one kind of technology using thermal sensitive ink for printing. There are some aliases such as dye sublimation or thermal dye transfer.

As shown in Fig.2.5, while printing, paper rollers and ink ribbon rollers rotate, and the line velocity of the paper is the same with ink ribbon. At the same time, the thermal print head is pressed against the platen roller. The ribbon with yellow, magenta, cyan dyes and an overcoating will sublimate to vapor because of the heat generated from the thermal print head, and then be absorbed by the coating on the special paper step by step. Since each heating element on thermal print head can generate 256 gradients of heat and there are three different colors of dye, D2T2 can print a colorful image with 16 million colors. Besides, compared with other print technologies, there is an overcoating on the photo printed by D2T2. Therefore, the photo preservation is easier and there is a better resistance to ultraviolet, water, or dirt. There are three steps during the printing process [7].

Step 1: Ribbon Searching – Before printing, the ribbon must be located at the initial position for the whole printing. As shown in Fig.2.6, the paper is at the opposite side of the printer at this time. The ribbon rollers rotate to search the initial position of the ribbon. During this step, the tension of the ribbon is in a loose state.

Step 2: Paper Feeding – As shown in Fig.2.7, the paper is drawn into printer by capstan roller and passes through the platen roller to the other side. At this time, the ribbon rollers are fixed.

Step 3: Printing – As shown in Fig.2.8, when the ribbon is ready for printing, thermal print head will be pressed against the platen roller and ink ribbon will attach to the paper on the platen roller. Then ink ribbon rollers and capstan roller begin rotating simultaneously in the same line velocity to form monochromatic image on the paper.

After the monochromatic image is formed, the thermal print head will be raised and the paper will be rewound to the state before printing for the next color printing until all the dyes of yellow, magenta, cyan and the coating are printed on the paper.

2.1.4 Thermal Wax Transfer

Thermal wax transfer is also called thermal transfer. It typically consists of a donor, a receiver and a thermal print head. In the case the thermal print head has a fixed energy level and results in an approximately fixed dot size and constant density. This system is shown in Fig.2.9.

Thermal wax transfer printers operate with the same steps as dye diffusion thermal transfer printers to form images on papers and the configuration is almost the same. Thermal wax transfer printers use cyan, magenta, and yellow wax type of pigments instead of dye to produce images. Thermal wax transfer has a binary process. It means that for a given location on a page, either a lot of pigments are deposited or not. And various dithering techniques are used in order to create half tone level [8].

2.1.5 Variable Dot Thermal Wax Transfer

The working principle of variable dot thermal wax transfer is almost the same with thermal wax transfer. The difference is that in variable dot thermal wax transfer, the thermal print head is able to modulate energy. This results in a dot with a roughly fixed density but varying dot area and is shown in Fig.2.10. Consequently, dithering techniques used for traditional fixed dot size thermal transfer printing are not needed. Therefore, variable dot thermal wax transfer can modulate the dot size to form the gradation [8].

2.1.6 Continuous Tone and Half Tone

As shown in Fig.2.11 and Fig.2.12, for example, while generating a gradation from black to white, the printer with continuous tone can form the continuous color gradation because each dot has its own fullness of color. But in the printer with half tone, each dot has only one kind of color fullness, and it must use the dithering technique which is that there are lots of dots close to each other in a small area, and changing the density of dots to simulate the gradation. Therefore, the image quality of half tone can not reach the quality of continuous tone, especially when enlarging the photos.

For this reason, more dots per inch are needed in the printer using half tone to form clear images. But using continuous tone, 300 dots per inch is enough to form clear images. In above printing technologies, only dye diffusion thermal transfer is continuous tone. Variable dot thermal wax transfer is close to continuous tone, and the others are half tone [7].

2.1.7 Comparison with These Printing Technologies

Compared with inkjet, laser, dye diffusion thermal transfer, thermal wax transfer and variable dot thermal wax transfer, laser and inkjet are not fit for the requirements of mobile printer because the configuration of the laser printer is more complicated and inkjet needs larger space for the print head movement. Therefore, dye diffusion thermal transfer, thermal wax transfer and variable dot thermal wax transfer are better to use on the mobile printer.

Table 2.1 is the comparison of these three thermal printing technologies. In Preservation, all the three technologies are good because there is a coating layer printed on the photos, and the configurations of the three technologies are almost the same. In color performance, dye diffusion thermal transfer is the best because the way to form color gradation is continuous tone, and the performance of thermal wax transfer is inferior in the same dpi. As shown in Fig.2.13, the figures from left to right are printed individually on thermal wax transfer, variable dot thermal wax transfer and dye diffusion thermal transfer.

In continuous printing, thermal wax transfer and variable dot thermal wax transfer are better than dye diffusion thermal transfer because less energy is required to melt wax than to diffuse dye. Therefore, the thermal print head in dye diffusion thermal transfer may overheat while continuous printing. For the same reason, in power consumption, dye diffusion thermal transfer is higher than the others. Consequently, with the same power, thermal wax transfer and variable dot thermal wax transfer can print more pieces than dye diffusion thermal transfer.

Finally, in the cost, because the pigment (wax) and the receiver (paper) of thermal wax transfer or variable dot thermal wax transfer are less expensive than the corresponding things of dye diffusion thermal transfer, the cost of dye diffusion thermal transfer is higher.

According to the reasons above, variable dot thermal wax transfer and dye diffusion thermal transfer are the better printing technologies and both of them can be used in the future print module design because of the same configuration.

2.2 Marketing Research

There are many kinds and many types of printers on market. Here is an introduction about the mobile printers whose weight is about 1Kg or lower than 1 Kg.

2.2.1 CANON

Table 2.2 lists the four mobile printers of CANON on market. The specifications of four products are almost the same. The most differences between them are the print paper size and whether it can use the battery or not.

2.2.2 ALPS

There are three products of ALPS, PTMTL28, PTMTL27 and PTMTL14. (In Table 2.3) They are just the print modules. It seems that ALPS only produce the print module, not the whole printer.

2.2.3 Other Companies

As shown in Table 2.4, there are also other mobile printers made by other companies, such as SONY, PANASONIC, KODAK and FUJIFILM, etc. Both of SONY and PANASONIC have one product. And there are several mobile printers of KODAK, here list only one product because other products just support for different kinds of digital cameras. Besides, the mobile printer of FUJIFILM can print the photos taken by the camera on mobile phones. Users can use IrDA to send the photos from cell phone to the printer directly.

From Table 2.2 to Table 2.4, there are two things worth to notice. First, most of the mobile printers use dye diffusion thermal transfer. Only the products of ALPS and PANASONIC SV-20 use variable dot thermal wax transfer. Second, almost all the mobile printers are made by the companies which also made digital cameras. It means that these companies have also paid attention to the market of image output, not only the market of image input such as cameras.

2.3 The Configuration of Thermal Transfer Printer

As shown in Fig.2.14, a thermal transfer printer can separate into five subsystems, print module, paper feed, power supply, frame, control unit and user interface. Besides the control unit and paper feed, the main subsystem for the printing is the print module. It includes paper feed, thermal print head and ink ribbon modules.

2.3.1 Print Head Module

Print head module consists of thermal print head, platen roller, transmission means, motor, spring, platen roller and cooling means. The thermal print head is separated from the platen roller normally. While printing, the motor will rotate and the thermal print head will be pressed with the platen roller by transmission means. The spring will make the pressure uniform.

2.3.2 Ink Ribbon Module

Ink ribbon module consists of ink ribbon, ink ribbon cassette, tension limit means, motor and roller. While printing, the rollers will wind ink ribbon and tension limit means will keep the tension of ink ribbon and remain the line velocity of ink ribbon in a constant without changing by the radius of ink ribbon rollers increasing or decreasing.

2.3.3 Paper Feeding Module

Here the paper feed also need at least one motor for driving the paper rollers to draw the paper into printer.

As mention before, there are three times repeating from step 2 to step 3 to form the colorful image. In general thermal transfer printer, it may need three or four motors to drive the paper feed, thermal print head movement and wind ink ribbon. And using more motors will cause more power consumption and larger space. Therefore, how to drive all these three parts with fewer motors is important.

2.4 Remarks

1. Dye diffusion thermal transfer and variable dot thermal wax transfer are better choices for using on mobile printer.
2. Most of the mobile printers on the market use dye diffusion thermal transfer printing technology now.
3. Thermal print head module, ink ribbon module and paper feeding module are the main parts for the design of print module.
4. General thermal transfer printers use three motors to complete the whole printing process.

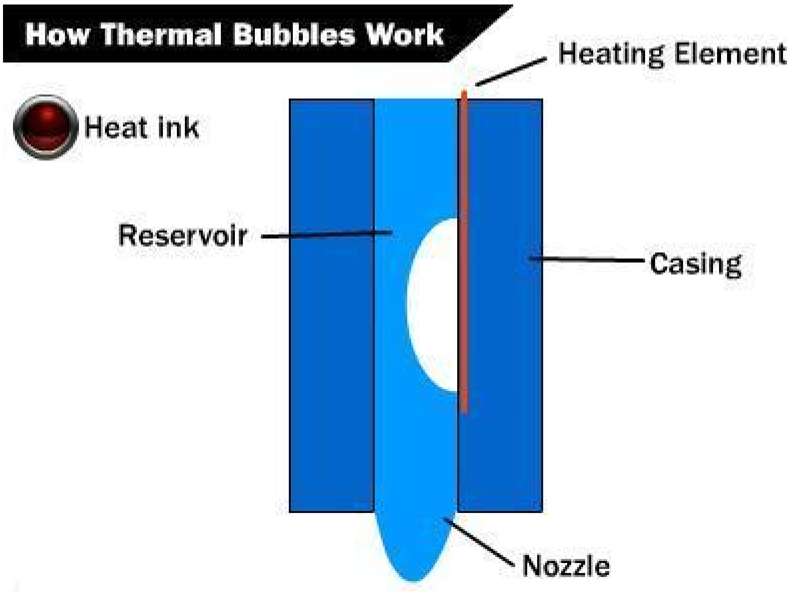


Fig.2.1 Inkjet - Thermal bubble [5]

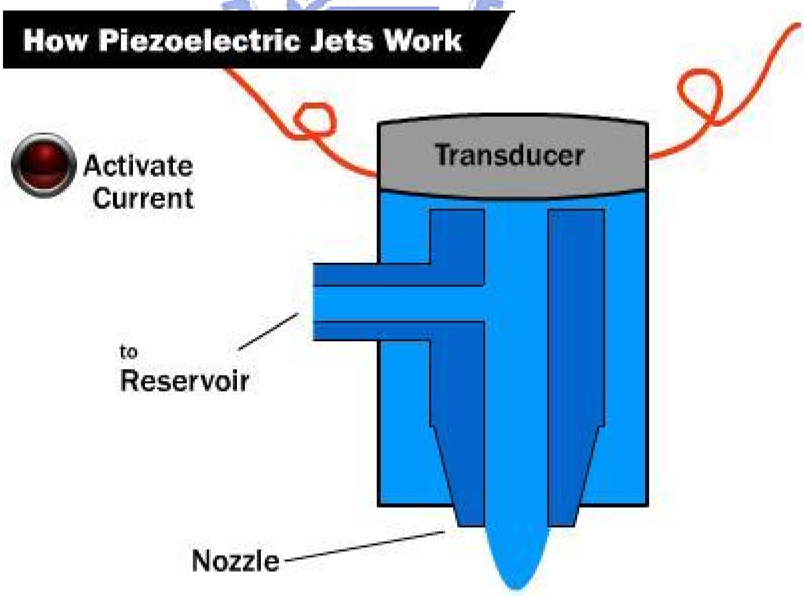


Fig.2.2 Inkjet – Piezoelectric [5]

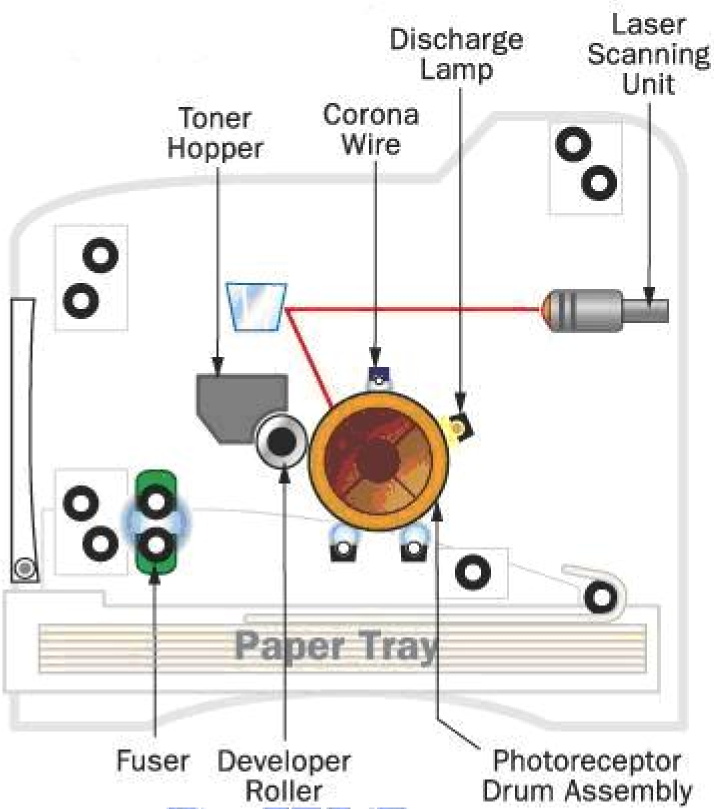


Fig.2.3 Basic laser printer components [6]

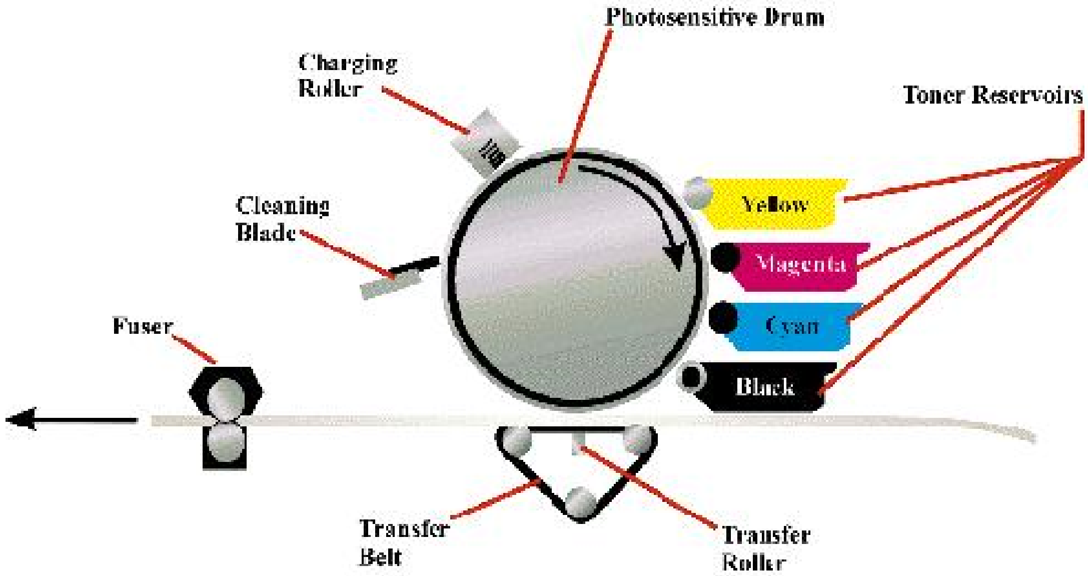


Fig.2.4 The path of paper in laser printer

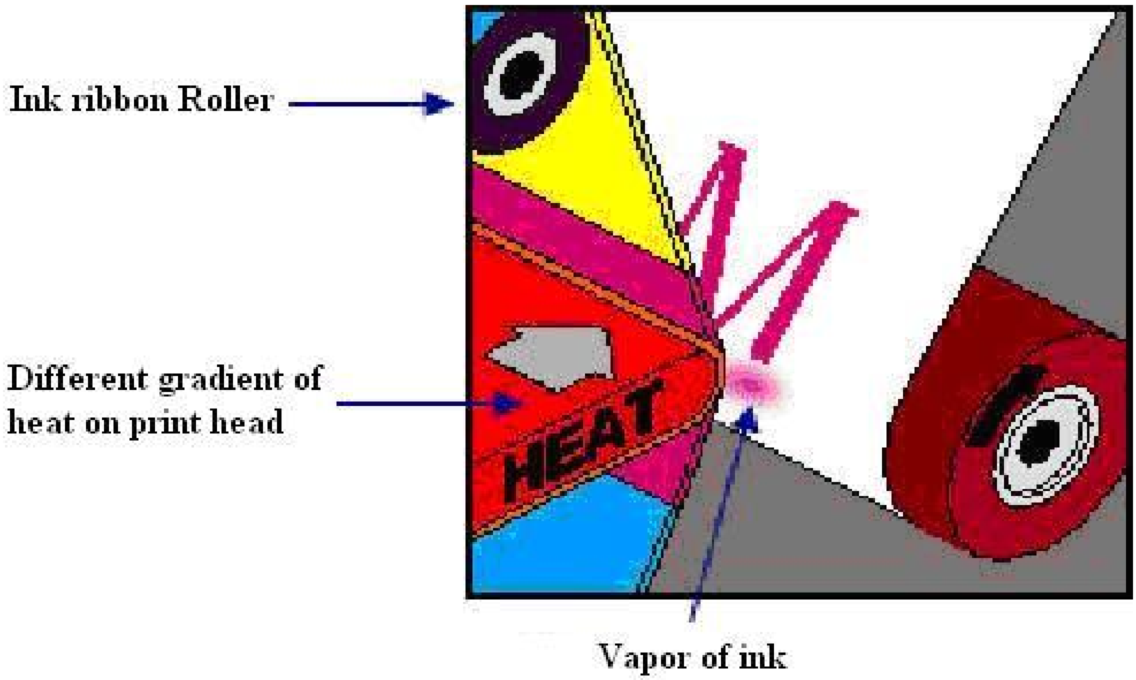


Fig.2.5 Dye diffusion thermal transfer [7]

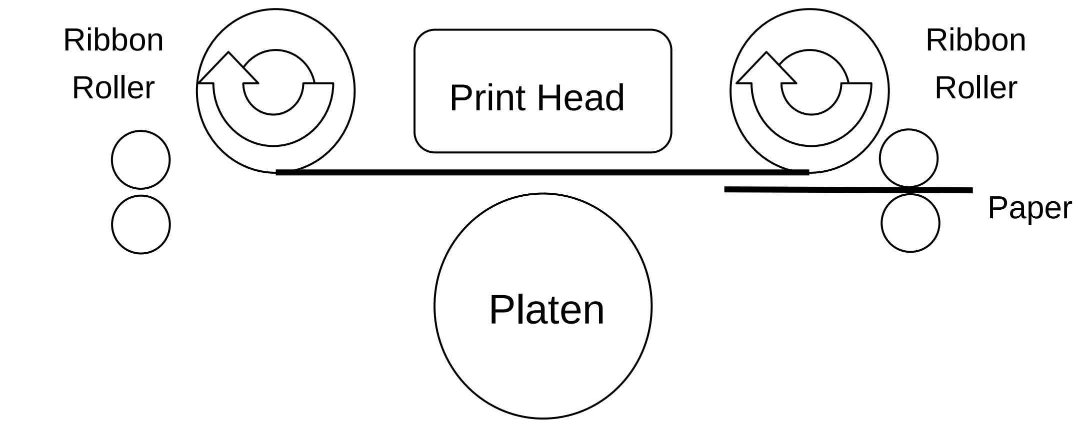


Fig.2.6 Step1 – Ribbon search in dye diffusion thermal transfer

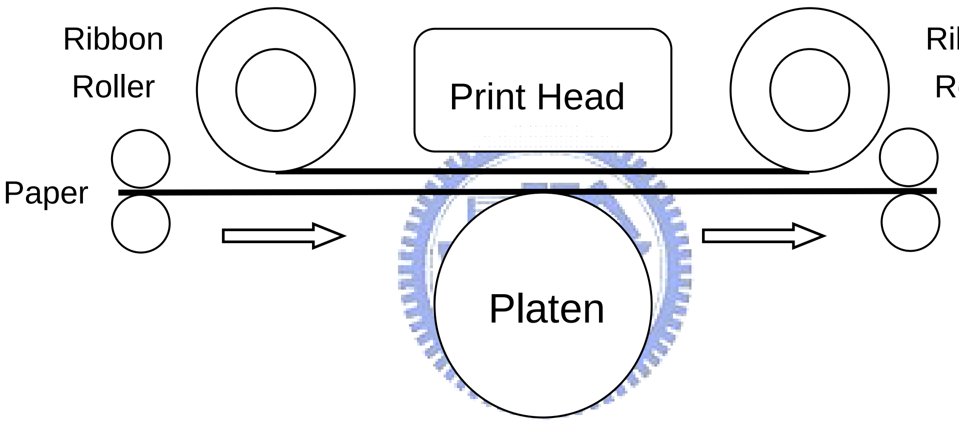


Fig.2.7 Step2 – Paper feed in dye diffusion thermal transfer

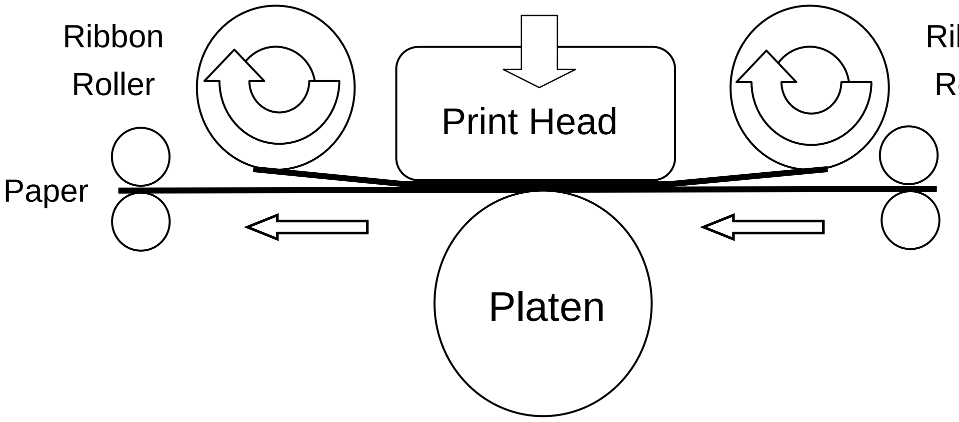


Fig.2.8 Step3 – Print in dye diffusion thermal transfer

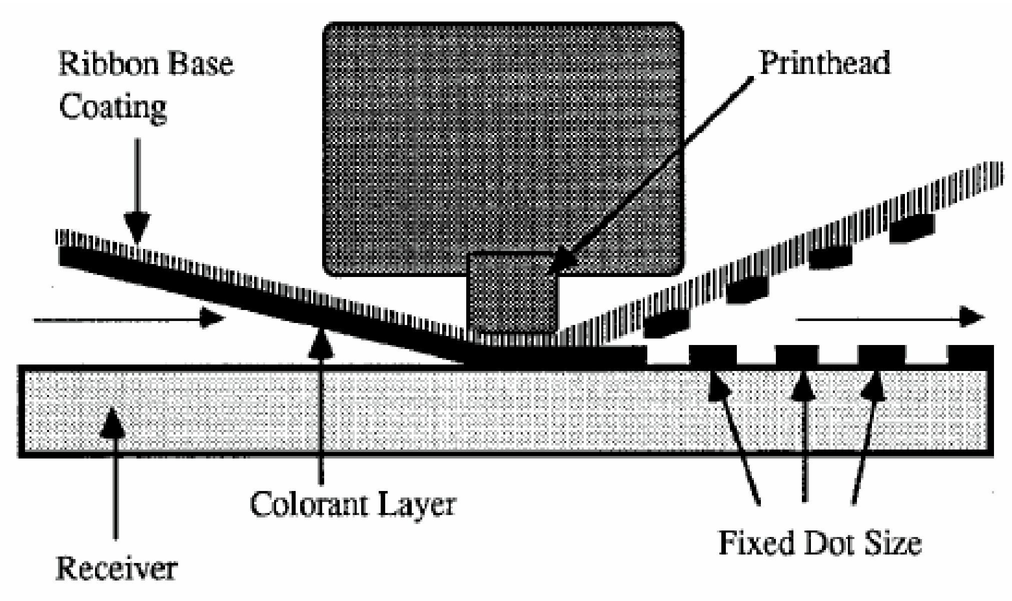


Fig.2.9 Thermal wax transfer [8]

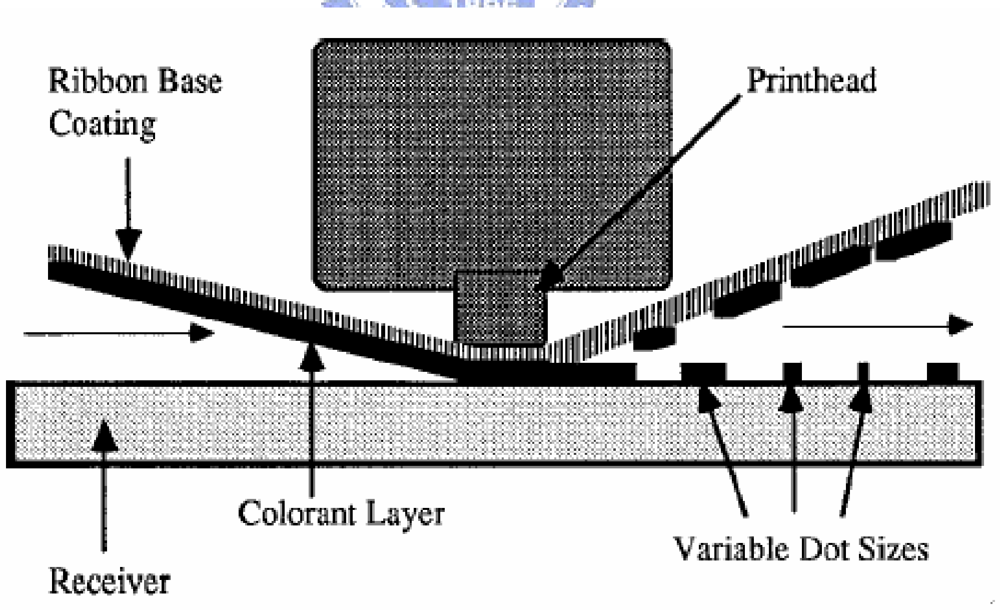


Fig.2.10 Variable dot thermal wax transfer [8]

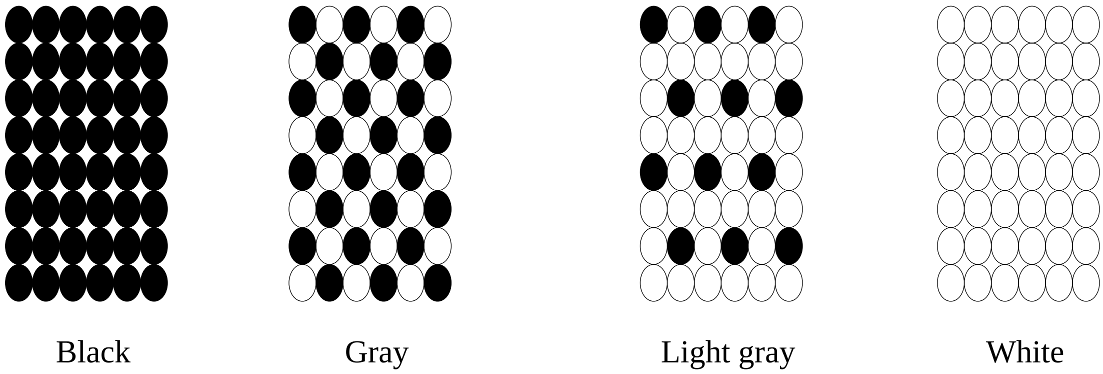


Fig.2.11 Dithering technique

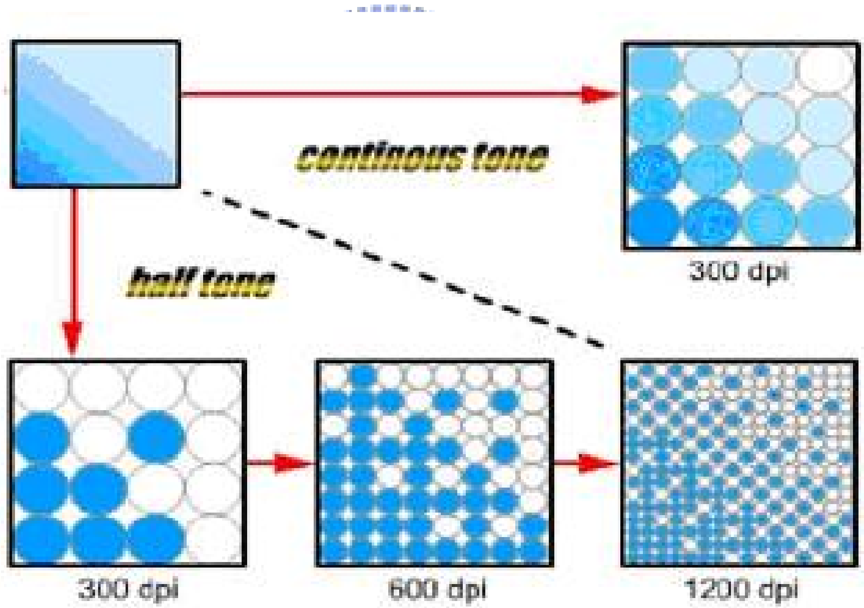


Fig.2.12 Fig. 2.12 Continuous tone and half tone [7]

Table 2.1 Comparison of thermal printing technologies

Technology / Function	Dye Diffusion Thermal Transfer	Thermal Wax Transfer	Variable Dot Thermal Wax Transfer
Preservation	Good	Good	Good
Configuration	Simple	Simple	Simple
Color performance	Best	Good	Better
Continuous printing	Bad	Good	Good
Power consumption	Higher	Lower	Lower
Cost	Higher	Lower	Lower

Fig.2.13 Portion of 300 dpi image printed on thermal printing technologies [8]

Table 2.2 Canon's products

Company	CANON	CANON	CANON	CANON
Model	CP-330	CP-300	CP-220	CP-200
Photo				
Printing Method	Dye Sublimation	Dye Sublimation	Dye Sublimation	Dye Sublimation
Physical Dimensions (W*H*D)	170x123x55 (mm)	170x55x123 (mm)	170x119x54.8 (mm)	170x119x54.8 (mm)
Weight(g)	860	860	820	820
Printing Time (sec)	Postcard Size: 85 Credit Card Size: 40 8-Mini Labels: 40 Wide Size: 106	Postcard Size: 85 Credit Card Size: 40 8-Mini Labels: 40	Postcard Size: 85 Credit Card Size: 40 8-Mini Labels: 40 Wide Size: 106	Postcard Size: 85 Credit Card Size: 40 8-Mini Labels: 40
Resolution	300x300 dpi	300x300 dpi	300x300 dpi	300x300 dpi

Table 2.3 Products of ALPS

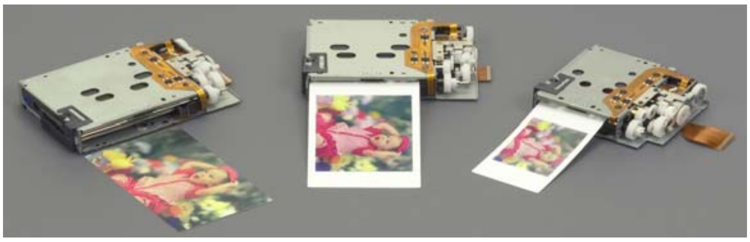
Company	ALPS		
Model	PTMTL28	PTMTL27	PTMTL14
Photo			
Printing Method	Variable Dot Thermal Wax Transfer	Variable Dot Thermal Wax Transfer	Variable Dot Thermal Wax Transfer
Physical Dimensions (W*H*D)	96.6x17.4x61.1 (mm)	88.6x17.4x61.1 (mm)	71.6x17.4x61.1 (mm)
Weight(g)	159	148	120
Printing Time (sec)	90	90	60
Resolution	290 dpi	254 dpi	203 dpi
Paper Size (mm)	85x54	91x55	69x38

Table 2.4 Products of other companies

Company	Kodak	Fuji Film	OLYMPUS	PANASONIC
Model	Printer Dock Plus	NP-1	P-200	SV-P20
Photo				
Printing Method	Dye Sublimation	N/A	Dye Sublimation	Variable Dot Thermal Wax Transfer
Physical Dimensions (W*H*D)	334x188x83 (mm)(with tray)	117.5x41.5x105.5 (mm)	121x52x153 (mm)	111.1x35x68.3 (mm)
Weight(g)	1110	250	830	267.86
Printing Time (sec)	60	40	90	95 sec/sheet (AC Adaptor); 120 sec/sheet (Battery)
Resolution	N/A	254 dpi	320 dpi	290 dpi
Paper Size (mm)	MAX: 184x102 MIN: 51x34	86x54	80x125.6	85.725x54

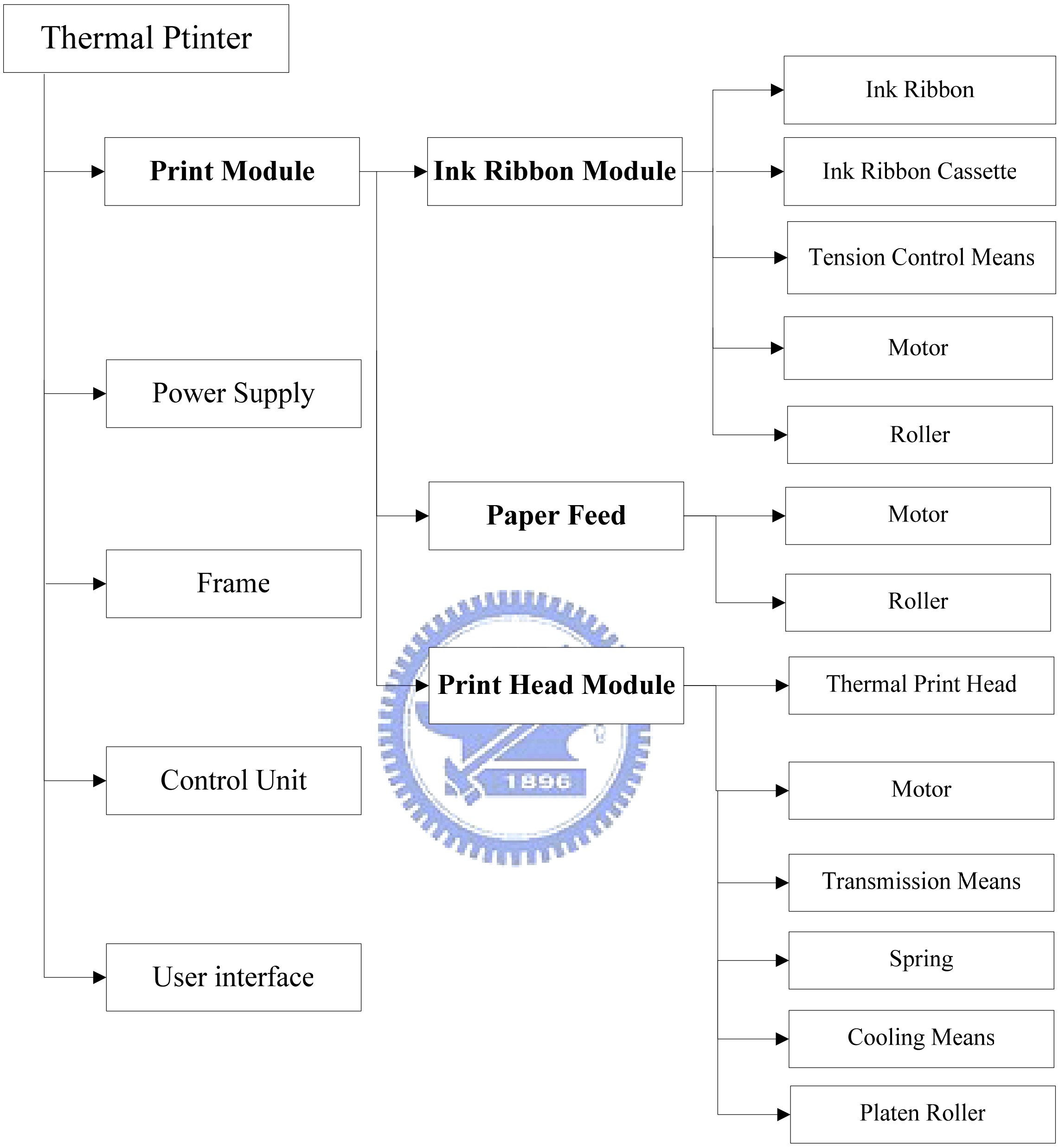


Fig.2.14 Subsystem of thermal printer

Chapter 3 Design Method and Requirements

3.1 TRIZ

3.1.1 Introduction of TRIZ

TRIZ, as a Russian abbreviation, is equal to "Theory of Innovative Problem Solving" (TIPS). And it was born in the second half of the twentieth century and developed by Genrich Altshuller and his colleagues. Now it is being developed and practiced throughout the world [9].

Before TRIZ, authorized thought about creative and human innovations was based on a paradigm that believed the creation as an unknown phenomena. But Altshuller believed that:

1. Creation is not an unknown and unreachable function.
2. Creation followed a special and achievable principles.
3. It is possible to do the inventions with non-inventor persons, if they learn the innovating principles and algorithms.

TRIZ research began with the assumption that there are universal principles of invention that are the basis for creative innovations that advance technology, and that if these principles could be identified and codified, they could be taught to people to make the process of invention more predictable. The research has proceeded in several stages over the last 50 years. Over 2 million patents have been examined, classified by level of inventiveness, and analyzed to look for principles of innovation. The three primary findings of this research are as follows:

- Problems and solutions were repeated across industries and sciences.
- Patterns of technical evolution were repeated across industries and sciences.
- Innovations used scientific effects outside the field where they were developed.

In the application of TRIZ all three of these findings are applied to create and to improve products, services, and systems.

3.1.2 The Foundation of TRIZ

This section provides a short introduction to some basic TRIZ tools. There are five ideas in TRIZ, technical systems, levels of innovation, law of ideality, contradictions and evolution of technical systems [10].

<u>Technical Systems</u>

Everything that performs a function is a technical system. Any technical system can consist of one or more subsystems. Each of the subsystems is also a technical system unto itself and each performs its own function. The hierarchy of technical systems spans from the least complex, with only two elements, to the most complex with many interacting elements. When a technical system produces inadequate or harmful functions, it may need to be improved. This requires the imaginative reduction of the system to its simplest state. In TRIZ, the simplest technical system consists of two elements with energy passing from one element to the other.

Levels of Innovation

Analysis of a large number of patents reveals that not every invention is equal in its inventive value. Altshuller proposed five levels of innovation.

- Level 1: A simple improvement of a technical system.
- Level 2: An invention that includes the resolution of a technical contradiction.
- Level 3: An invention containing a resolution of a physical contradiction.
- Level 4: A new technology is developed containing a breakthrough solution that requires knowledge from different of science.
- Level 5: Discovery of new phenomena

Altshuller concluded from his research that a large number of patents belong only to Level 1 and Level 2. Using TRIZ can help designers elevate the innovative solutions to Level 3 and Level 4.

Law of Ideality

The goal of any technical system is to provide some function. And the Law of Ideality means that the technical system can have the same functions without introducing any new mechanism or device into the system, and the system tends to become more effective, reliable and simple throughout its lifetime. There are several ways to make a system more ideal:

1. Increase the amount of functions of the system
2. Transfer as many functions as possible to that working element which produces the system's final action

3. Transfer some functions of the system to a supersystem or to the outside environment.
4. Utilize internal and external resources that already exist and are available.

<u>Contradictions</u>

Contradiction analysis is a powerful tool. As mentioned before, the most effective solutions are achieved when solving a technical problem which contains a contradiction. Contradictions can be divided into technical contradiction and physical contradiction. A technical contradiction occurs when designers try to improve one characteristic or parameter of the technical system and it causes another characteristic or parameter to worsen. Physical contradiction appears when two opposite properties are required from the same element of a technical system or from the technical system itself.

(A) Solving technical contradiction

After Altshuller analyzed more than 40,000 patents, he generalized 40 inventive principles [11]. Altshuller developed contradiction matrix in 1970s, the column and row of matrix include 39 features, as shown in Table 3.1. First process of this method is to find the parameter that designers want to improve in the column. Then find the relational harmful parameter in the row. The intersection of two parameters includes some useful principles. All 40 principles are common concepts, as shown in Table 3.2; and designers must use creativity to let these principles apply questions.

(B) Solving physical contradiction

The main technique of solving physical contradiction is "Separation": separate factors in different space or time. Use math model to describe as follows: assume physical contradiction has form like parameter $A > 0$, $A < 0$ at time $t = t_i$, position $X =$

(x_i, y_i, z_i) . The method is let $A > 0$ at time $t = t_j$, position $X = (x_j, y_j, z_j)$; $A < 0$ at time $t = t_k$, position $X = (x_k, y_k, z_k)$. This way can solve contradiction $A > 0$ and $A < 0$ simultaneously.

Evolution of Technical Systems

Altshuller established eight Patterns, or Lines, of technical systems evolution:

1. Life cycle
2. Dynamization
3. Multiplication cycle (Transition to Bi- or Poly- system)
4. Transition from macro to micro level
5. Synchronization
6. Scaling up or down
7. Uneven development of parts
8. Replacement of human (Automation)

Designers can follow the eight patterns to realize the trend of evolution and get some innovative ideas from the index of system evolution.

3.2 Requirements

Some requirements must be conformed when designing the print module on photo printer. For example, the number of motors, size, power consumption, cost, manufacture, etc. Because of the mobile requirement, the size and printing time are concerned at the beginning of design. Therefore, the requirements for size and printing time are indicated in this section.

3.2.1 Size

Size of Component

Compared with general printer, the components for mobile printer, such as gears, motor, thermal print head, must be smaller to satisfy the mobile requirement. During the design process, the size of these components has to be concerned.

In order to satisfy the requirement, the size of print head used here is about 64mm*22.45mm*5mm, and the module number of gear used in power transmission is 0.3.

Allocation

In mobile printer, most of the space is used for the paper in and ink ribbon cassette. Therefore, the space for drive mechanism is less oppositely. When considering the small size for mobile, the allocation for all the components is important.

Furthermore, motor is one of the components with large size and much weight. Because all the three main parts, print head module, ink ribbon module and paper feed, need the driving means, at least three or four motors are required in general. It results in the larger size of the whole printer. Therefore, how to drive the three parts and the allocation of drive mechanism with fewer motors must be concerned, too.

3.2.2 Printing time

Another important requirement of mobile printer is the printing time. If finishing one colorful printing costs too much time, users may complain the product and reduce the interest to buy the product. Here are two factors which will effect the total printing time.

Motor

Both the ribbon and paper are drawn by rollers which are driven by motors. Therefore, the rotational speed of motor is the main factor to effect the printing time. But the rotational speed of motor will be limited by the accuracy, the heating elements on print head, etc.

Mechanism

Most of printers use about three motors to drive the whole print module. Therefore, each module, for example, the print head module or capstan roller, is driven by independent motor and it will not spend too much time while changing steps. But when designing a small print module, it may use some mechanism to reduce the number of motors. Therefore, it may take some time for change steps.

From the requirements above, using some mechanism design to reduce motors may be the better way to satisfy the requirements. And it is the problem which should be solved first. After that, the allocation of whole print module, including the print head module, the ribbon cassette and the transmitting mechanism, can be decided.

3.3 Objectives

After the marketing research, the objectives for the print module on mobile printer have been decided.

1. **Size**: According to the present mobile printers, the average size is about 138mm*104.5mm*44mm, but the design of ALPS is smaller than other products. Therefore, the design of print module on mobile printer should be near or smaller to the size of ALPS products.
2. **Printing time**: Here ALPS PTMTL28 is the objective product. The printing time, 90s for one color photo print, is the objective value.
3. **Motors**: In order to increase the number of pieces which can be printed with charging the battery one time, the number of motors used in the print module must equal or less than two.
4. **Steps**: Fewer steps in the printing process can save more power and time. At least there should be 3 steps for printing, paper feeding and ribbon searching.

3.4 Remarks

1. TRIZ solves technical contradiction problems with contradiction matrix. 39 parameters and 40 principles are in the contradiction matrix. Principles are related to design parameters.
2. Space and printing time are the two main requirements for mobile at the beginning of design.
3. Motor reduction and driving mechanism are important to satisfy the requirements at the beginning of design.

Table 3.1 39 features of system

1. Weight of moving object	2. Weight of stationary object
3. Length of moving object	4. Length of stationary object
5. Area of moving object	6. Area of stationary object
7. Volume of moving object	8. Volume of stationary object
9. Speed	10. Force
11. Stress or pressure	12. Shape
13. Stability of the object's composition	14. Strength
15. Duration of action by a moving object	16. Duration of action by a stationary object
17. Temperature	18. Illumination intensity
19. Use of energy by moving object	20. Use of energy by stationary object
21. Power	22. Loss of energy
23. Loss of substance	24. Loss of information
25. Loss of time	26. Quality of substance/the matter
27. Reliability	28. Measurement accuracy
29. Manufacturing precision	30. External harm affects the object
31. Object-generated harmful factors	32. Ease of manufacture
33. Ease of operation	34. Ease of repair
35. Adaptability re versatility	36. Device complexity
37. Difficulty of detecting and measuring	38. Extent of automation
39. Productivity	

Table 3.2 40 principles

1	Segmentation	21	Skipping
2	Separtion	22	"Blessing in disguise"
3	Local quality	23	Feedback
4	Asymmetry	24	Intermediary'
5	Merging	25	Self-service
6	Universality	26	Copying
7	Nested doll	27	Cheap short-living objects
8	Anti-weight	28	Mechanics substitution
9	Preliminary anti-action	29	Pneumatics and hydraulics
10	Preliminary action	30	Flexible shells and thin films
11	Beforehand cushioning	31	Porous materials
12	Equipotential	32	Color changes
13	The other way round'	33	Homogeneity
14	Spheroidality - curvature	34	Discarding and recovering
15	Dynamics	35	Parameter changes
16	Partial or excessive actions	36	Phase transitions
17	Another dimension	37	Thermal expansion
18	Mechanical vibration	38	Strong oxidants
19	Periodic action	39	Inert atmosphere
20	Continuity of useful action	40	Composite structures

Chapter 4 Conceptual Design

4.1 Present Designs

In order to avoid infringing the present designs or products, searching related information is necessary. The patents about the mechanism of small printer using thermal transfer are very less. Many of the patents focus on the control system or the process of thermal transfer to form images on the paper.

General printers use more than one motor to control the whole print module for completing the printing process. As shown in Fig. 4.1 and Fig. 4.2, the mobile photo printer uses three motors (Number 41, 46, 48) [12]. But there is another mobile printer design worth to notice. It is the product of ALPS, as shown in Fig. 4.3 and Fig. 4.4 [13]. There is only one motor used in the printer design of ALPS. It uses a special cam gear *A* and two planet gears *B3* and *B4* to change the modes in printing process, as shown in Fig. 4.5 and Fig. 4.6. Besides, there are two differences between ALPS design and general printers. One is that the ribbon rollers in general ink ribbon cassette is far from each other, but the rollers in ALPS design are at the same side [14]. Therefore, the size can be reduced because the two spaces for ribbon in the ribbon cassette are combined into one space. Another difference between ALPS printers and general printers is that the print head is active and platen roller is fixed in normal printer, but in ALPS printers the print head is fixed and platen roller is active to be pressed against print head or leave print head.

Fig. 4.5 shows the shape of cam gear *A*. There are two recesses (*A1*, *A2*) and two ends of slot (*A3*, *A4*) worth to notice on cam gear *A* and two areas without teeth. Behind the cam gear, there are two cams, one for ribbon lever and another for platen roller. Fig. 4.6 shows that the lever *B* is concentric with sun gear *B1* and can swing up and down with it. On the lever *B* there are two planet gears (*B3* and *B4*) and one stud *B2* constrained in the slot of cam gear *A*. The sun gear *B1* drives capstan gear and capstan roller by transmitting gear train. Capstan roller drives paper in or out of the printer.

4.1.1 Steps of Printing Process in ALPS

Step 1: Ribbon searching – When ribbon searching, the upper planet gear *B3* tends to drive the cam gear *A* but the stud *B2* is stopped by the recess *A1* so that the planet gear *B3* does not engage the cam gear *A* and the cam gear stays. At this time, ribbon lever is rotated by the clockwise rotation of sun gear *B1* and the ribbon gear engages the gear which connects to ribbon roller to wind the ribbon. (Fig. 4.7)

Step Changing – After the ribbon is in correct position, the sun gear starts to rotate counterclockwise so that the stud *B2* leaves the recess *A1* of slot on cam gear and lever *B* rotates counterclockwise to let lower planet gear *B4* drives the cam gear *A*. Therefore, the cam gear *A* also rotates counterclockwise. (Fig. 4.8)

Step 2: Feeding Paper Forward – When the stud *B2* is around the second recess *A2* on cam slot, the sun gear *B1* rotates clockwise to let the stud get into the recess. At this step the upper end of ribbon lever is stopped by the ribbon cam behind the cam gear so that the ribbon gear can't drive the ribbon roller. Therefore, paper is drawn into the printer by capstan roller to detect the length of paper without driving ribbon (Same as the printing direction). (Fig. 4.9)

Step 3: Feeding Paper Backward – After detecting the length of paper, The sun gear *B1* rotates counterclockwise to change step from 2 to 3. When the stud *B2* arrives to one end of the slot *A3*, there is an area without teeth close to top side of cam gear and lower planet gear *B4* will enter the area. Therefore, the cam gear *A* will stop since lower planet gear *B4* can not drive it any more. Meanwhile the stud *B2* is at the end of slot causing the lever and cam both stay. At this time, paper is drawn by capstan roller in the opposite direction, and the ribbon lever is still stopped by the ribbon cam so that the ribbon won't be winded. (Fig. 4.10)

Step 4: Printing – While printing, the sun gear *B1* rotates clockwise to change step from 3 to 4. The stud *B2* follows the inner slot from the end of slot *A3* to the end of slot *A4* and the platen roller will be pressed against print head by the cam for platen roller behind the cam gear *A*. There is another area without teeth at middle layer of cam gear *A*. When the stud *B2* reaches the end *A4*, upper planet gear *B3* enters the area without teeth at the same time. Therefore, the cam gear will stop. After that, the sun gear B1 rotates clockwise continuously and ribbon gear on ribbon lever will engage the gear connected to ribbon roller. (Fig. 4.11)

4.2 Conceptual Designs

In this section, several conceptual designs of print module mechanism are proposed.

4.2.1 Concept 1

The concept 1 is shown in Fig. 4.12. It is similar to normal printer design, but ink ribbon roller and capstan roller are driven by the same motor. Therefore, there are only two motors used in the design.

The concept 1 can be divided into two sections. Section 1 is the transmission for paper and ribbon, as shown in Fig. 4.13. Section 2 is the transmission for print head as shown in Fig. 4.14. In section 1, gear *C* is connected to capstan roller for feeding paper and it always engages sun gear *A*. There is a planet gear *E* at the end of ribbon lever *D*. Gear *B* connects to ribbon roller.

Step 1: Ribbon Searching – While searching the correct position of ribbon, sun gear *A* is driven by motor and rotates clockwise. The ribbon lever *D* will rotate with sun gear *A* in the same direction. Therefore, ribbon gear *E* will engage gear *B* to drive the ribbon roller. (Fig. 4.15)

Step 2: Paper Feeding – After the ribbon gets in the right position, users put the paper into printer and motor rotates in the opposite direction so that ribbon lever *D* rotates counterclockwise because of the opposite rotating direction of sun gear *A*. Therefore, ribbon gear *E* disengages gear *B* and ribbon will not be winded while feeding paper into printer. (Fig. 4.16)

Step 3: Printing – When the paper and ribbon are both at the right positions, another motor *2* will act and the cam *F* will rotate 180 degrees to press the thermal print head against the platen roller. After that, motor *1* will rotate in the same direction of step 1 and ribbon gear will engage gear *B* to complete one color printing. (Fig. 4.17)

When one color is printed on the paper, motor 2 acts again and the cam E will rotate 180 degrees to release the print head. After print head released, the mechanism will change to step 2 to draw paper into printer again for the next color printing. When the three colors and one coating layer are printed, the whole printing process is complete.

4.2.2 Concept 2

Because of the requirement of power consumption, the motors should be reduced. But each part needs the energy to be driven. Therefore, there is a contradiction between the two characteristics. Table 4.1 shows that use the contradiction of these two characteristics, “Power” which is improved and “Use of energy by a moving object” which is getting worse, to find principles in the contradiction matrix. In the contradiction matrix there are four principles that can solve the contradiction.

Principle 6: Universality

Principle 16: Partial or excessive actions

Principle 19: Periodic action

Principle 37: Thermal expansion

Concept 2 is produced by using the principle 6. Fig. 4.18 shows there are two motors used in concept 2. Concept 2 can be separated into three sections. Section 1 is the power source. Motor *1* transmits power to compound gear *A*, as shown in Fig. 4.19. As shown in Fig. 4.20, section 2 is the step-changing device that consists of a motor *2*, a cam *C* and a rotating arm *B*. There are two small gears *D1* and *D2* which are fixed together and can rotate freely at the end of rotating arm *B*. Cam *C* and rotating arm *B* are fixed on the axis of motor *2* and gear *A* in section 1 can rotate freely on the axis of motor *2*. Gear *D2* engages the gear with smaller pitch diameter of gear *A*. Section 3 is the three step gears set. Gear *E* and gear *H* transmit power to ribbon roller. Gear *F* and gear *G* transmits power to capstan roller. Gear *H* and gear *G* are not fixed together and can rotate individually. (Fig. 4.21)

Step 1: Ribbon Searching – As shown in Fig. 4.22, motor *2* doesn’t act and the rotating arm *B* stays so that gear *D2* engages gear *E* and motor *1* can transmit power to ribbon roller.

Step 2: Paper Feeding – After ribbon searching, motor *1* stops and motor *2* acts to rotate rotating arm *B* about 90 degrees clockwise so that gear *D1* will engage gear *F*. Then motor *1* will act to transmit power to capstan roller. (Fig. 4.23)

Step 3: Printing – While Ribbon searching and paper feeding are done, motor *2* rotates 90 degrees again and gear *D1* and *D2* at the end of rotating arm can engage gear *G* and gear *H*. Cam *C* also presses print head against platen roller simultaneously because of the action of motor *2*. Then motor *1* act to transmit power to ribbon roller and capstan roller at the same time and complete one color printing. (Fig. 4.24)

After repeating the step 2 to step 3 for four times, the whole printing process is finished.

4.2.3 Concept 3

Concept 3 is generated by the innovative design method "SCAMPER check list" and the technique "Transfer" is used. In the manual gearbox of car, the clutch engages different gears to transmit power. And the printer design here is similar because there must be fewer motors used in printer design so that step-changing to complete the printing process is important. Therefore, this idea of gearbox in car is transferred into concept 3. As concept 2, concept 3 also uses a motor to switch the steps, as shown in Fig. 4.25. And it can be divided into three sections.

Fig. 4.26 shows section 1 is the power source of the printer. And the gears here are longer than general gears. Motor *1* can transmit power to gear *A*. Section 2 is the step-changing device, as shown in Fig. 4.27. The axis of motor *2* is longer than general motor and there is a spiral gear *B* fixed on it. There is also spiral shape in the inner side of Gear *C*. and the teeth at the two sides of gear *C* are sharpened so that gear *C* can shift along the motor axis to engage other gears. In section 3, shown in Fig. 4.28, there are three gears on the same axis and they can rotate freely and individually. Gear *F* connects to ribbon roller. Gear *E* connects to capstan roller and gear *D* connects to a cam that can press print head against platen roller or release it. Also, both sides of the three gears have to be sharpened.

Step 1: Ribbon Searching – At this time motor *2* acts and drives gear *C* to engage ribbon gear F. Then motor *1* acts to transmit power to ribbon roller and wind ribbon to right position. (Fig. 4.29)

Step 2: Paper Feeding – Motor *2* acts again and drives gear *C* to engage gear *E*, and motor *1* transmits power to capstan roller drawing paper into printer after gear *C* and gear *E* engage together. (Fig. 4.30)

Step 3: Pressing Print Head – After step 2 and 3, gear *C* is driven by motor *2* to engage gear *D*. And gear *D* will drive the cam (Not shown) to press print head against platen roller by the power transmitted from motor *1*. (Fig. 4.31)

Step 4: Printing – At this step gear *C* will be driven by motor *2* to engage gear *E* and gear *F*. And then motor *1* acts to draw paper and wind ribbon simultaneously for one color printing. (Fig. 4.32)

After one color printed, printer will go back to step 3, but this time cam will rotate 180 degrees to release print head, and then go back to step 2 drawing paper into printer again. Next, follow step 3 and step 4 to complete another color printing. After all the colors and coating are printed, the printing process is completed.

4.2.4 Concept 4

Concept 4 is also generated by using the technique "Transfer" of innovative design method "SCAMPER check list". Here the principle of the device to press or release print head is like a click ball-point pen. Fig. 4.33 is the 3D view of concept 4. Concept 4 can be divided into two sections.

Section 1, as shown in Fig. 4.34, is the device for pressing or releasing print head. There are two deformable arms *B1* and *B2* at one side and some teeth on the other side of component *B*. There is a bayonet on both of the deformable arms *B1* and *B2*, and a spring under compound *B*. One end is fixed on the printer frame and the other is fixed on the bottom of compound *B*. Compound *B* is fixed with print head (Not shown). Component *A* is an electromagnetic switch. The mechanism of section 2 is the same as section 1 in concept 1, as shown in Fig. 4.35. Gear *D* connects to capstan roller and gear *H* connects to ribbon roller. But there is a gear engaging sun gear *C* which connects to gear *I* in section 1.

The process for pressing or releasing print head

Fig. 4.36 is the state that the print head is released. In this state, the deformable arm *B2* is locked at the aperture of frame and spring is tensioned. While entering the step of printing, the electromagnetic switch *A* will push to the aperture and *B2* is deformed, as shown in Fig. 4.37. At this time, spring will pull compound *B* down and the teeth at the right side will engage gear *I*. In the state of Fig. 4.38, electromagnetic switch *A* will restore to the normal state, and spring is not pressed or tensioned, but gear *I* will rotate by the power of motor and continue to push compound *B* down. In the state of Fig. 4.39, deformable arm *B1* enters the aperture of frame and locked. The teeth on the right side of compound *B* don't engage gear *I* and spring is compressed. Print head is pressed against the platen roller in the state. If releasing print head, the process is opposite to the process of pressing print head.

Step 1: Ribbon Searching – In this step, section 1 is not active and the state of section 2 is the same as the step 1 of section 1 in concept 1. Ribbon gear *G* engages gear *H* and transmits power to ribbon roller. (Fig. 4.40)

Step 2: Paper Feeding – Section 1 is also not active, and the step is the same as step 2 of section 1 in concept 1, too. (Fig. 4.41)

Step 3: Printing – In this step, section 1 will follow the process of pressing print head. After that, motor will act and drive paper and ribbon simultaneously for printing. (Fig. 4.42)

For the next color printing, section 1 will release print head and section 2 will repeat step 2 to step 3 until the printing process finishes.

4.2.5 Concept 5

Fig. 4.43 shows the mechanism of Concept 5 which is similar to concept 2, but there is only one motor used. In the printer design of ALPS and the concepts above, they all use the clockwise or counterclockwise rotation of motor to drive ribbon roller and capstan roller. But in concept 5, one directional rotation of motor is used to drive ribbon roller and capstan roller, the other is used to change the steps.

Concept 5 can be divided into three sections. Section 1 in Fig. 4.44 is the device to control the power output transmitting to drive ribbon roller and capstan roller or to change the steps. There is a gear *E* rotatably jointed at one end of plate *B* and a component with gear teeth F fixed at the other end of plate *B*. There is a gear *G* rotatably jointed at the end of rotating arm *C*. The distance between component *F* and axis *D* is the same as the distance between gear *G* and axis *D*. And the axis of gear *G* and component *F* are coaxial. Plate *B* and rotating arm are fixed on axis *D*. Component *A* which includes two gears *A1* and *A2* can rotate about axis *D* and engage gears *E* and *G*.

Fig. 4.45 shows that section 2 consists of a cam, gear *H*, rotating arm *J* planet gear *K* and sun gear *I*. Gear *H* and cam are fixed on the axis. Planet gear *K* is jointed rotatably at the end of rotating arm *J*, and rotating arm *J* is fixed on one side of gear *H*. Sun gear *I* engages gear *K*.

Section 3 includes four gears, as shown in Fig. 4.46. Gear *L* and gear *N* can transmit power to ribbon roller and the other two gears *M* and *O* can transmit power to capstan roller. Gear *N* and gear *O* are fixed together. However, the paper will be drawn into printer when power is output from gear *M* and be drawn out when power is output from gear *O* because there is one more gear in the gear train connecting with gear *M* or the gear train connecting with gear *O*.

The way to change power output

The drawing at the down left of Fig. 4.47 is the mode to change step. The drawing at the down right of Fig. 4.47 is to output the power of motor to ribbon roller and capstan roller. While changing one step to another step, gear *A* rotates clockwise and plate *B* rotates in the same direction. Then gear *E* will engage gear *H* and rotating arm will rotate clockwise to change step. After the rotating arm reaches the right position, the sun gear *A* will rotate counterclockwise and bring drive plate *B* rotating in the same direction. Then gear *E* will disengage and gear *G* will engage gear *I*. At the same time, component *F* will engage gear *H* and fix it. Therefore, the power will be only transmitted to ribbon roller and capstan roller.

Step 1: Ribbon Searching – In this step, after motor transmits power to rotate gear *H* making the planet gear *K* engaging gear *L*, motor will rotate in the opposite direction transmitting power to ribbon roller. (Fig. 4.48)

Step 2: Paper Feeding – After motor drives rotating arm and make gear *K* engaging gear *M*, power can be transmitted to capstan roller and draw paper into printer. (Fig. 4.49)

Step 3: Printing – When ribbon and paper is ready, motor drive rotating arm again make gear *K* engaging gear *N*. At the same time, print head is also pressed by cam. Then power transmits from gear *K* to gear *N* and *O* to drive ribbon roller and capstan roller for printing. (Fig. 4.50)

As the concepts mentioned above, the design will repeat the step 2 and step 3 until three colors and one coating are printed.

4.2.6 Comparison

As shown in Table 4.2, there are three motors used in concepts 1 to 3 and only 1 motor used in concepts 4 and 5. Next, more steps in the printing process will take more time to form a colorful image. Concept 3 is worse than other concepts because it needs more steps for one color printing. Third, since there are some special components which need to be manufactured in concept 3 and concept 4, for example, the gears in concept 3 and component B in concept 4, the cost of manufacture are higher than other concepts. Fourth, besides the sensor to locate the length of paper, the position of ribbon or the position of mechanism, concept 4 needs an extra electrical device, the electromagnetic switch. Therefore, it will have higher power consumption.

Compare the five concepts about the power consumption, concept 1 to concept 3 need two motors to complete the printing process and concept 4 needs a electrical device. Only concept 5 uses one motor without other electrical device. For the reasons above, concept 5 is the better than the other four concepts. Therefore, concept 5 is chosen to be the design of print module.

4.3 Remarks

1. General printers use more than one motor to complete the printing process, but only one motor is used in the printer design of ALPS.
2. Concept 1 uses one motor to control pressing or releasing print head, another motor use to drive ribbon roller and capstan roller.
3. Concept 2 uses one motor to supply the power and the other motor to change steps and control the cam for print head at the same time.
4. As concept 2, one motor is used to supply power and the other is used to change steps in concept 3.
5. Concept 4 needs an electromagnetic switch to control print head pressed or not. Only

one motor is used in the design.

6. Concept 5 uses one rotating direction of motor to drive the capstan roller and ribbon roller, the other direction to change steps and control print head.
7. Concept 5 is better than other concepts because of the lower power consumption.

Table 4.1 Part of contradiction matrix

Characteristics		Characteristics that is getting worse				
		…	Brightness	**Use of energy by moving object**	Use of energy by a stationary object	…
Characteristics to be improved	⋮	…				…
	Energy spent by a stationary object	…				…
	Power	…		16, 6, 19, 37		…
	Loss of energy	…				…
	⋮	⋮	⋮	⋮	⋮	⋮

Table 4.2 Conceptual design comparison

Concept	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Number of motors	2	2	2	1	1
Steps	3	3	3	3	3
Manufacture	Easy	Easy	Hard	Hard	Easy
Other electrical Device	No	No	No	Yes	No
Power Consumption	High	High	High	High	Low

Fig. 4.1 Product of Olympus

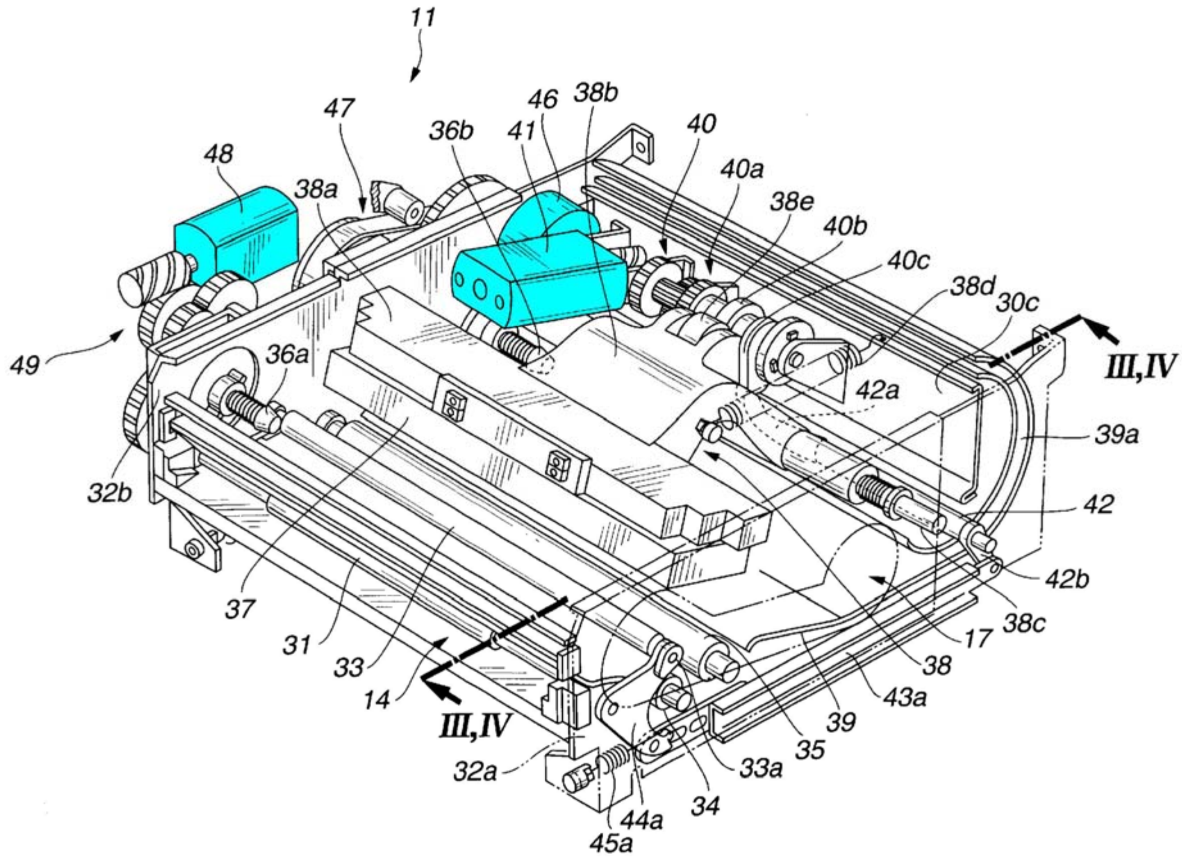


Fig. 4.2 The structure of Olympus product [12]

Fig. 4.3 Products of ALPS

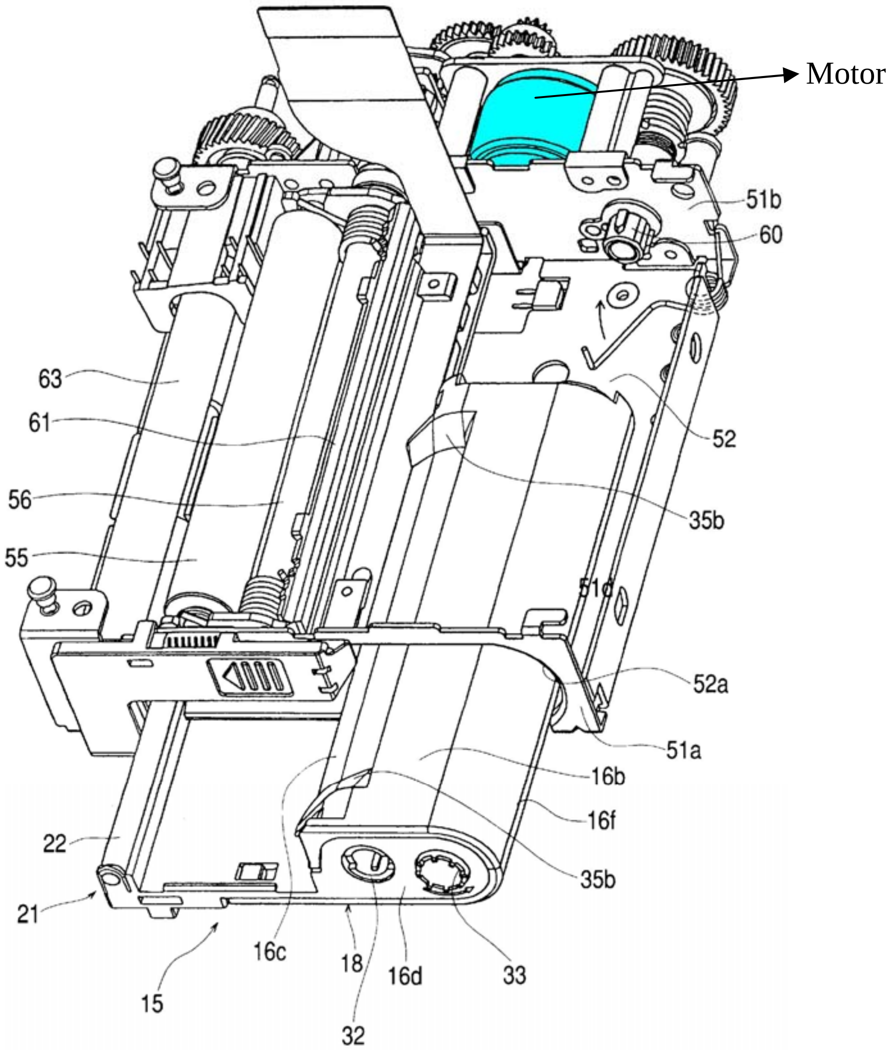


Fig. 4.4 Structure of ALPS product [13]

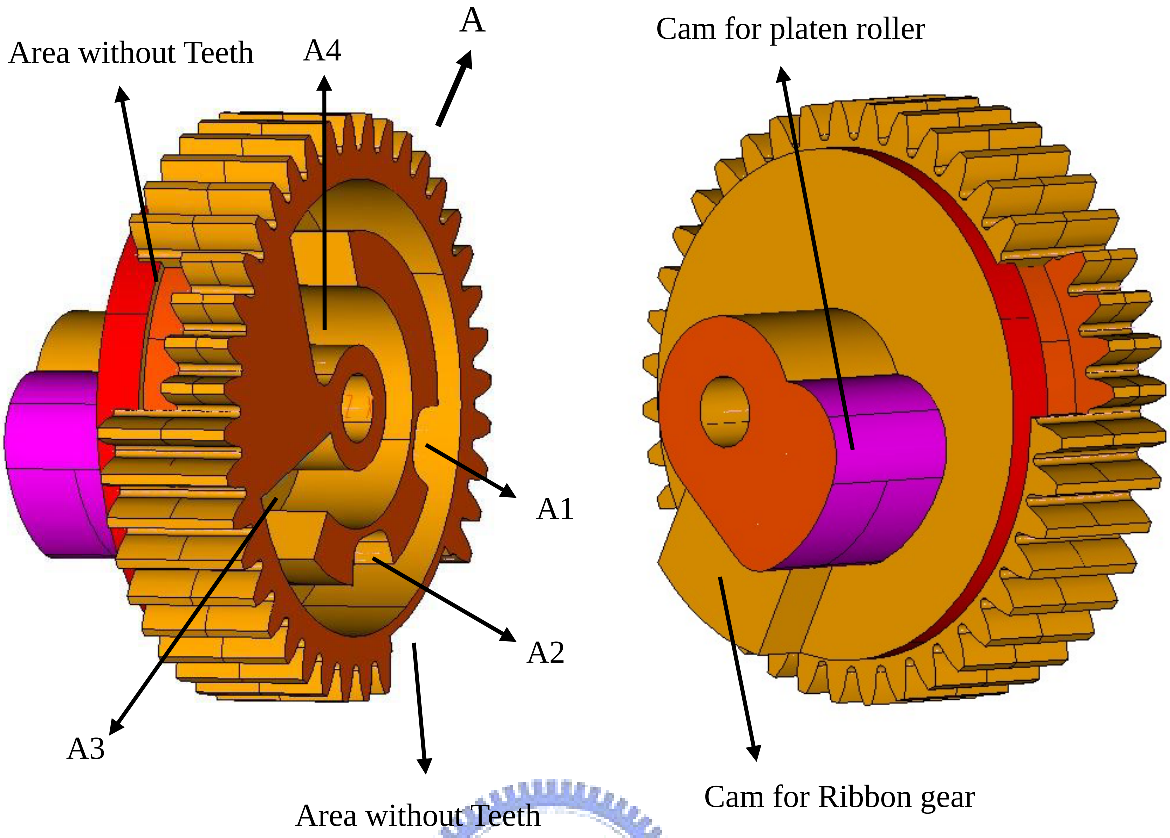


Fig. 4.5 Cam gear in ALPS design

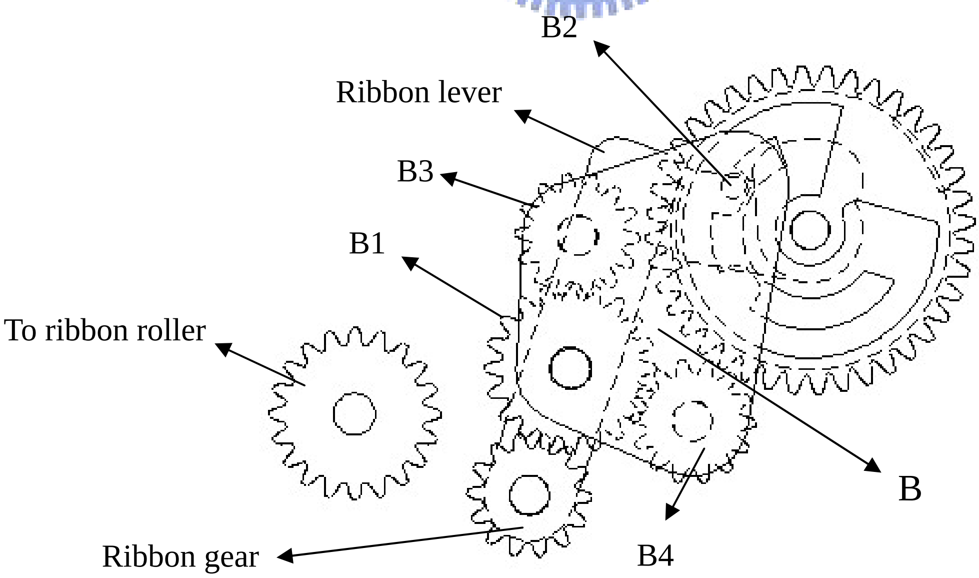


Fig. 4.6 The design of ALPS

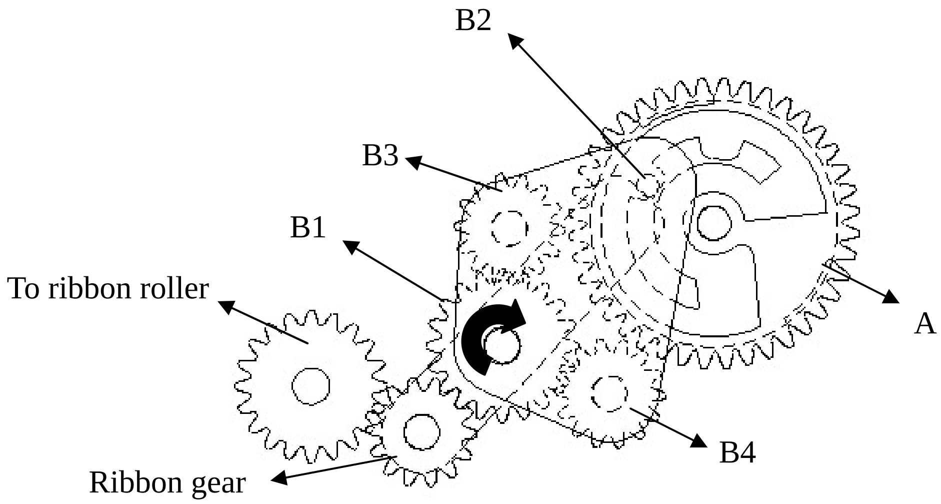


Fig. 4.7 Step 1- Ribbon Searching of ALPS

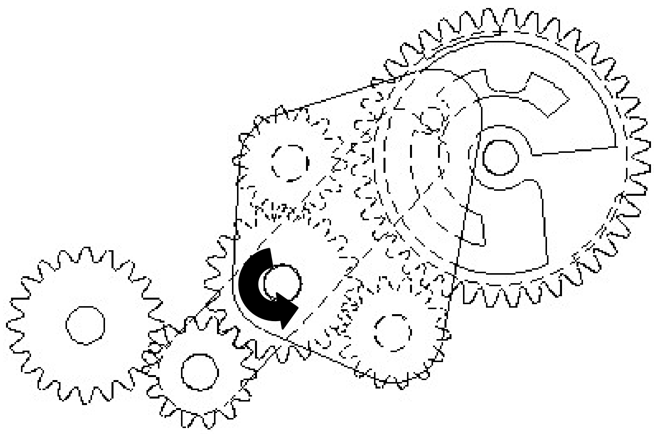


Fig. 4.8 Step 1 to Step 2 of ALPS

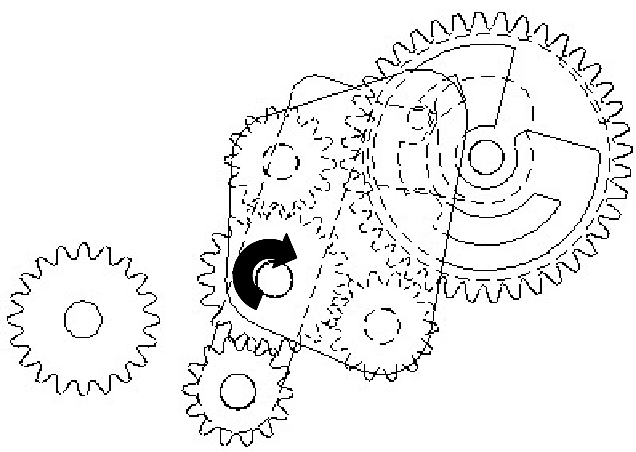


Fig. 4.9 Step 2- Feeding Paper Forward of ALPS

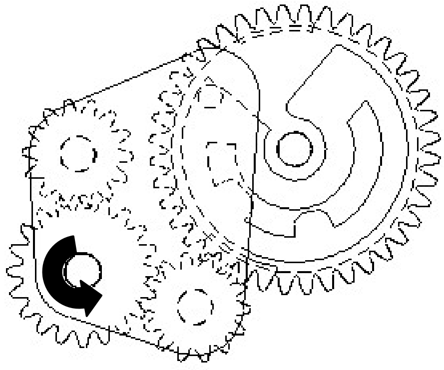


Fig. 4.10 Step 3- Feeding Paper Backward of ALPS

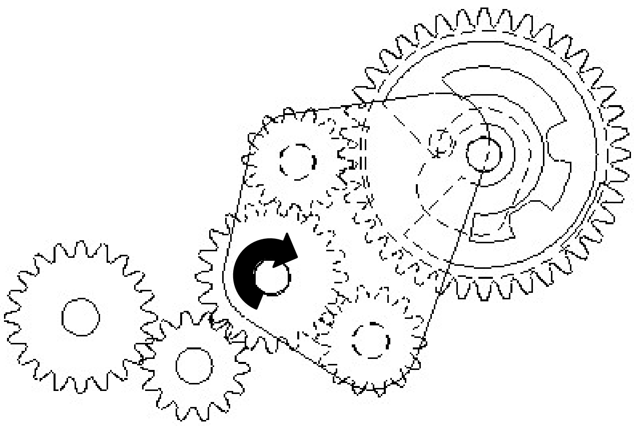


Fig. 4.11 Step 4- Printing of ALPS

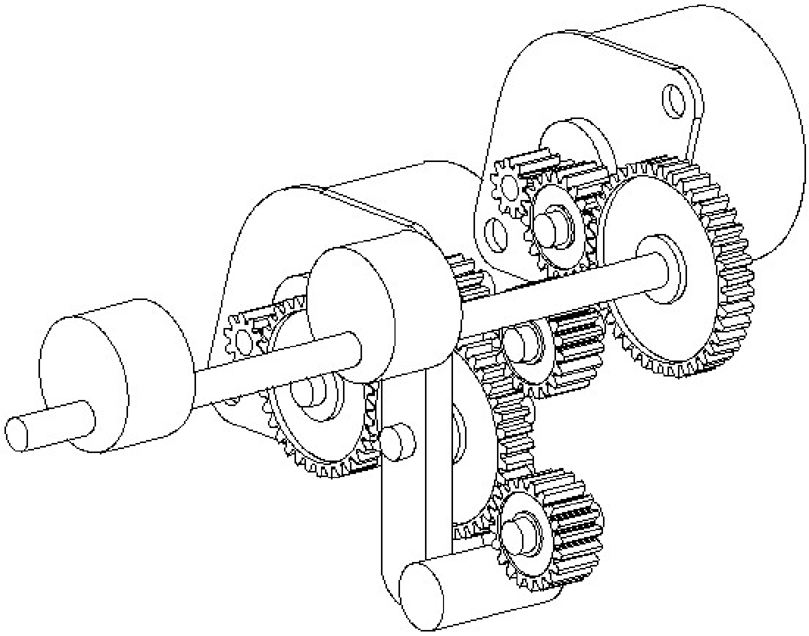


Fig. 4.12 3D view of concept 1

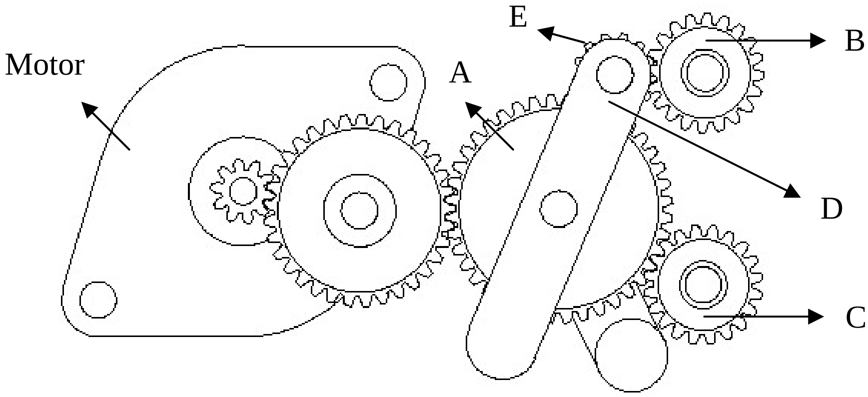


Fig. 4.13 Section 1 of concept 1

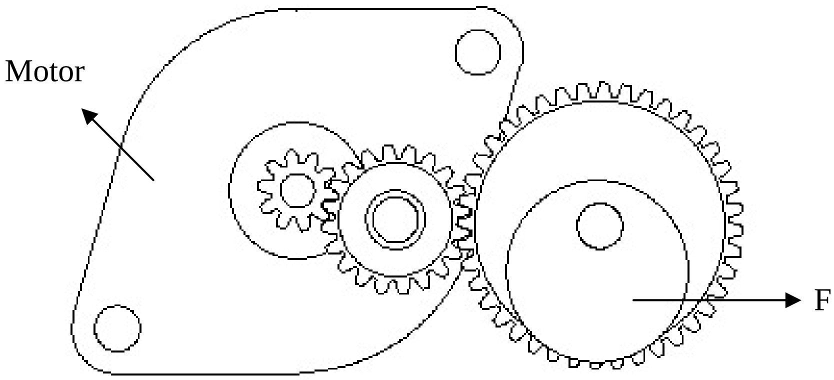


Fig. 4.14 Section 2 of concept 1

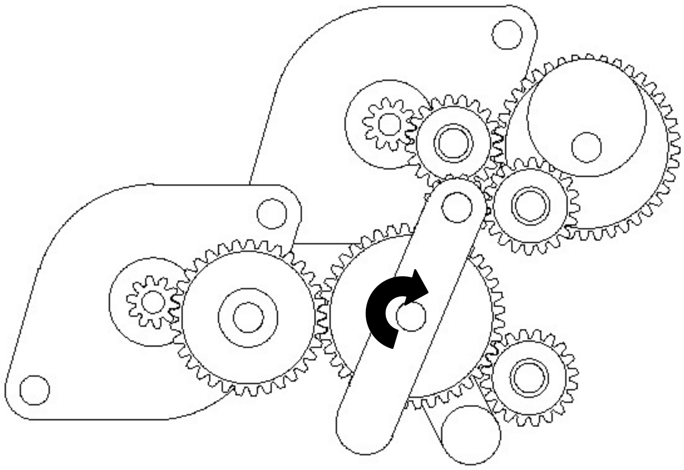


Fig. 4.15 Step 1 – Ribbon Searching of concept 1

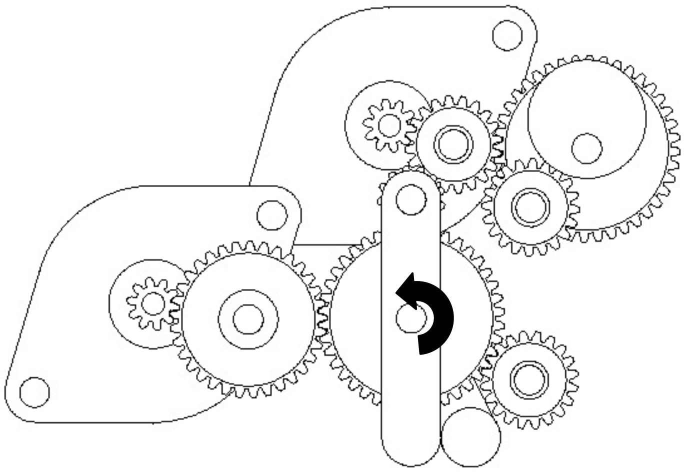


Fig. 4.16 Step 2 – Paper Feeding of concept 1

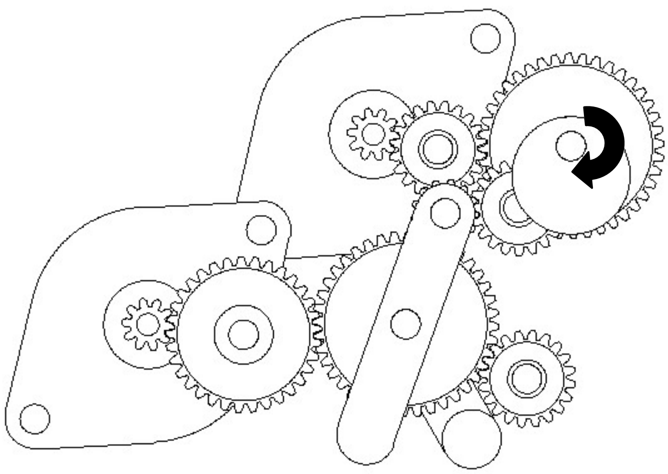


Fig. 4.17 Step 3 – Printing of concept 1

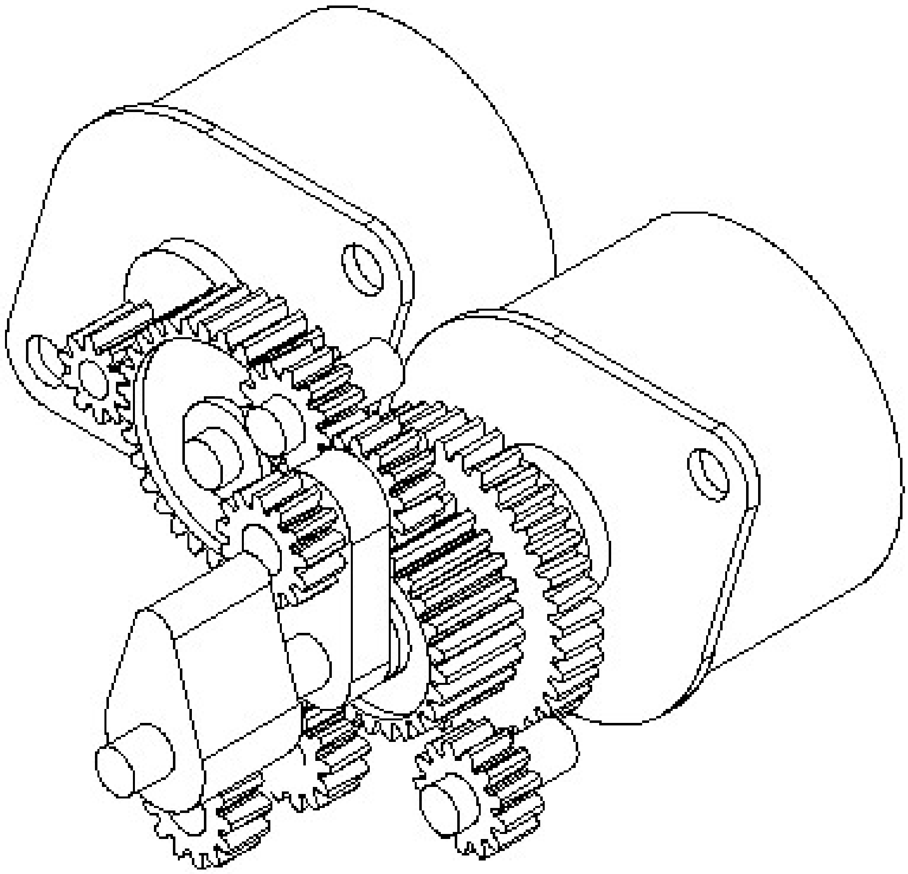


Fig. 4.18 3D view of concept 2

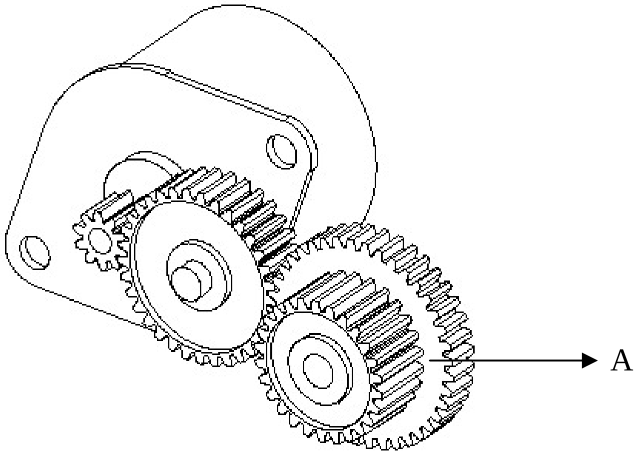


Fig. 4.19 Section 1 of concept 2

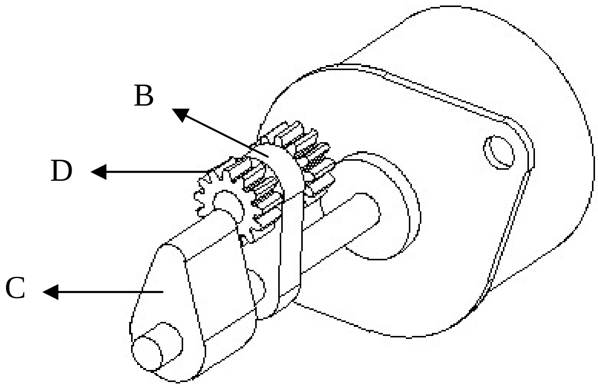


Fig. 4.20 Section 2 of concept 2

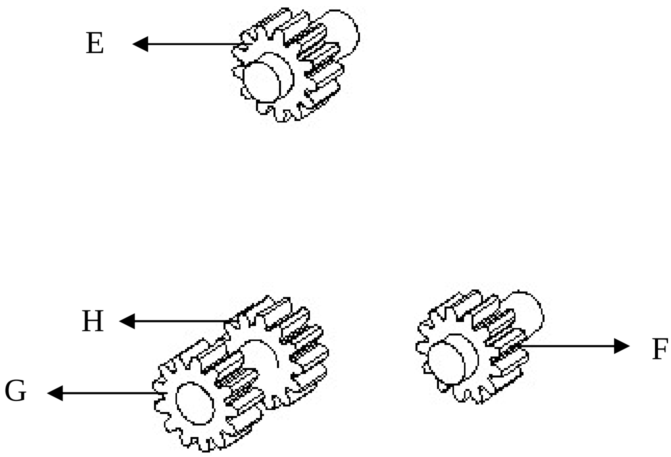


Fig. 4.21 Section 3 of concept 2

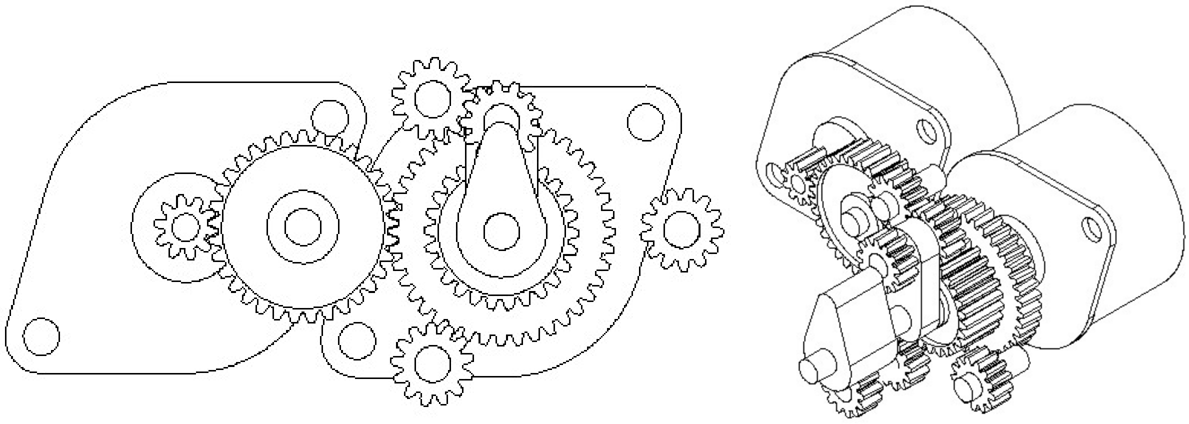


Fig. 4.22 Step 1 – Ribbon Searching of concept 2

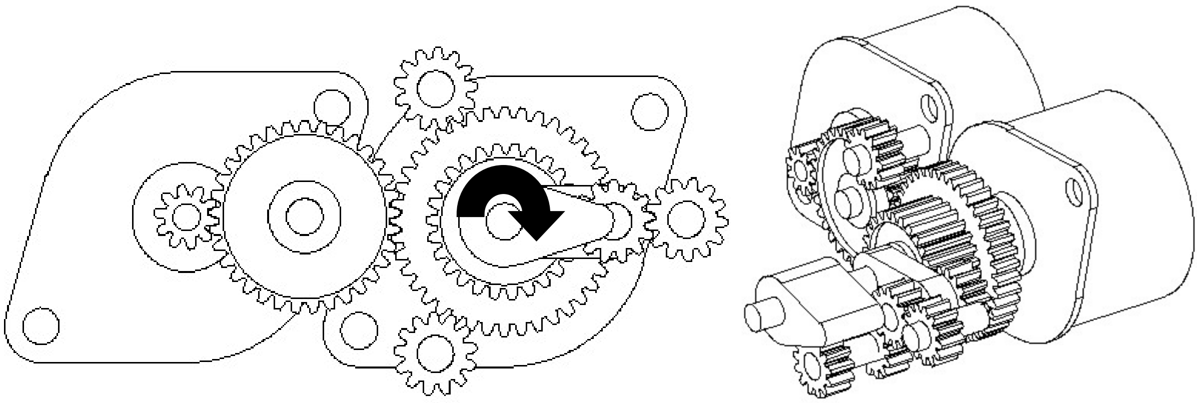


Fig. 4.23 Step 2 – Paper Feeding of concept 2

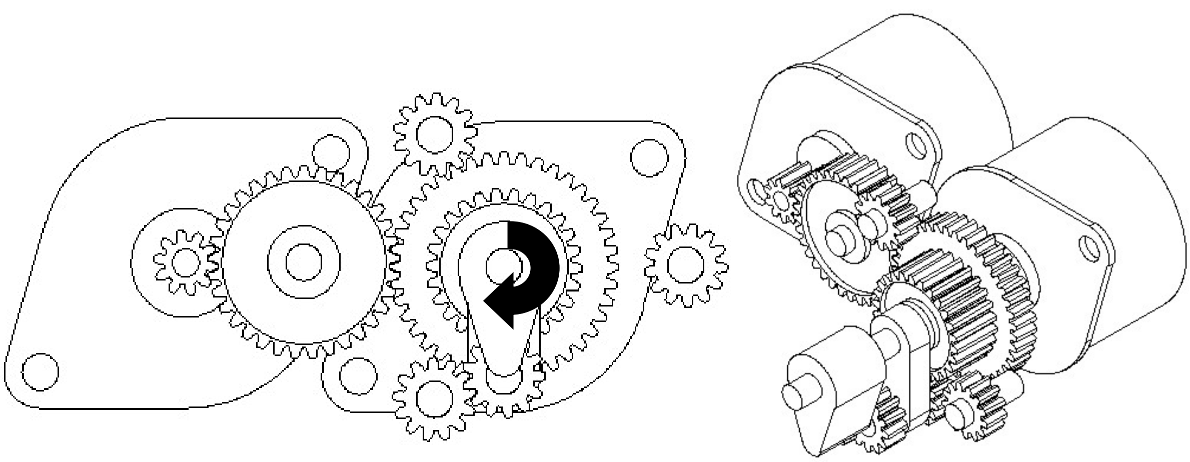


Fig. 4.24 Step 3 – Printing of concept 2

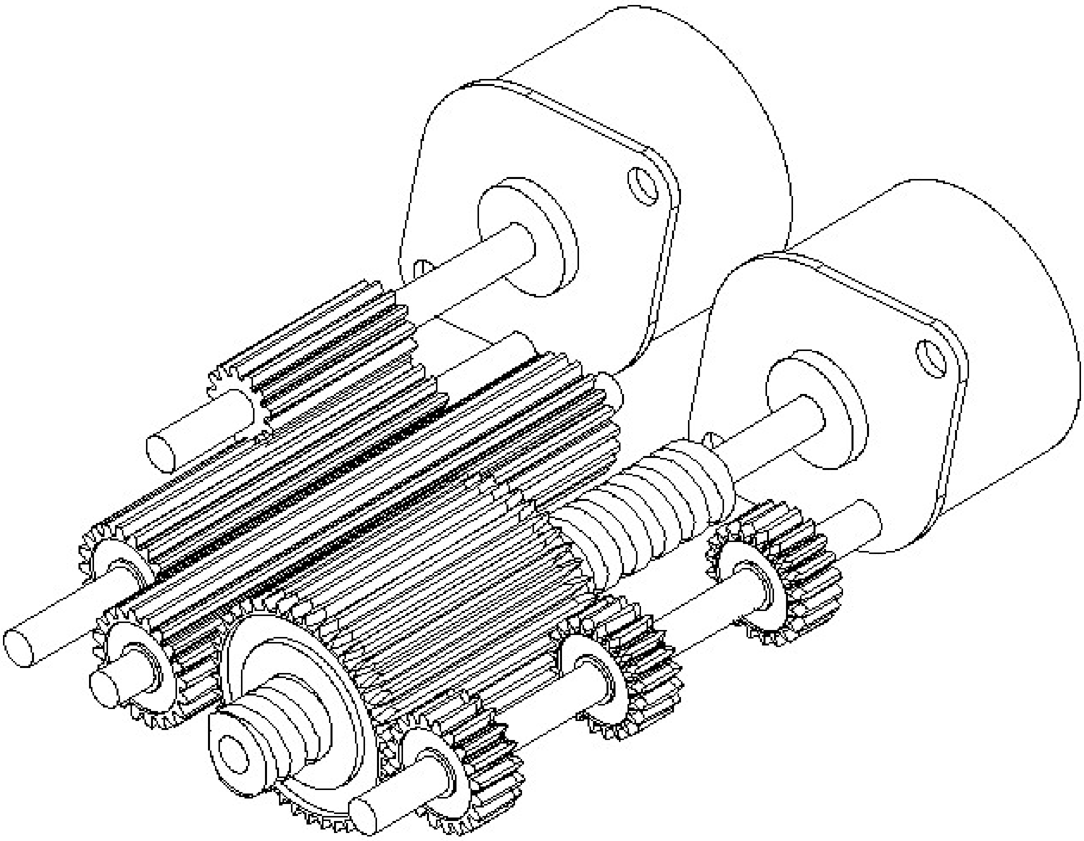


Fig. 4.25 3D view of concept 3

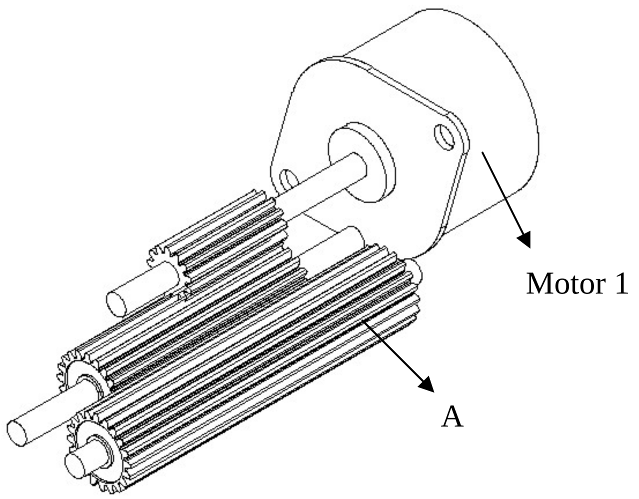


Fig. 4.26 Section 1 of concept 3

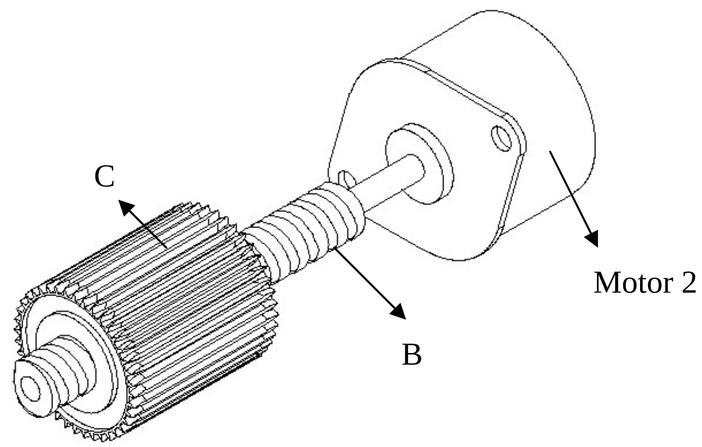


Fig. 4.27 Section 2 of concept 3

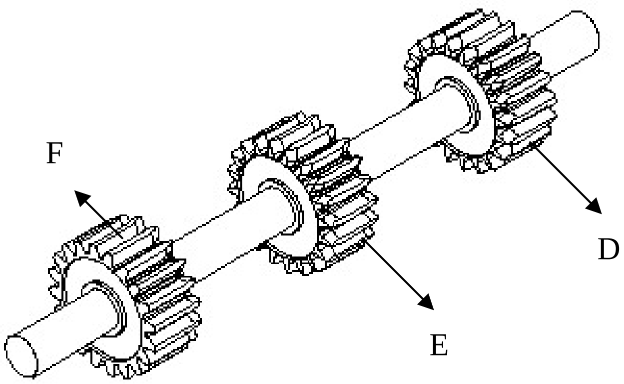


Fig. 4.28 Section 3 of concept 3

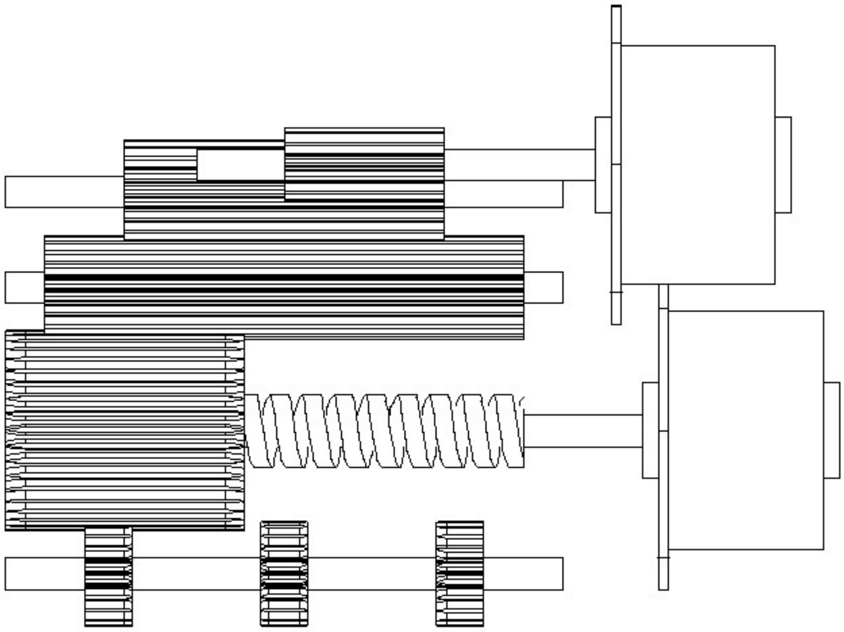


Fig. 4.29 Step 1 – Ribbon Searching of concept 3

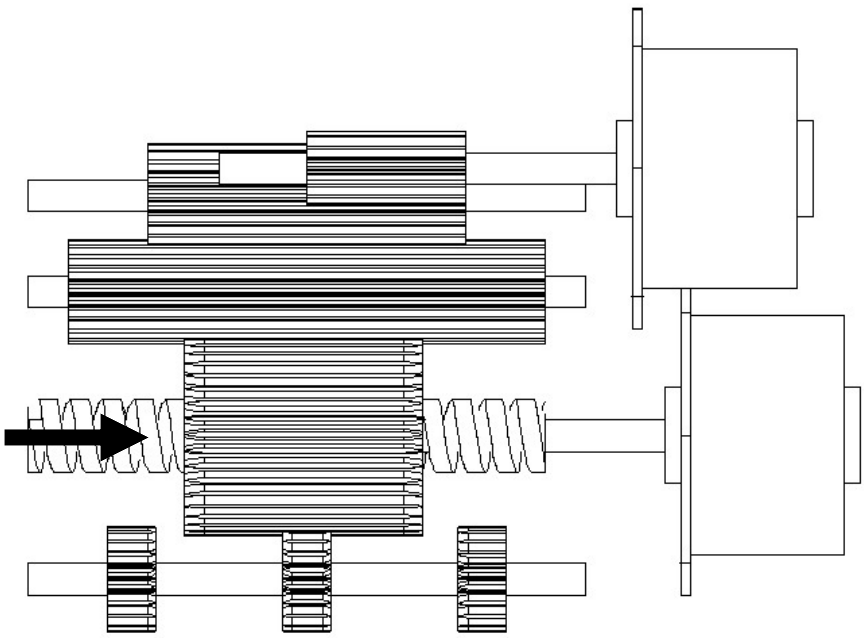


Fig. 4.30 Step 2 – Paper Feeding of concept 3

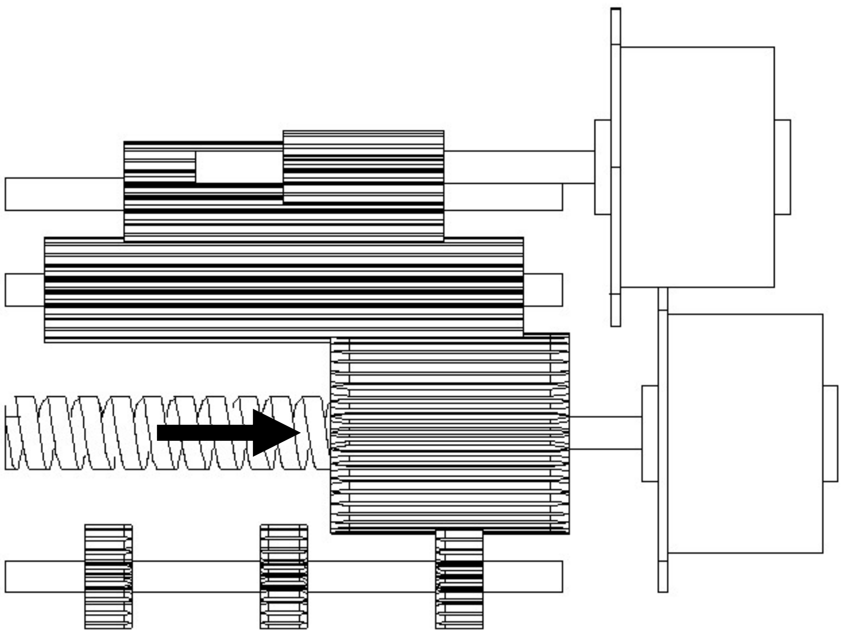


Fig. 4.31 Step 3 - Print Head Compressing of concept 3

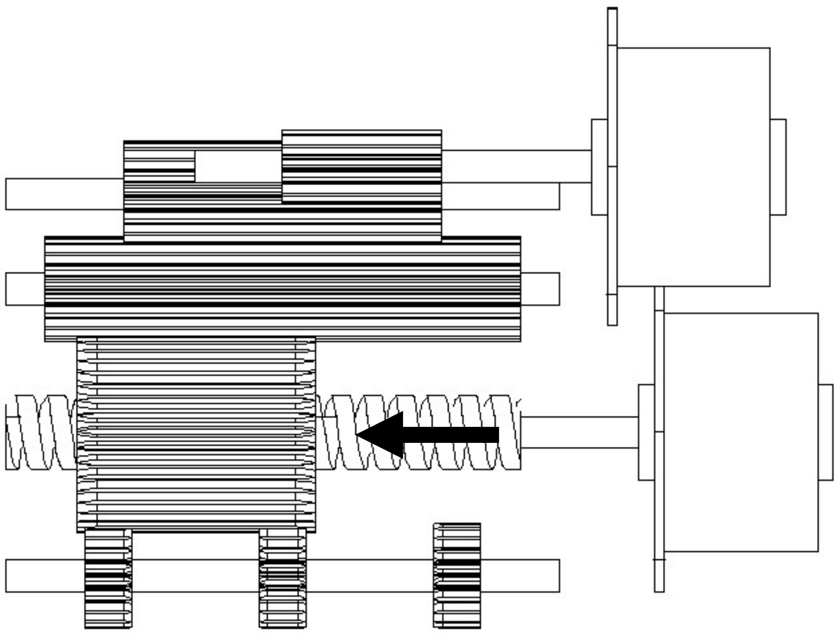


Fig. 4.32 Step 4 – Printing of concept 3

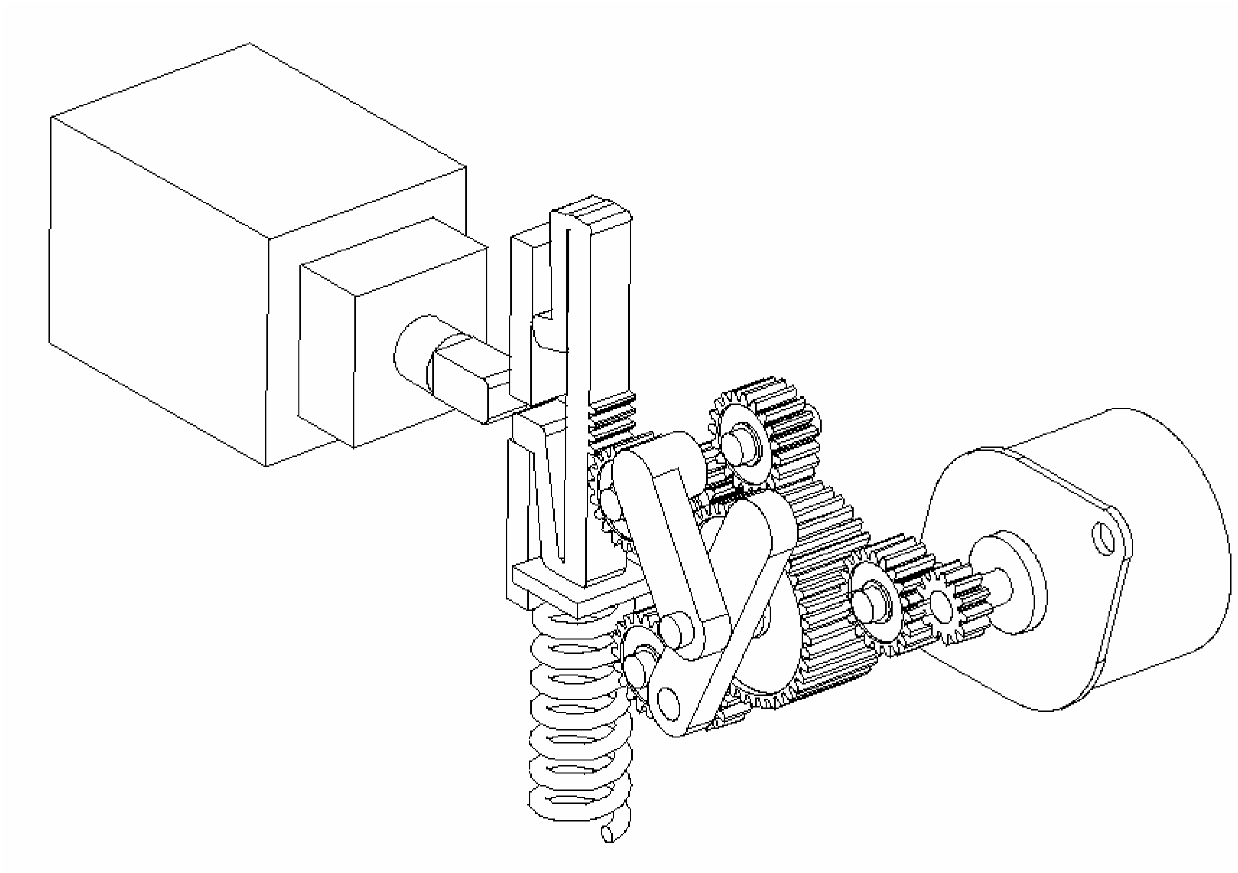


Fig. 4.33 3D view of concept 4

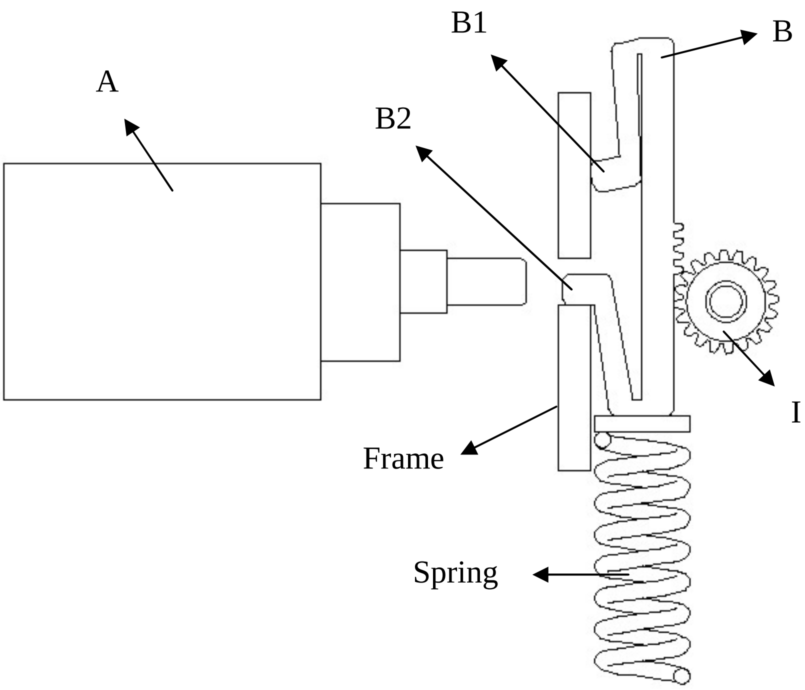


Fig. 4.34 Section 1 of concept 4

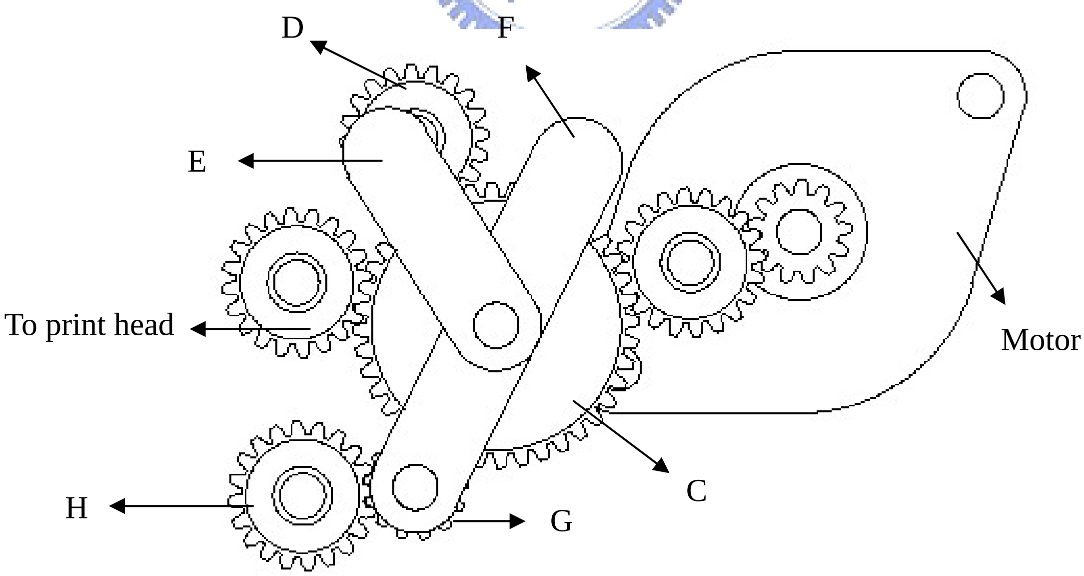


Fig. 4.35 Section 2 of concept 4

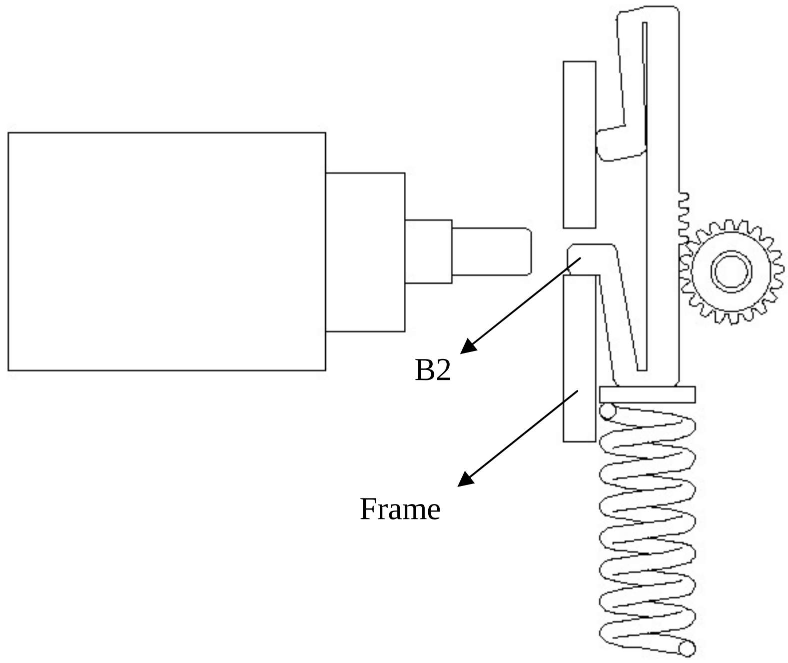


Fig. 4.36 State 1 of section 1 of concept 4

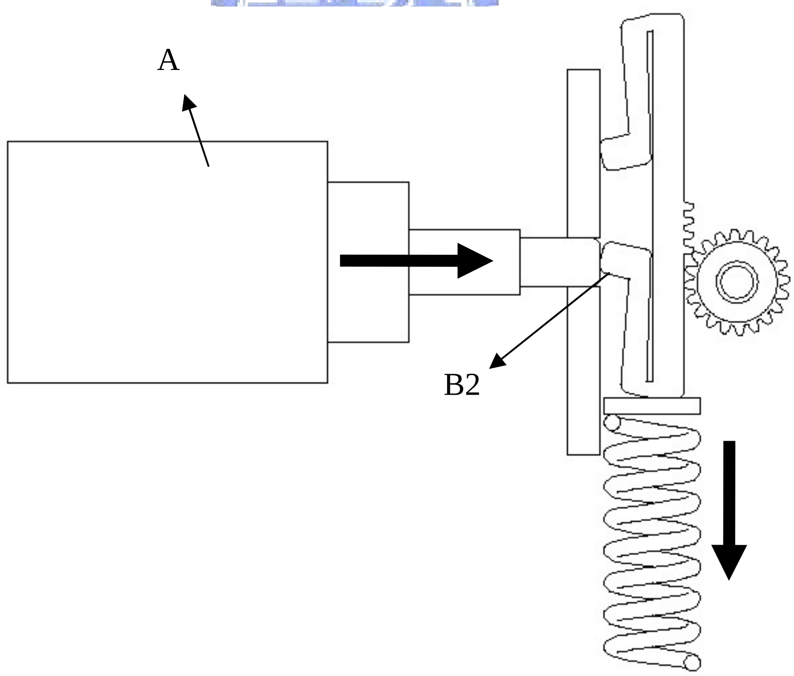


Fig. 4.37 State 2 of section 1 of concept 4

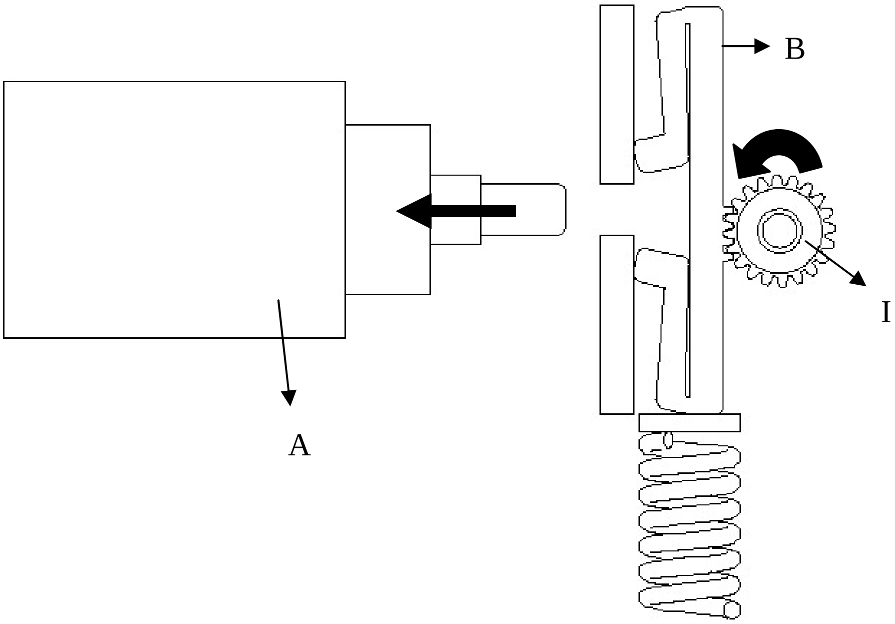


Fig. 4.38 State 3 of section 1 of concept 4

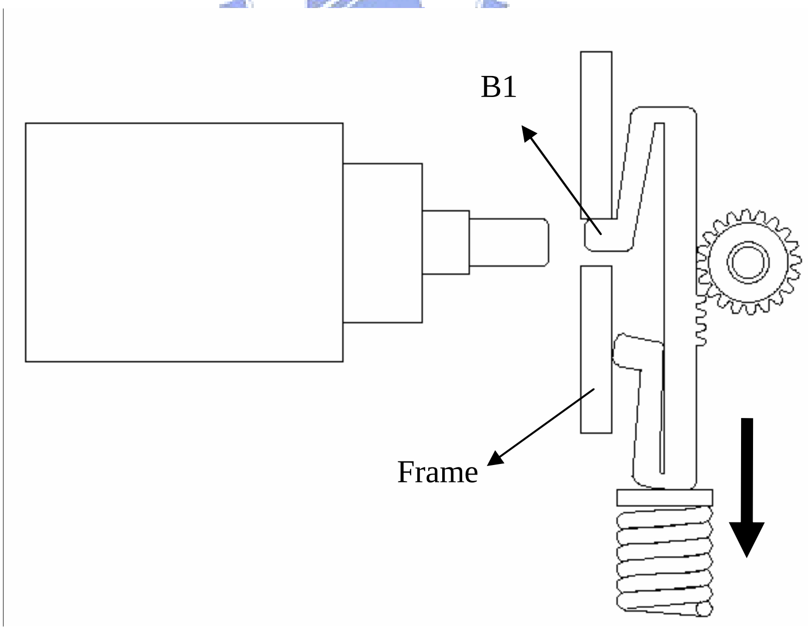


Fig. 4.39 State 4 of section 1 of concept 4

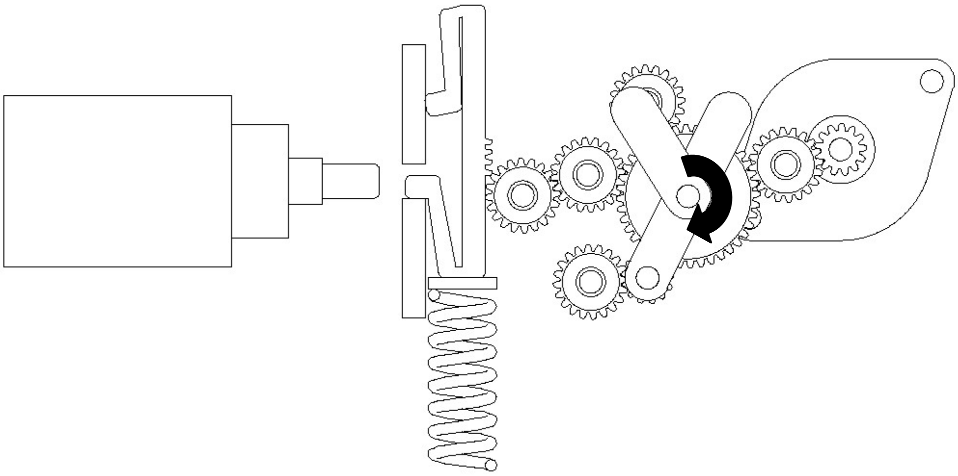


Fig. 4.40 Step 1 – Ribbon Searching of concept 4

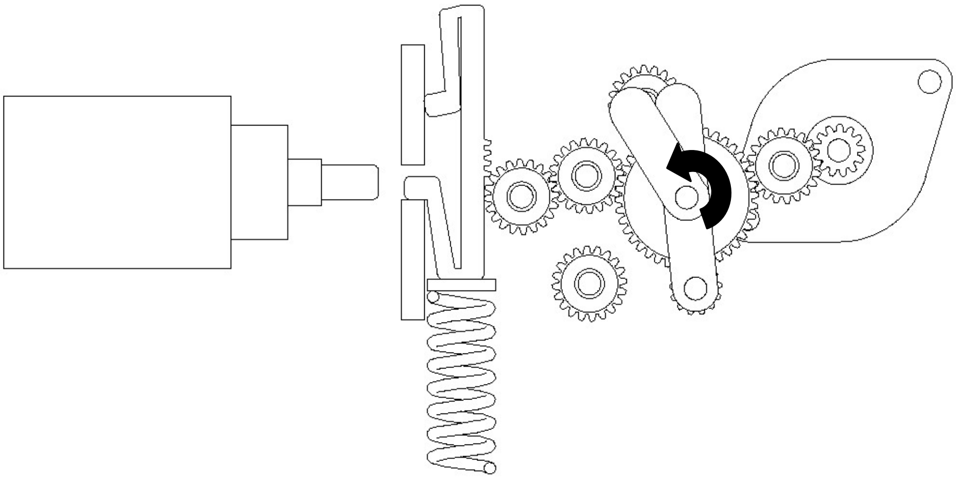


Fig. 4.41 Step 2 – Paper Feeding of concept 4

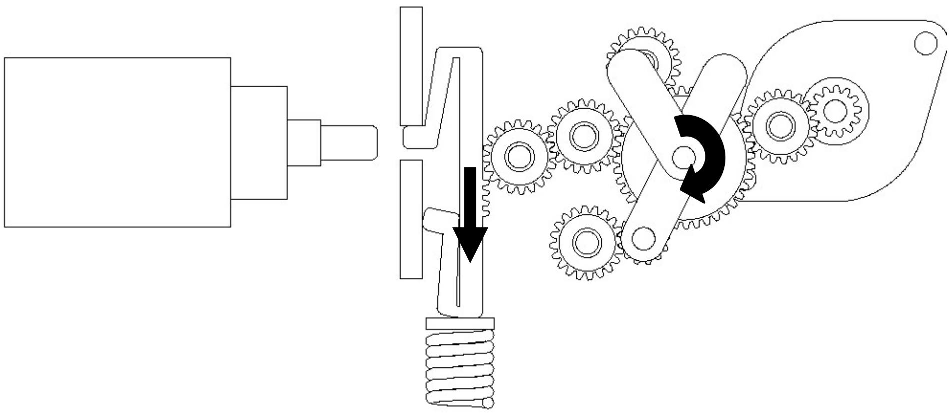


Fig. 4.42 Step 3 – Printing of concept 4

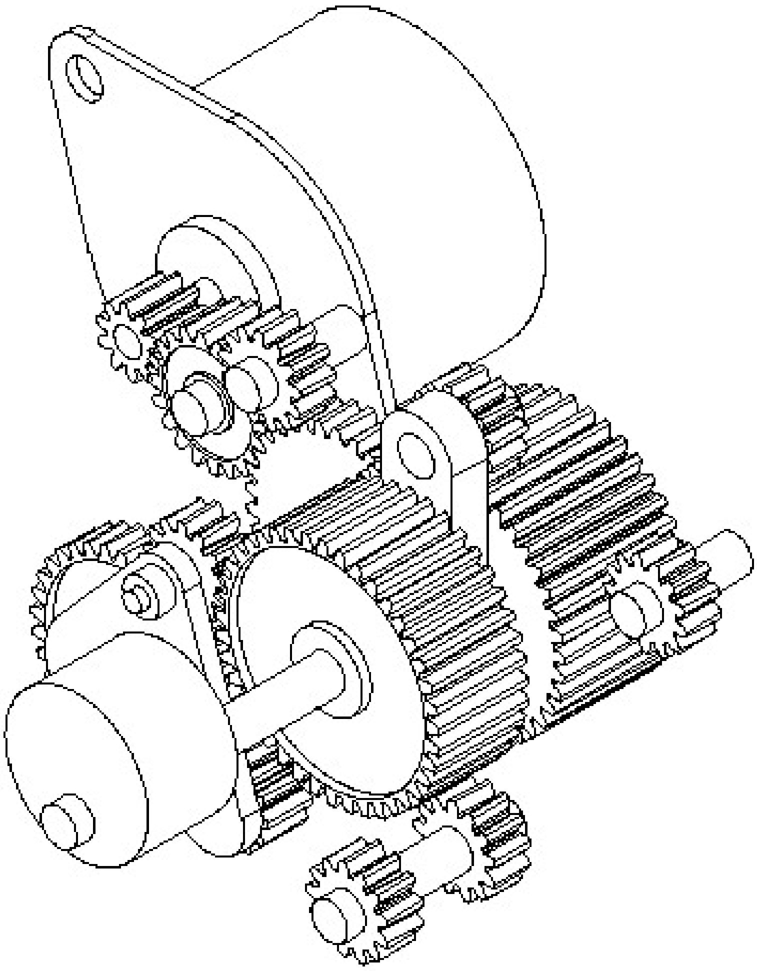


Fig. 4.43 3D view of concept 5

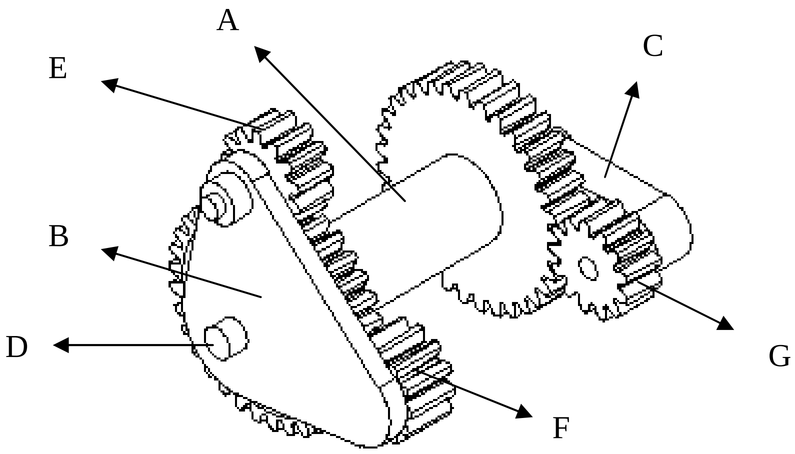


Fig. 4.44 Section 1 of concept 5

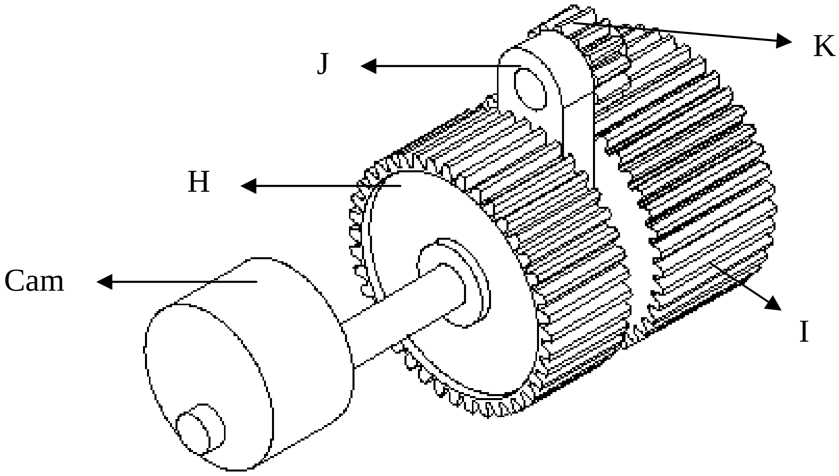


Fig. 4.45 Section 2 of concept 5

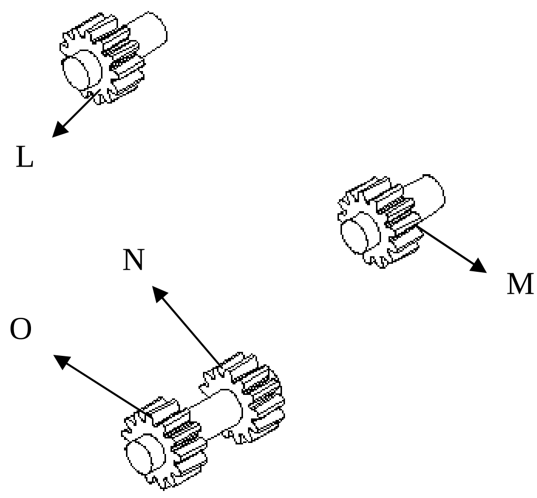


Fig. 4.46 Section 3 of concept 5

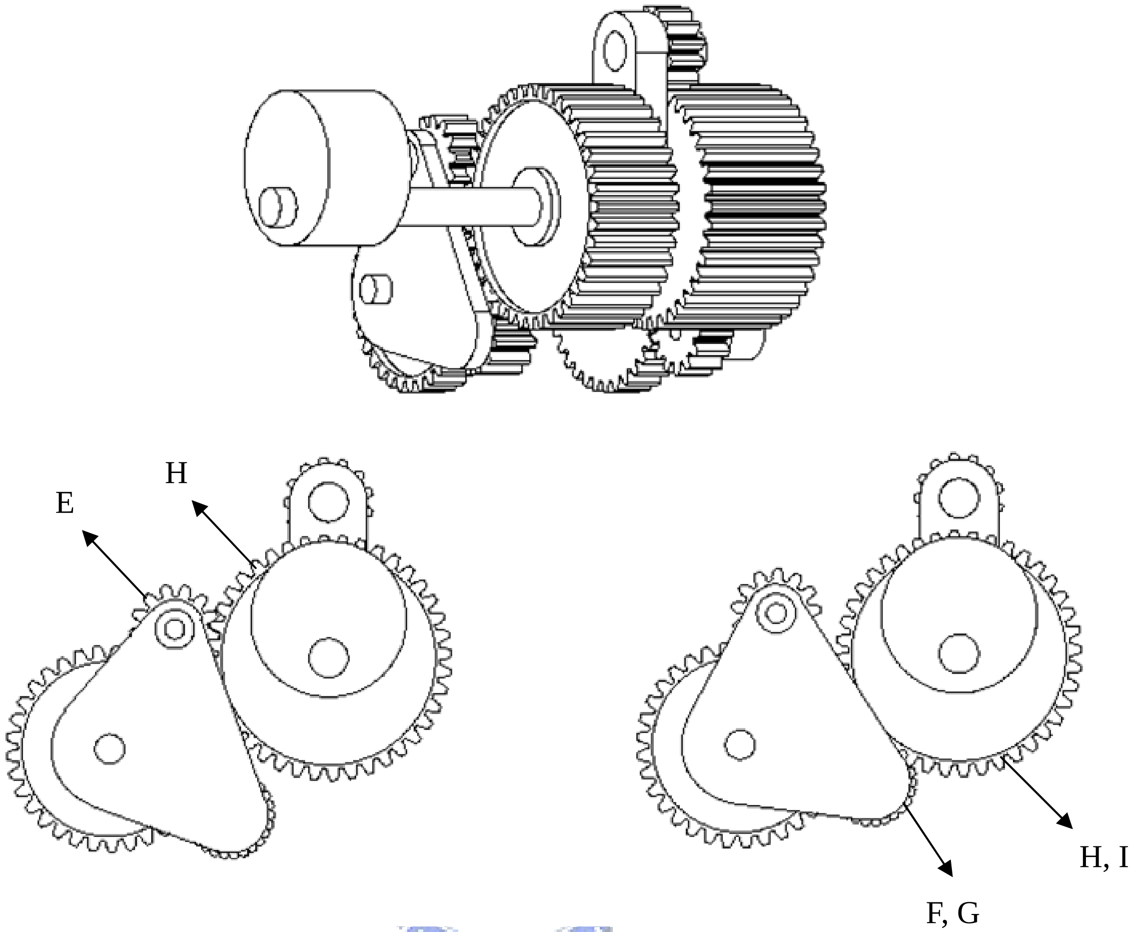


Fig. 4.47 Way of step-changing and power output of concept 5

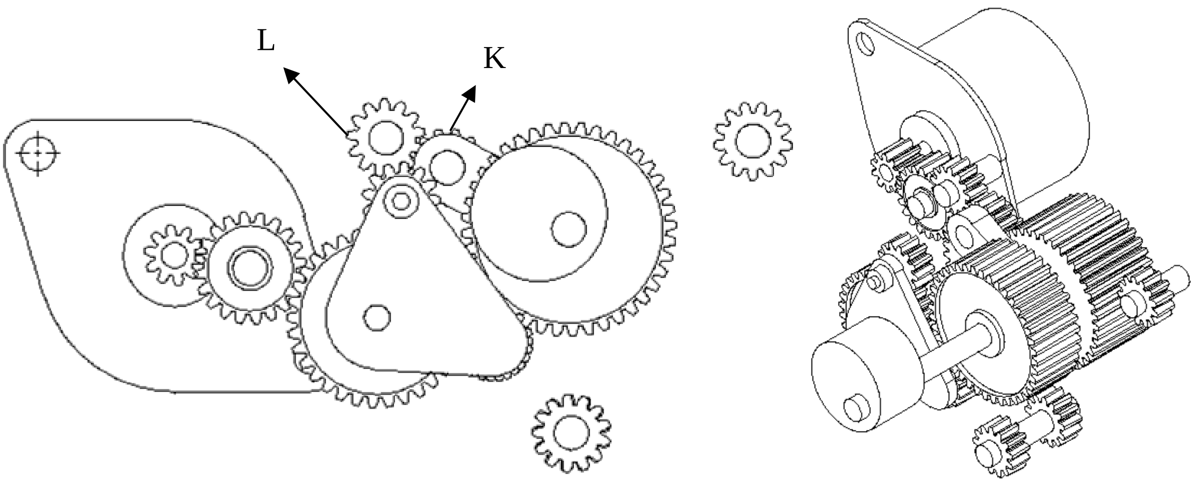


Fig. 4.48 Step 1 – Ribbon Searching of concept 5

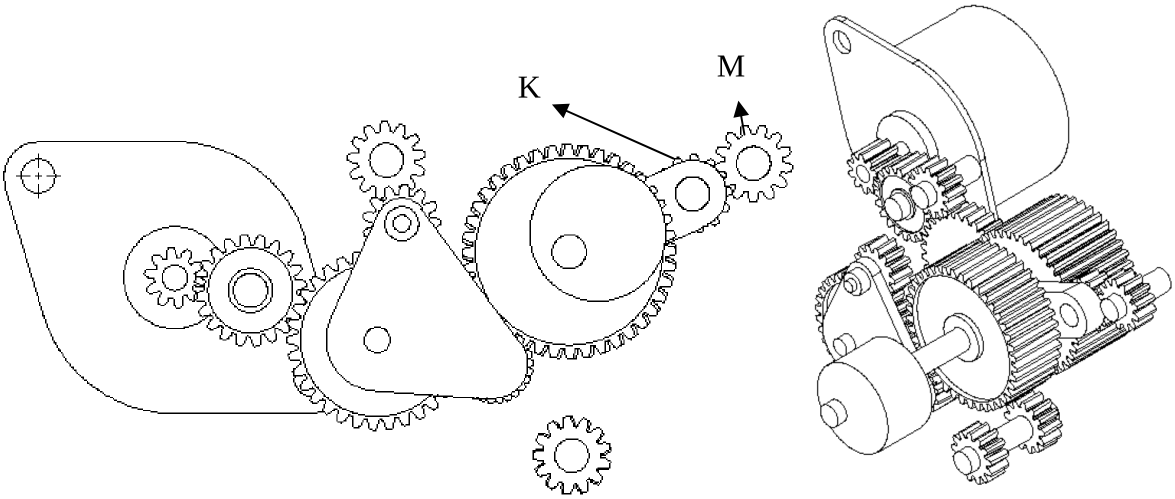


Fig. 4.49 Step 2 – Paper Feeding of concept 5

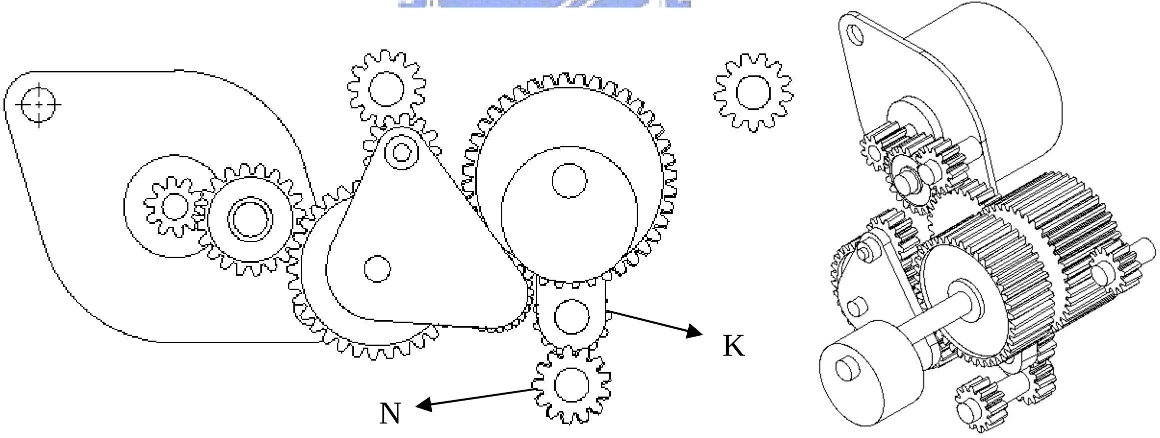


Fig. 4.50 Step 3 – Printing of concept 5

Chapter 5 Embodiment Design and Prototype

Because of the lower power consumption and only one motor used, concept 5 is chosen to be the design of print module. As mentioned before, the print module consists of print head, ink ribbon and paper feeding module. In this chapter, the whole design of print module is presented.

5.1 Embodiment

Because of the requirement of space, the allocation of concept 5 should be redesigned. Fig. 5.1 is the present design of print module. It includes printer frame, a motor, gear train, print head module and ink ribbon cassette, as shown in Fig. 5.2. The motor and gear train are at the left side and the ink ribbon cassette can be inserted from the right side. Paper can be drawn in and printed out from the front. The size of the embodiment design is 107.4mm*81.6mm*32.1mm, as shown in Fig. 5.3 (a) and Fig. 5.3 (b).

5.1.1 Printer Frame

The printer frame consists of the base and an upper cover. As shown in Fig. 5.4, there is a paper guide plate at the paper entrance so that paper can be directed to capstan roller straight. There is a hollow whose shape is like the ribbon cassette on the left side.

Because the ink ribbon cassette is inserted from the right side, but the print head module must be supported at both sides, one plate is meld on the upper cover of printer and away from the edge of cover about 3mm, as shown in Fig. 5.5, so that the ribbon cassette can be fully inserted into the print module.

5.1.2 Thermal Print Head Module

As mentioned before, general printer use cam to press or release thermal print head, but the printer of ALPS use cam to press or release platen roller. Here the design also uses cam to press thermal print head. Fig. 5.6 is the figure of present design. Use cam to press print head assembly against platen roller or release it from the platen roller.

Fig. 5.7 shows the detail of print head assembly. Print head *3* is fixed on the print head frame *2* by two screws *4*. The print head assembly can rotate around the axis *5*. Number *4* is a pressure plate. There are two spring set *A* and *B* in the assembly. One end of spring set *A* is fixed on the pressure plate *4*, and the other is fixed on print head frame *2*. One end of spring set *B* is fixed on the print head frame *2* and the other is fixed on the printer frame. The spring constant of spring *A* is larger than spring *B*. Spring set *A* is used to supply the pressure needed while printing and spring set *B* is used to release print head.

When print head is released in the steps of ribbon searching or paper feeding, the surface with smaller radius of cam attaches to the pressure plate because of the spring force of spring set *B*, as shown in Fig. 5.8. While printing, the cam will rotate and press the pressure plate. The spring set A will be compressed first and the print head assembly will attach to the platen roller, as shown in Fig. 5.9. Next, the cam rotates continuously and the pressure plate will be pressed. At this time, spring set B will be compressed to supply pressure, as shown in Fig. 5.10.

5.1.3 Ink Ribbon Cassette

Fig. 5.11 shows the 3D view of ink ribbon cassette. The roller for feeing ribbon is lower than the winding roller. There is an axis in the front of the feeding slot to make sure that the ribbon will follow the surface of ribbon cassette to the winding slot. And one hollow area is at the middle of the ribbon cassette for the print head to pass through. Because of the requirement of space, the capstan roller, passive paper roller and platen roller are under the ribbon cassette, as shown in Fig. 5.12.

5.1.4 Power Transmitting Mechanism

Fig. 5.13 is the side view of gear train in the printer design. It can be divided into three sections. Section 1 is the side of power source and consists of one motor, three compound gear and one power-transmitting gear as shown in Fig. 5.14. Section 2 in Fig. 5.15 is similar to concept 5, but the gear which connects to the gear train of ribbon roller (in Fig. 5.17) always engages the main power transmitting gear. And the cam is fixed on the axis *1* with a power-transmitting gear and a light interception plate. Use the light interception plate to determine the position of cam. Fig. 5.16 is the step-change cam gear. There are two surfaces on the cam, surface *1* is flat and surface *2* is circular with same radius. One planet gear which engages with main power transmitting gear is at the end of the rotating arm.

Section 3 consists of gear train *3A* for ribbon roller and gear train *3B* for capstan roller, as shown in Fig. 5.17 and Fig. 5.18. There is a clutch gear arm within gear train *3A* as a power-transmitting switch. In Fig. 5.18, gear line *1* has one more gear than gear line *2* for the different paper feeding direction.

5.1.5 Three Printing Steps

Step 1 in Fig. 5.19 shows that planet gear in section 2 doesn’t engage any gear and the ribbon clutch gear engages with the gear train *3A* because surface *2* of cam gear in section 2 contacts with the clutch gear arm of gear train *3A*. Therefore, ribbon can be searched without drawing paper.

Fig. 5.20 is the step to draw paper into printer. At this time planet gear of section 2 has rotated about 120 degrees and engaged with gear line *1* in gear train *3B*. Surface *1* of cam gear in section 2 contacts with clutch gear arm in gear train *3A* causing the clutch gear disengaging with gear train *3A* so that ribbon will not be drawn while feeding paper.

While printing, as shown in Fig. 5.21, planet gear of section 2 rotates about 120 degrees again and engages with gear line 2 in gear train 3B. Surface 2 of cam gear in section 2 contact with the arm again so that the clutch gear will engage with gear train 3A. At the same time print head is pressed. Then printer can drive paper and ribbon simultaneously to complete one printing process.

After one color printed, the cam gear will rotate clockwise about 240 degrees to step 2 again for next printing.

5.2 Prototype

The mechanism which can use only one motor to transmit power and complete the printing process is important in this design of print module on mobile printer. Therefore, the prototype will focus on the power transmitting mechanism to verify its functions.

5.2.1 Gear

The module of gears used in the embodiment print module design is 0.3. This kind of gear is hardly found on market. Therefore, the prototype use gears whose module is 0.5 and the pitch diameter is doubled. Because the gear thickness is only 3mm, some gears stick together instead of special thicker gears. Table 5.1 shows the total gears used in the prototype. Here use iron axes as the gear axes and its diameters depend on the bores of the gears. If the diameter of bore is larger than 4, a bushing is used so that the gear can use axis with the diameter about 3mm.

5.2.2 Manufacture

In the prototype, there are some components which should be manufactured, including cam gear for step changing, support plate, ribbon clutch arm, power switch plate and arm. The material used here is acrylic plastic. The thickness of acrylic plastic plate for support frame is about 1cm and the thickness of plate for the arm or power switch plate is 3mm.

Since the gear size of prototype is twice of the gear size in embodiment design, size of these components is also doubled. Fig. 5.22 to Fig. 5.25 are the drawings of these components of embodiment design whose size is half of the prototype. Follow these drawings, these components have been manufactured, as shown in Fig. 5.26 to Fig. 5.28.

5.2.3 Assembly

After the components are manufactured, they can be assembled. Fig. 5.29 to Fig. 5.31 are the photos of section 1, 2, 3A and 3B. The way to locate the gears is using some plastic bushings to clip the gears. Combine all the sections, Fig. 5.32 (a) and (b) are photos of the whole prototype of print module. The size of the prototype is about 160mm*62mm*60mm whose lengths are almost twice as long as the lengths of embodiment design.

5.3 Remarks

1. The size of the embodiment design is 107.4mm*81.6mm*32.1mm.
2. Two spring sets are used in the print head assembly for releasing the print head and supply enough pressure to melt the ink on the ribbon into paper.
3. The capstan roller and passive paper roller are near and under the ink ribbon cassette for space saving.
4. Ribbon gear connects to main power transmitting gear and the rotating arm is not downward vertically while the step of printing, so that it can reduce the gears used to connect ribbon roller or capstan roller.
5. The prototype proves the feasibility of concept 5. The main part, mechanism for step changing and power transmitting can work successfully.

Table 5.1 Gears used in prototype

Module	No. of Teeth	Pitch diameter(mm)	No. of Gears
0.5	16	8	16
	24	12	7
	40	20	6
	48	24	9
	64	32	1

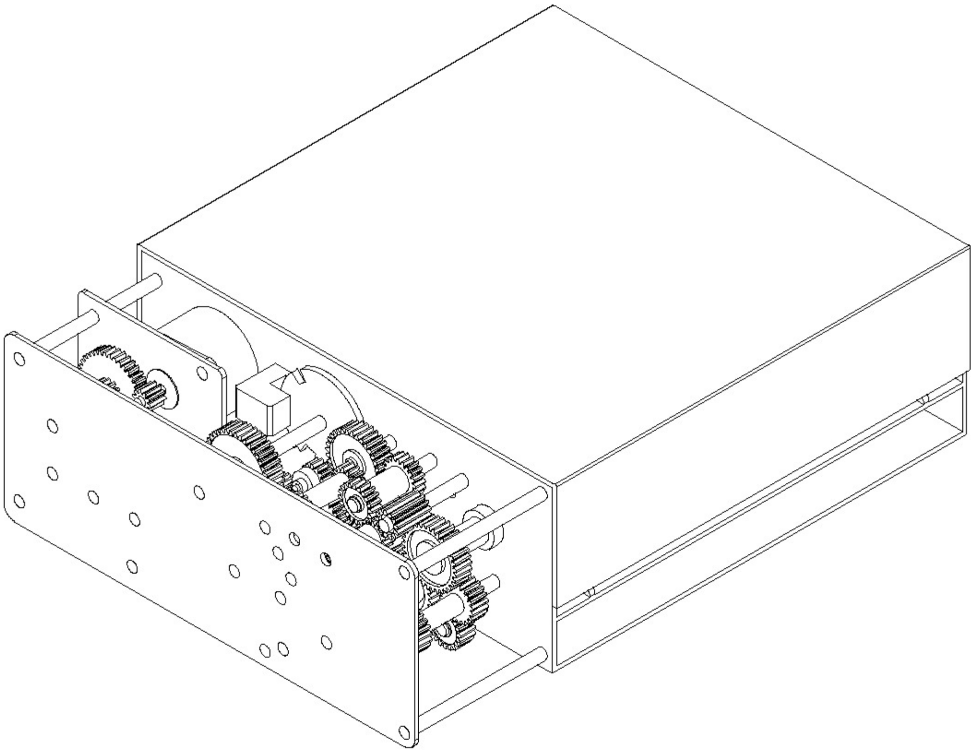


Fig. 5.1 The printer design

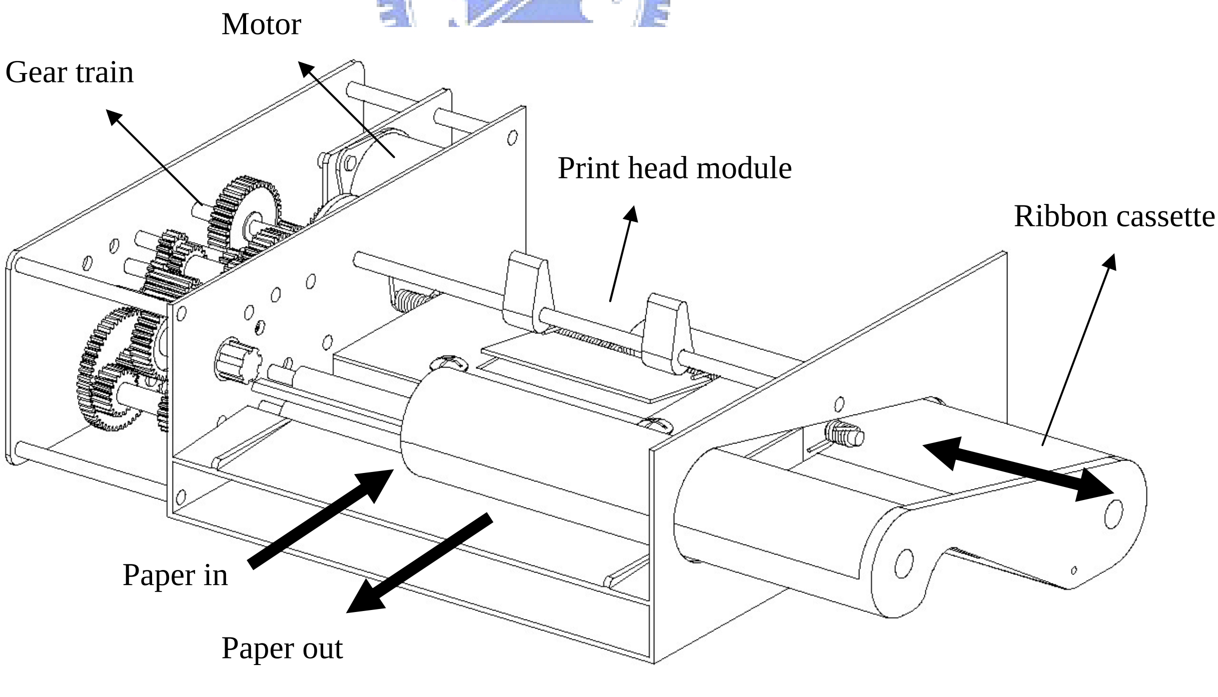
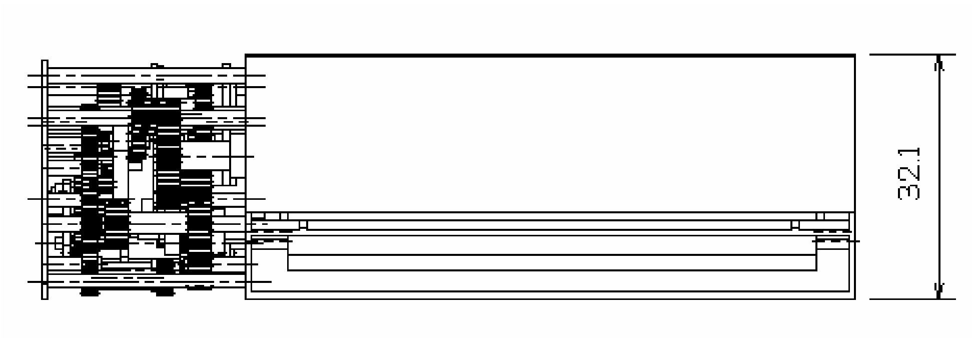
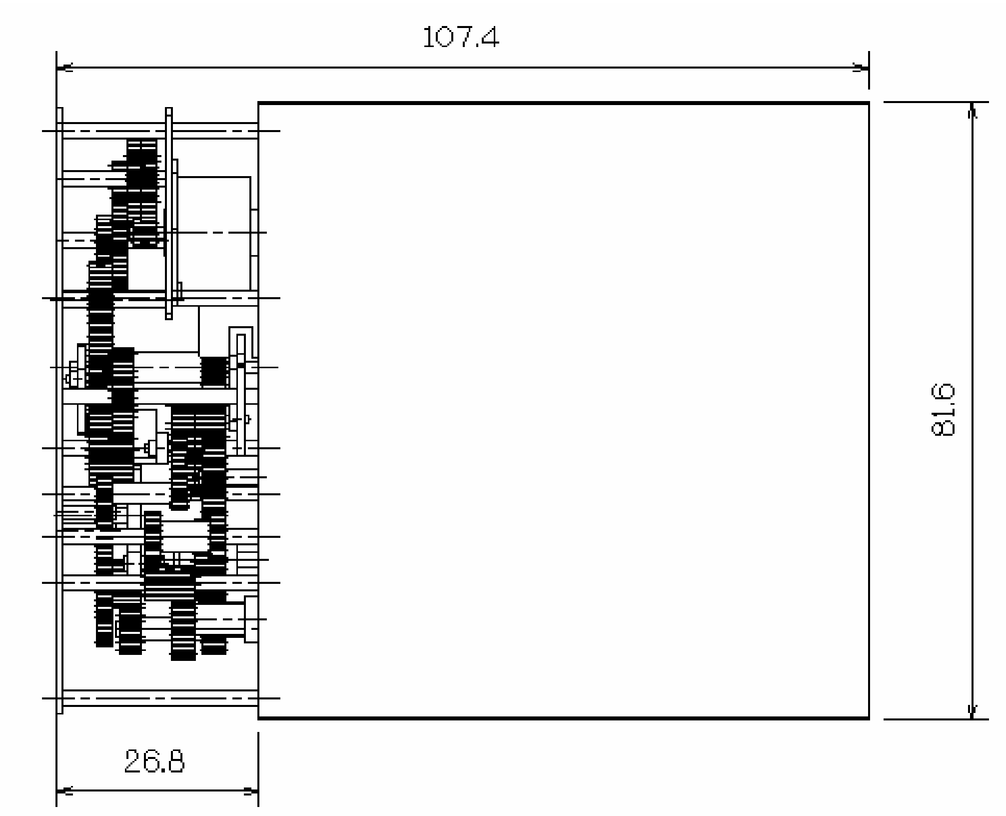


Fig. 5.2 The printer design



(a)



(b)

Fig. 5.3 (a) Front view (b) Top view of the whole print module

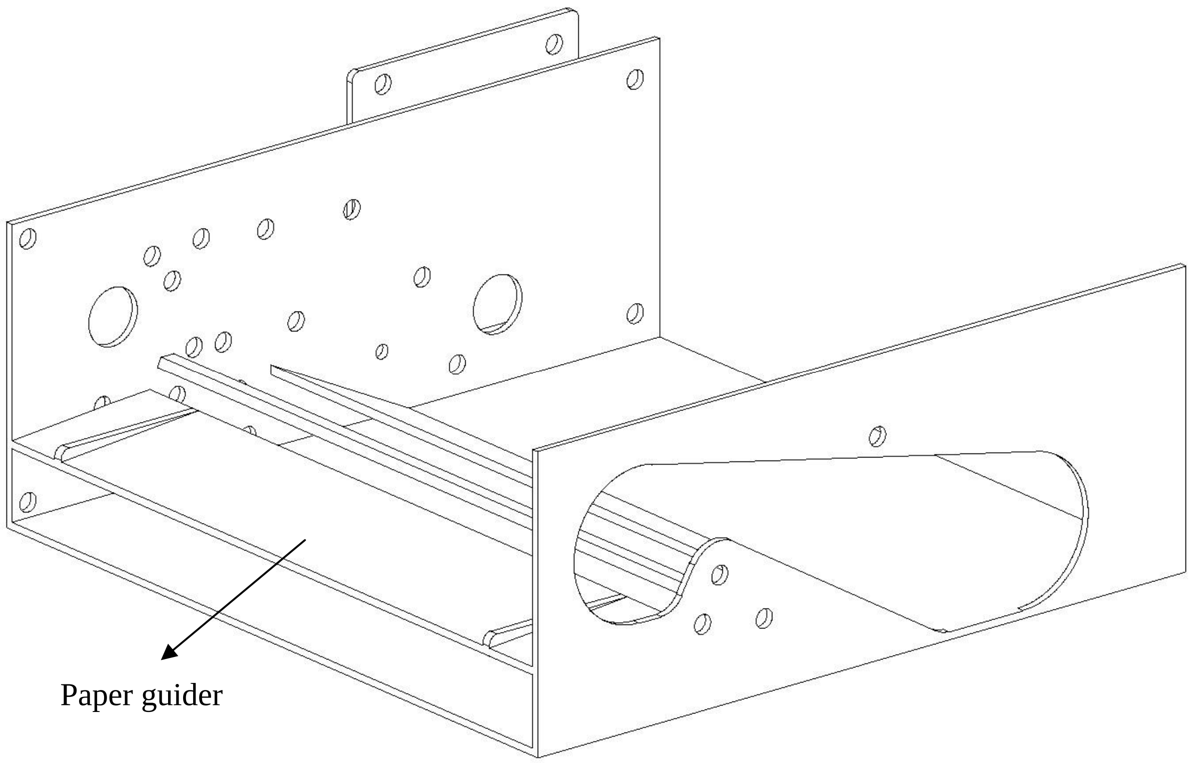


Fig. 5.4 Printer frame

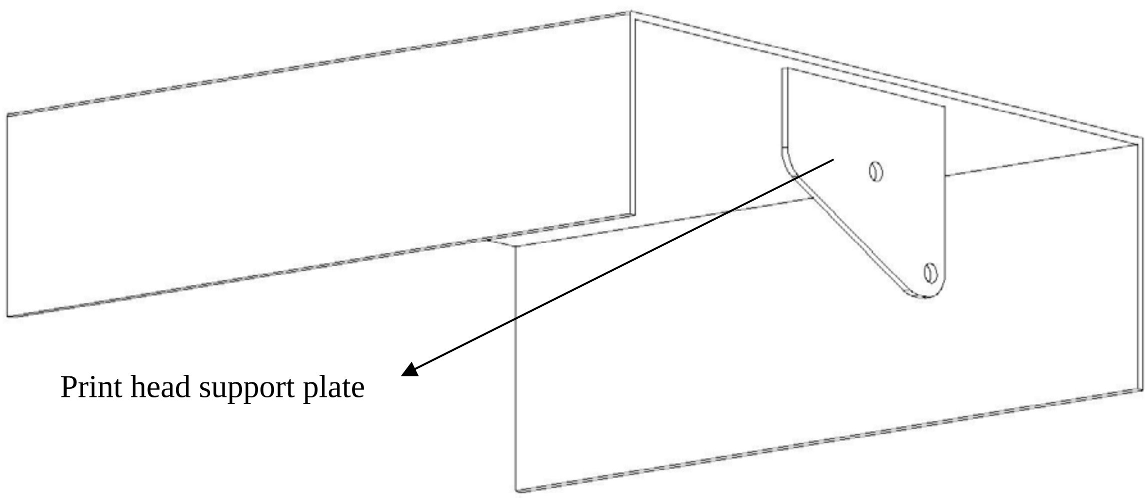


Fig. 5.5 Upper cover of printer

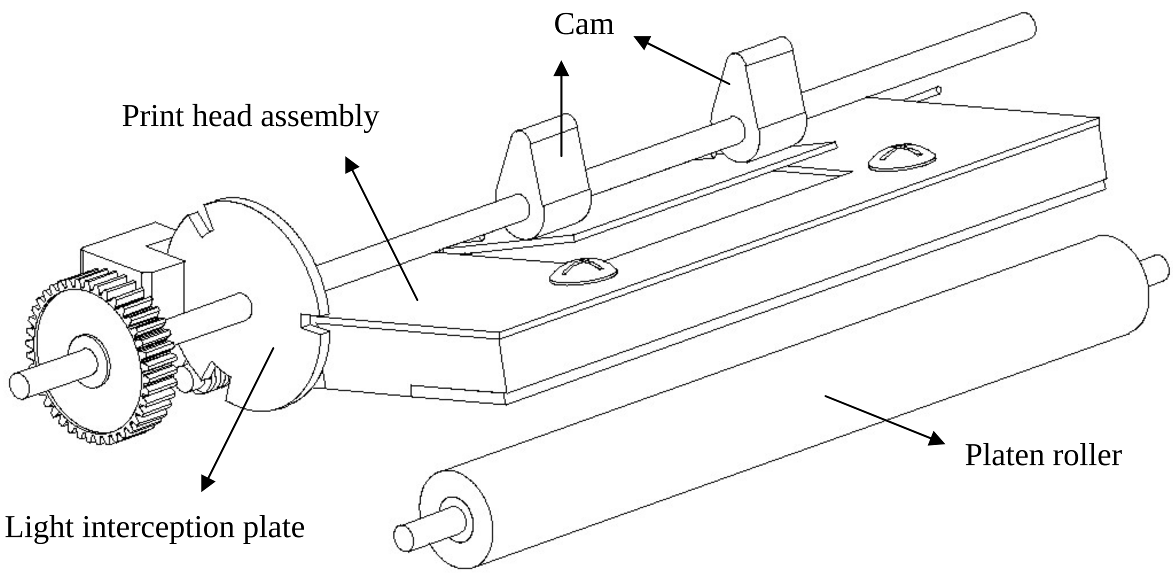


Fig. 5.6 Design of print head module

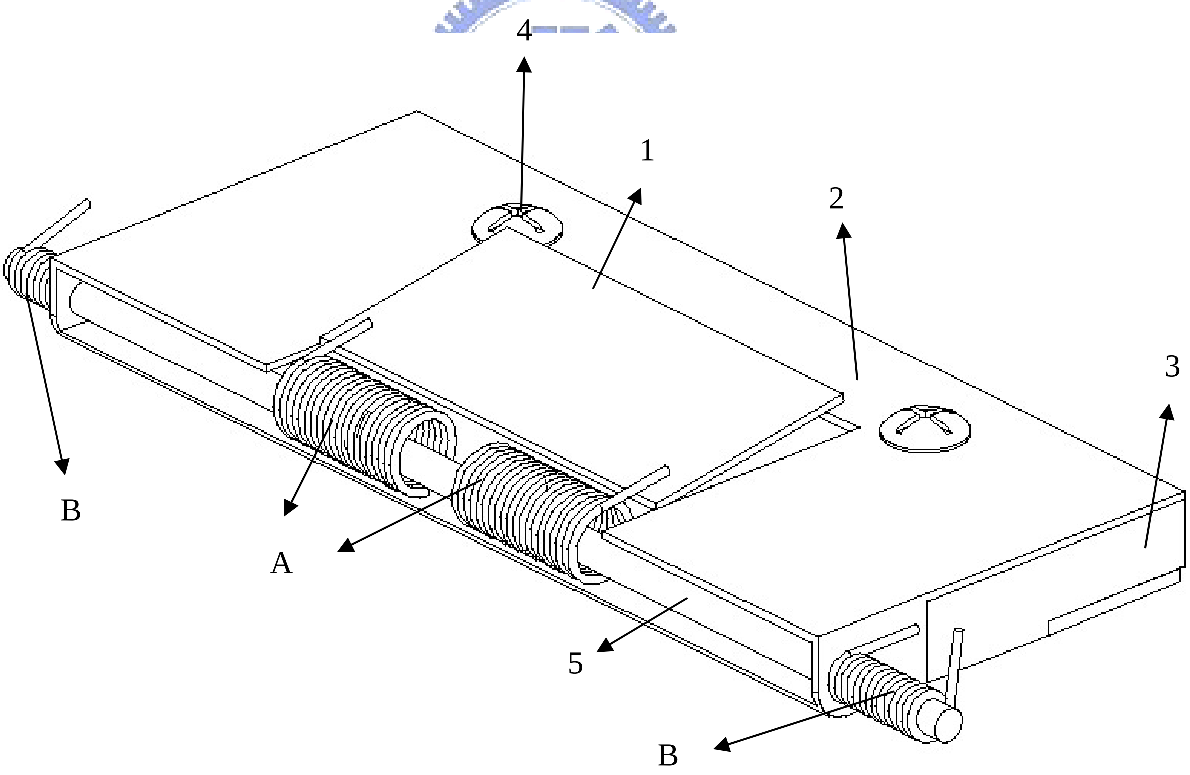


Fig. 5.7 Design of print head assembly

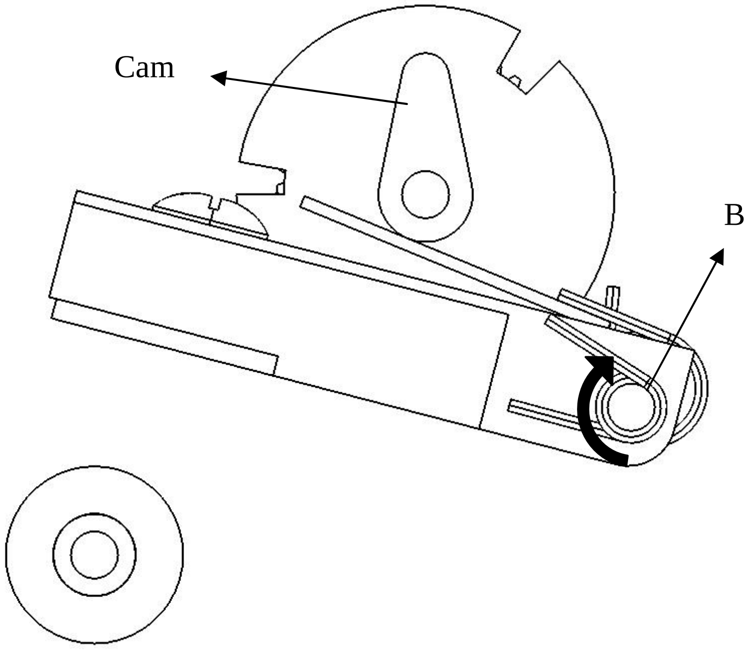


Fig. 5.8 State of print head released

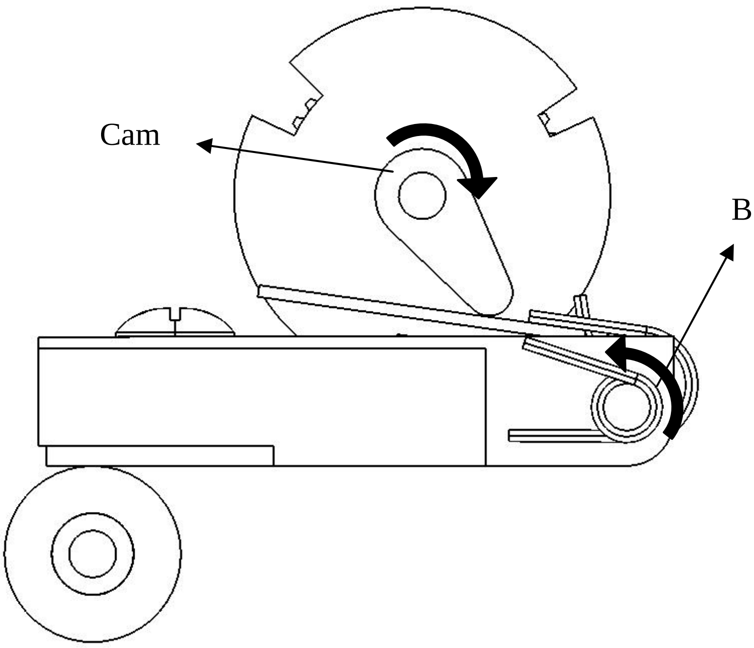


Fig. 5.9 State 1 of print head pressed

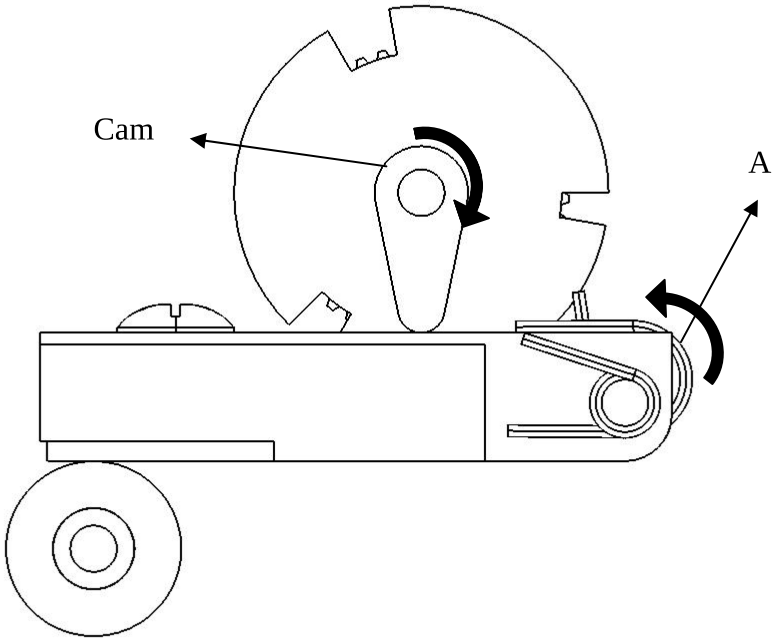


Fig. 5.10 State 2 of print head pressed

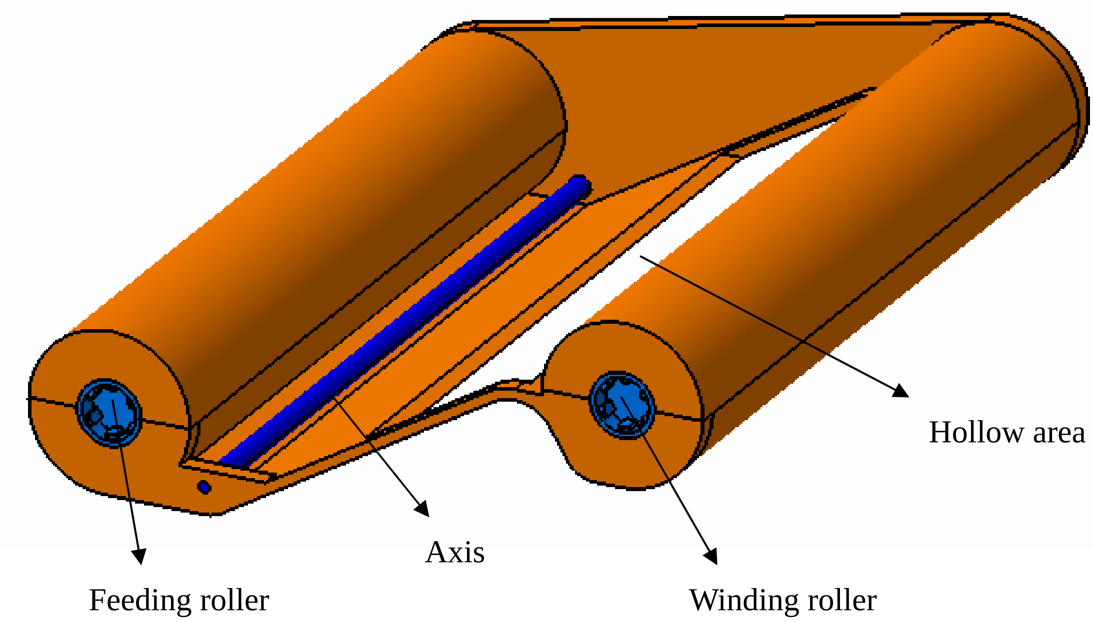


Fig. 5.11 Ink ribbon cassette

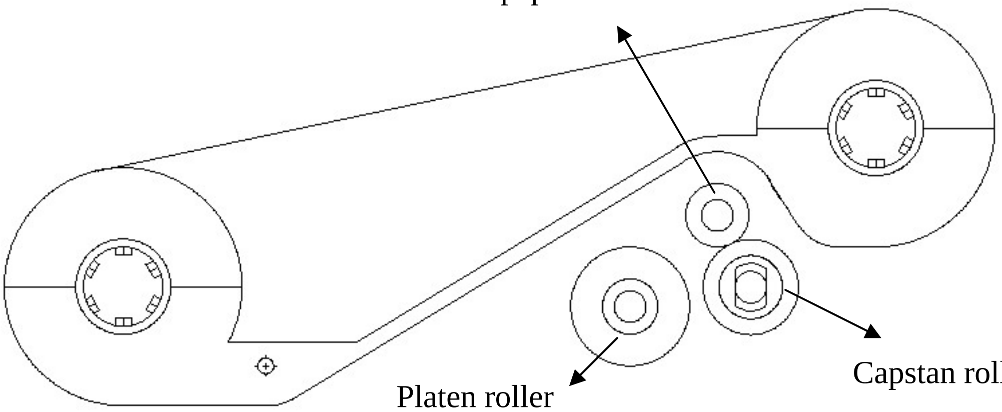


Fig. 5.12 Side view of ink ribbon cassette

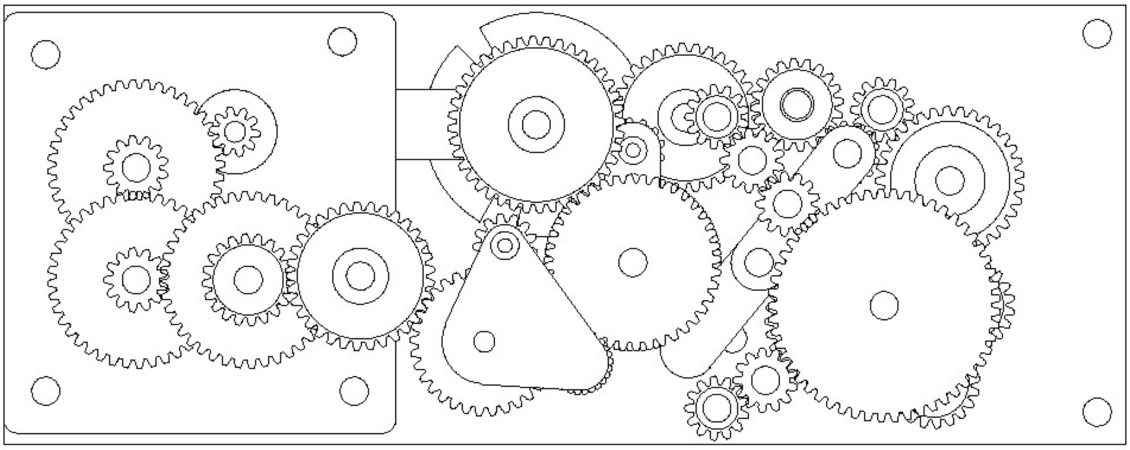


Fig. 5.13 Gear train of printer design

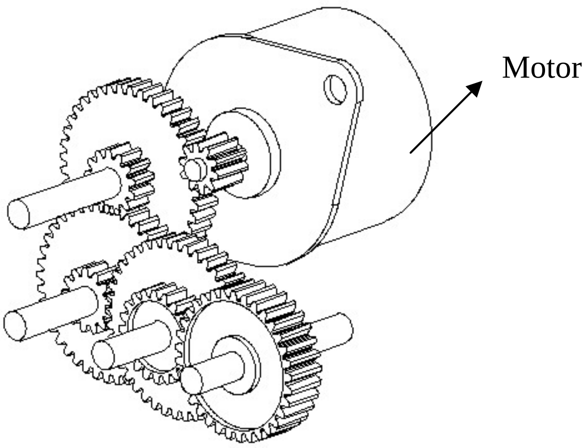


Fig. 5.14 Section 1 of gear train

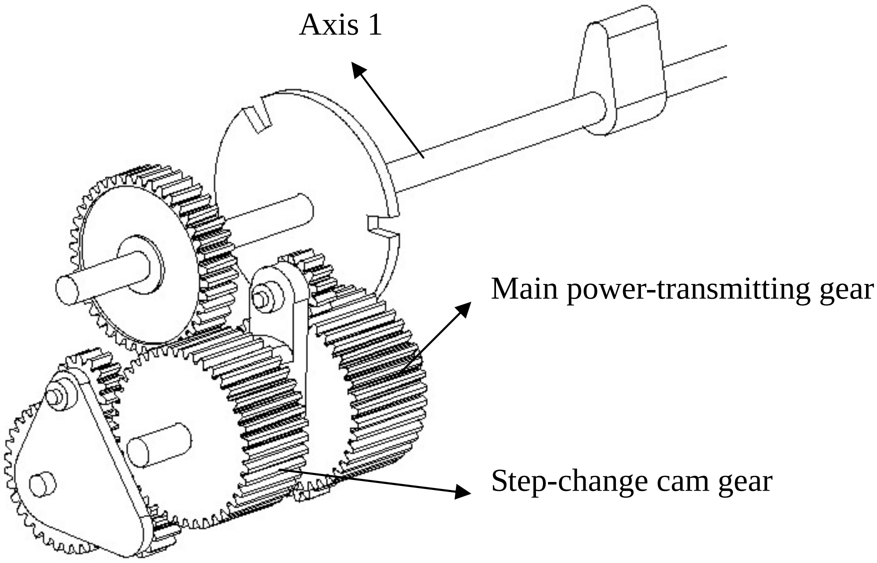


Fig. 5.15 Section 2 of gear train

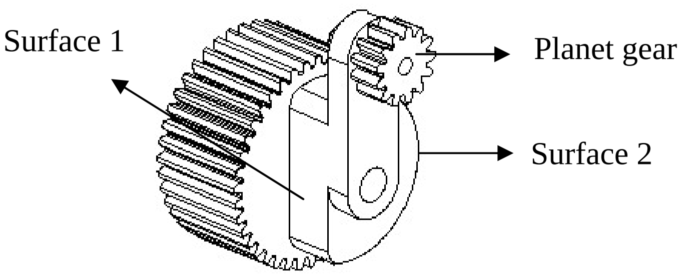


Fig. 5.16 Cam gear in printer design

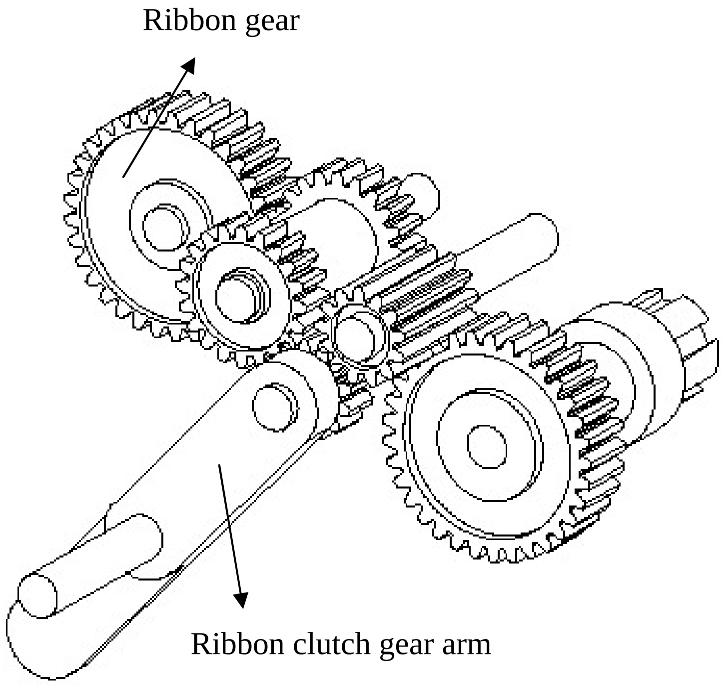


Fig. 5.17 Gear train 3A to ribbon roller

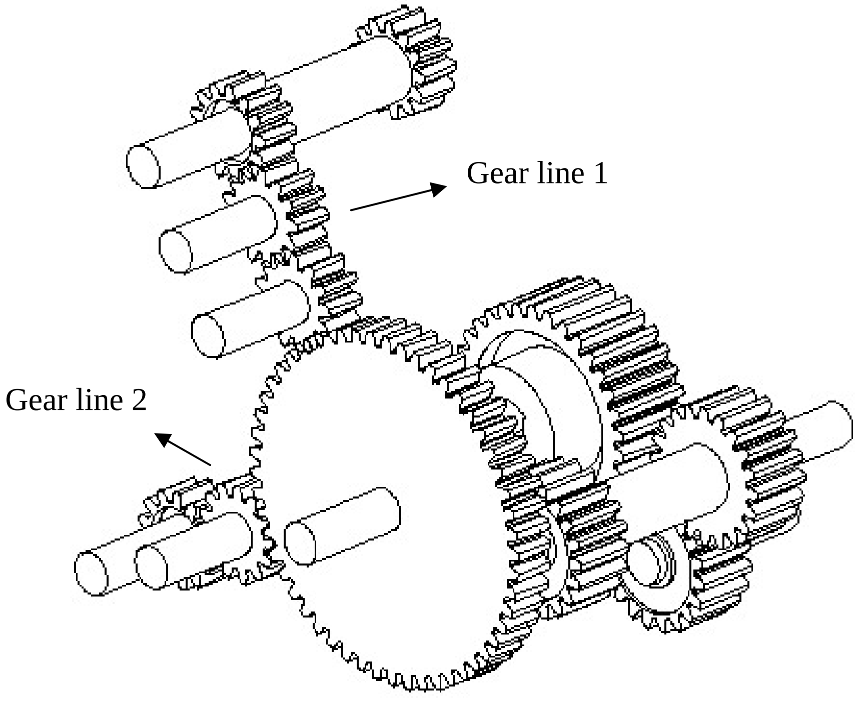


Fig. 5.18 Gear train 3B to capstan roller

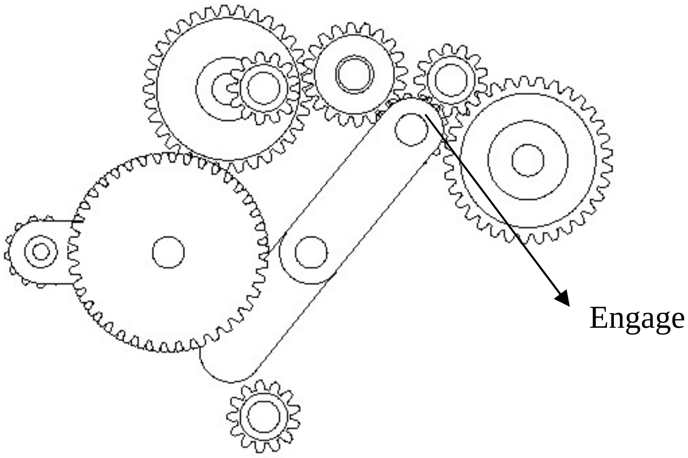


Fig. 5.19 Step 1 – Ribbon Searching

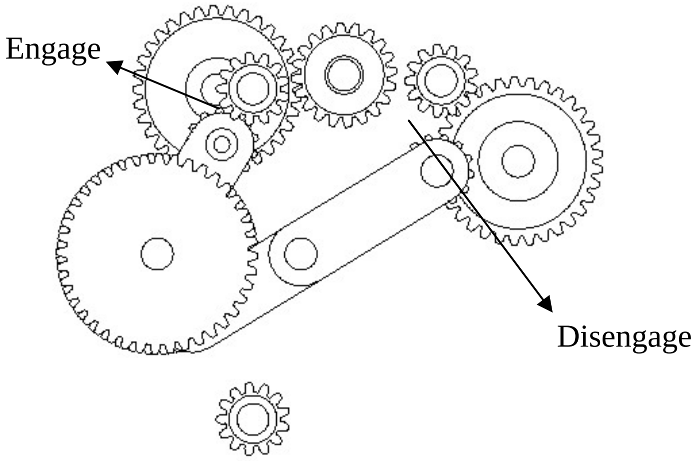


Fig. 5.20 Step 2 – Paper Feeding

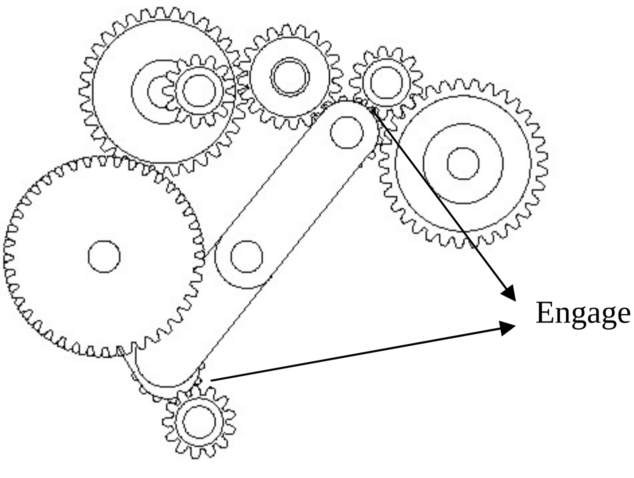


Fig. 5.21 Step 3 – Printing

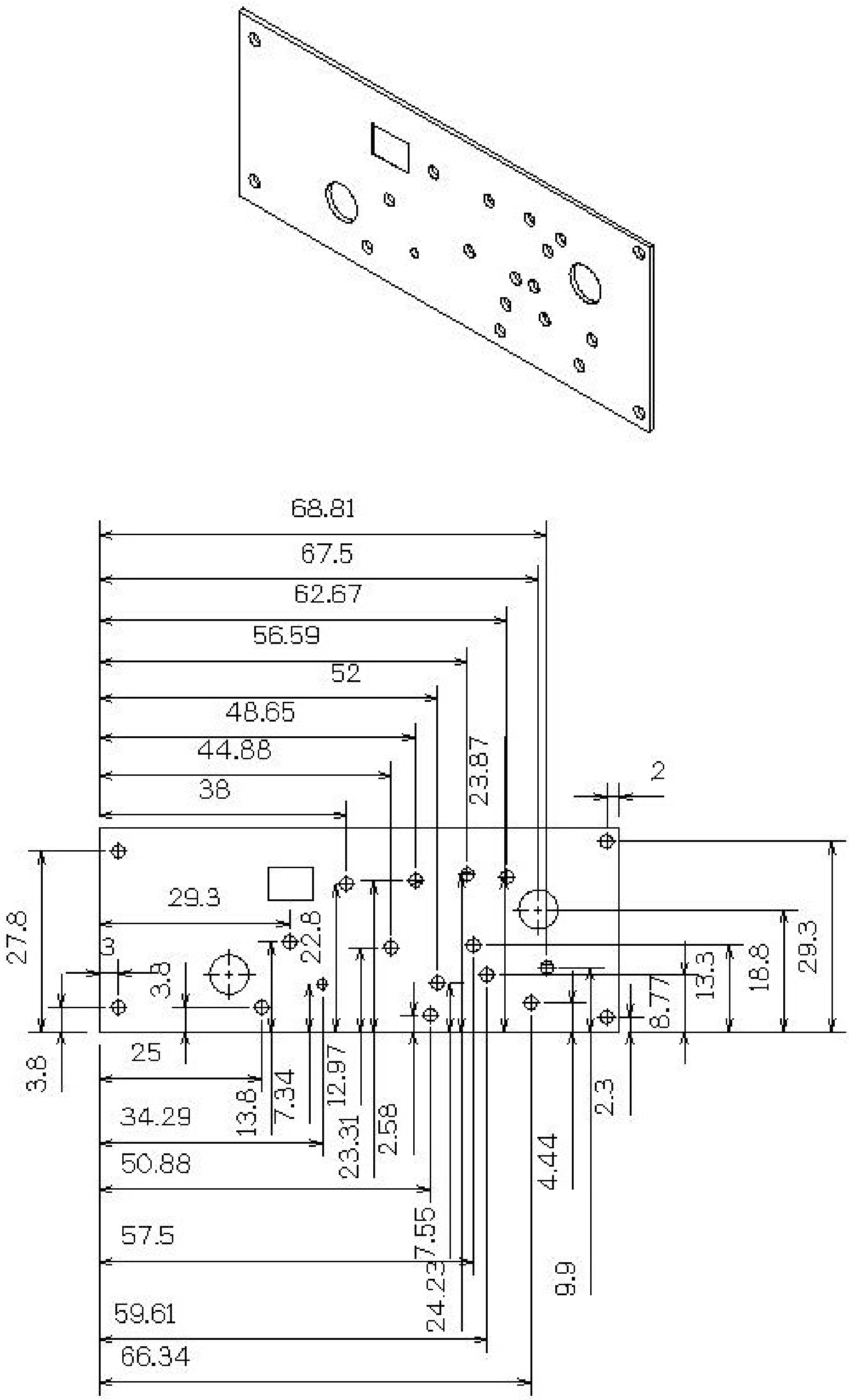


Fig. 5.22 Drawing 1 (One side of printer frame)

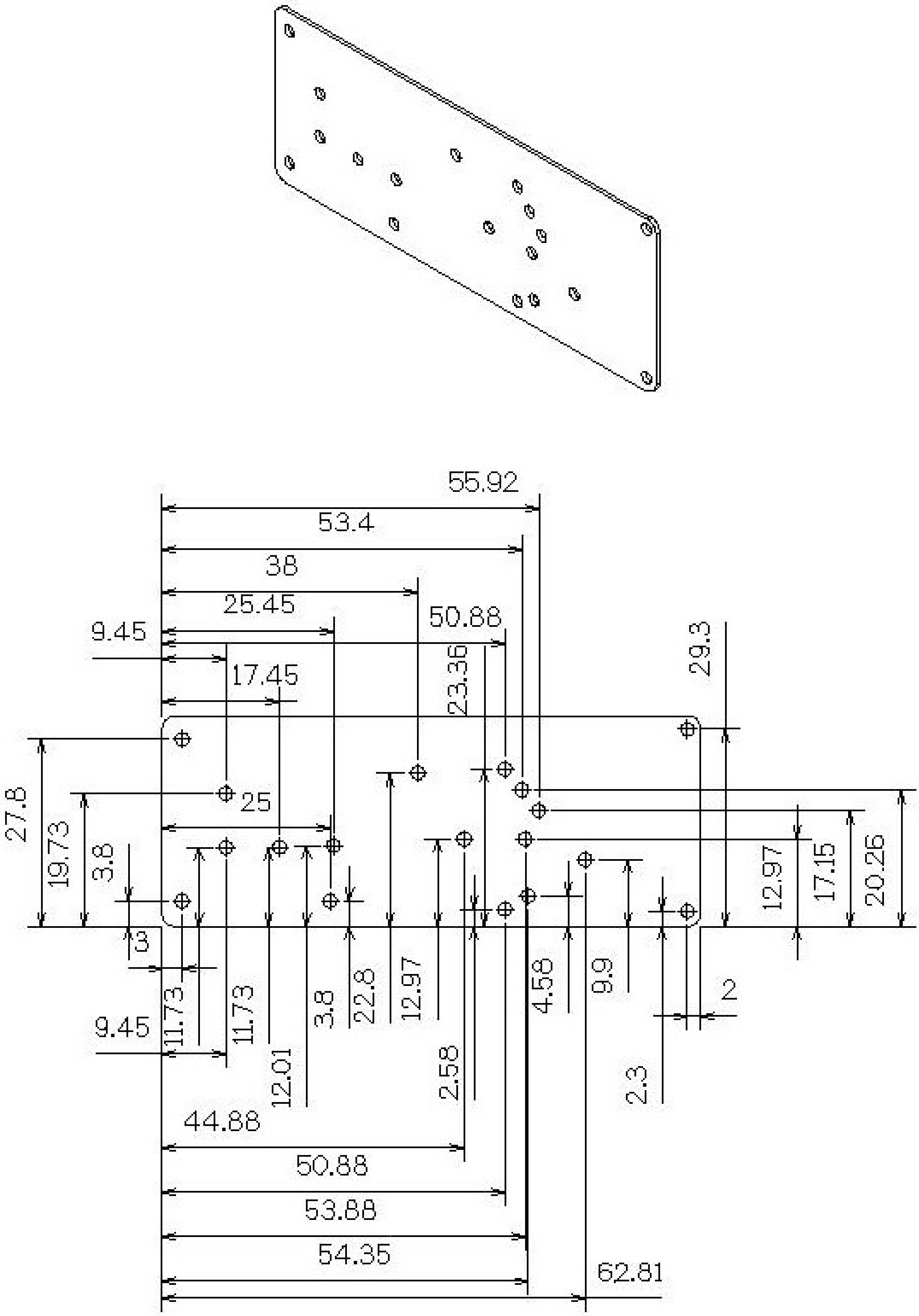


Fig. 5.23 Drawing 2 (Support plate for gear train)

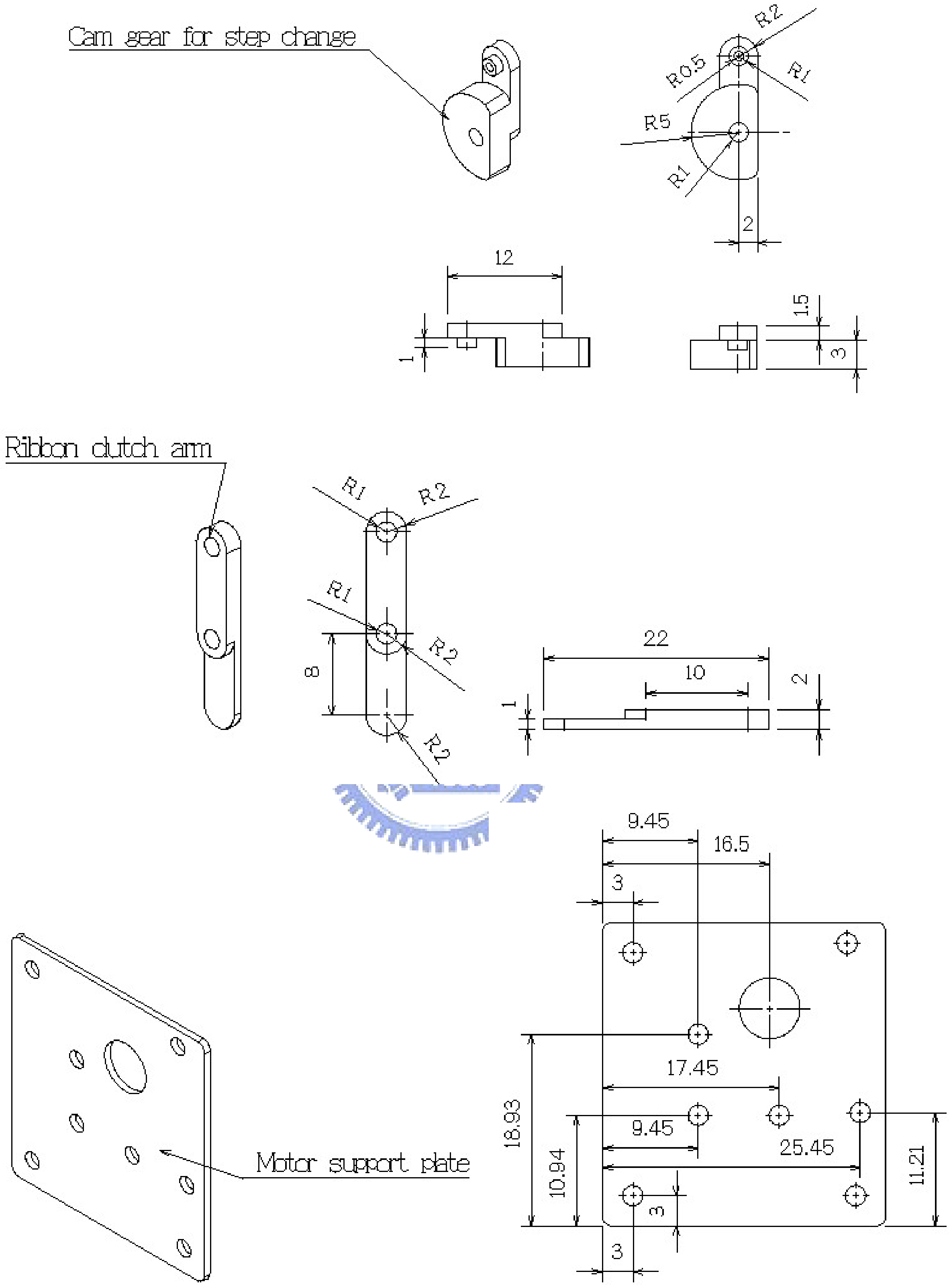


Fig. 5.24 Drawing 3 (Other components)

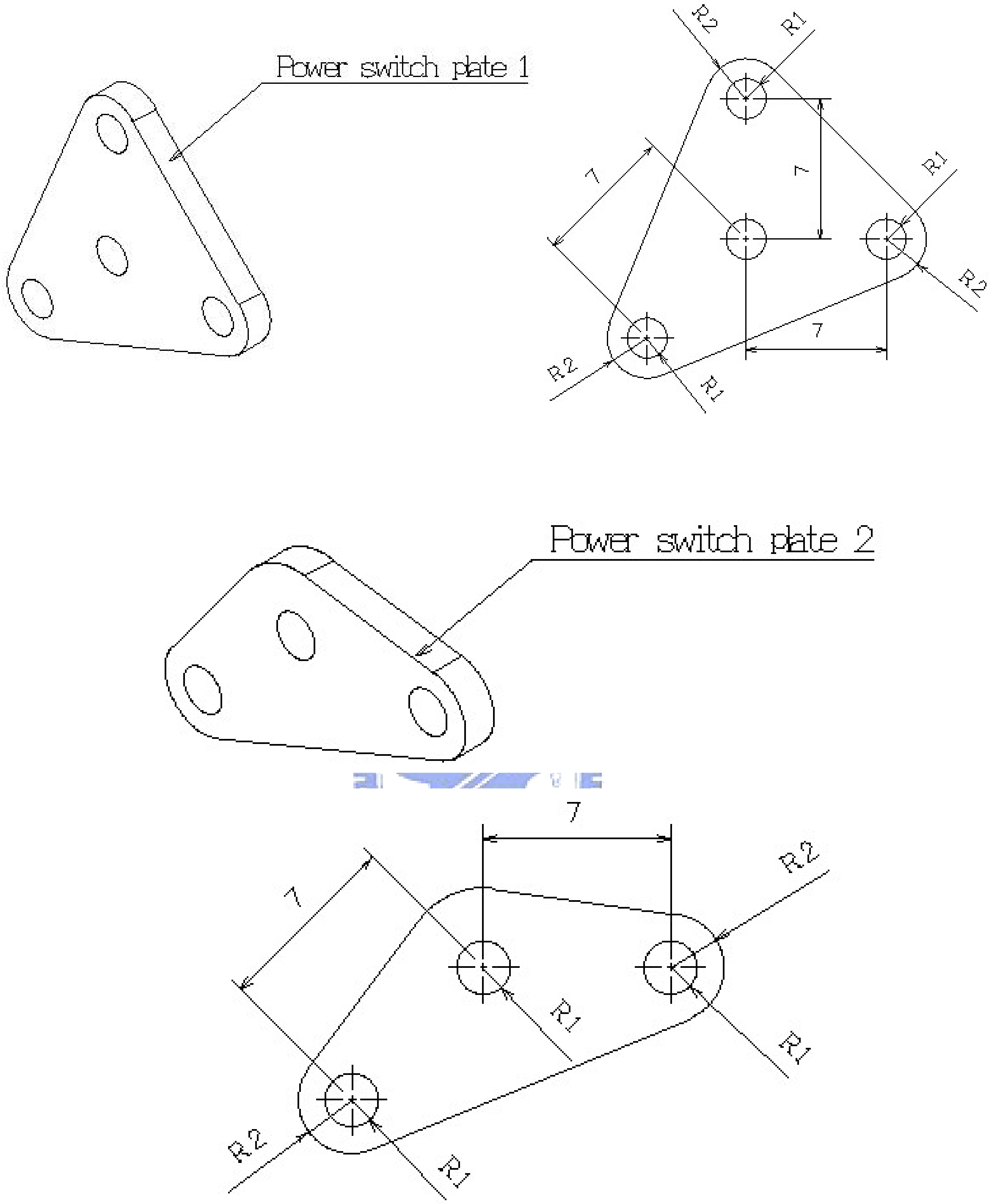


Fig. 5.25 Drawing 4 (Power switch plates)

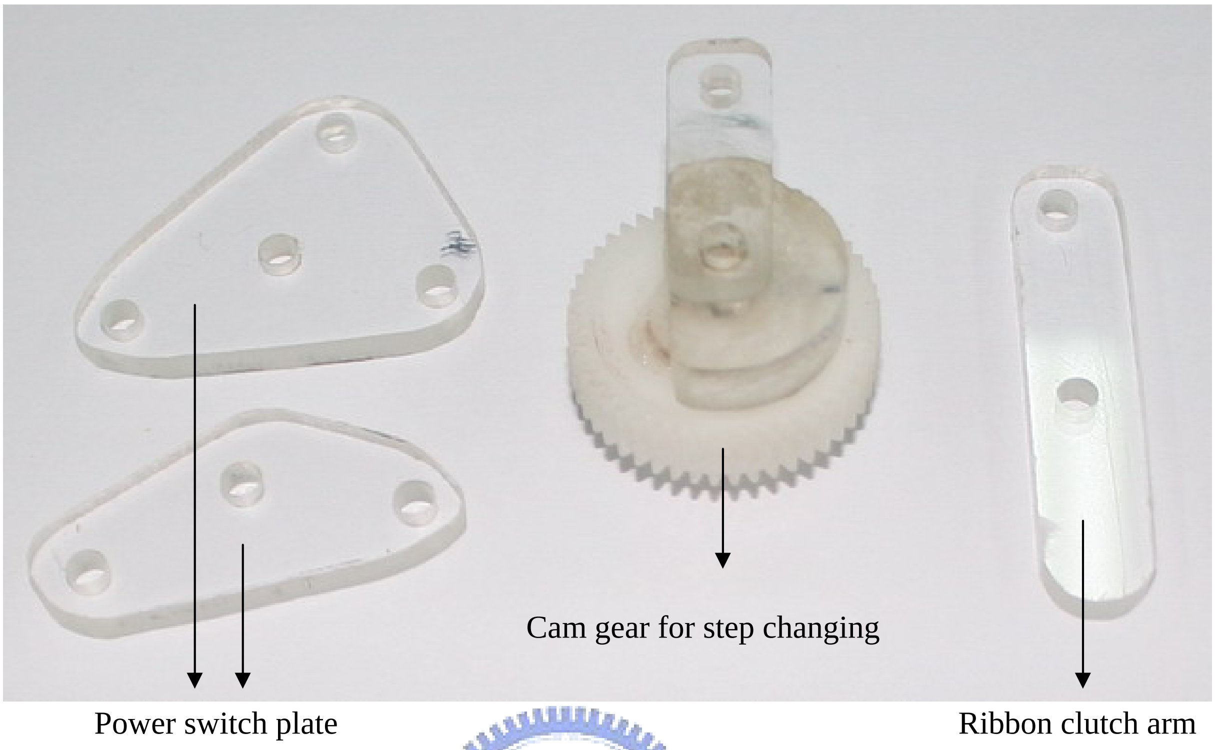


Fig. 5.26 Photo of the components

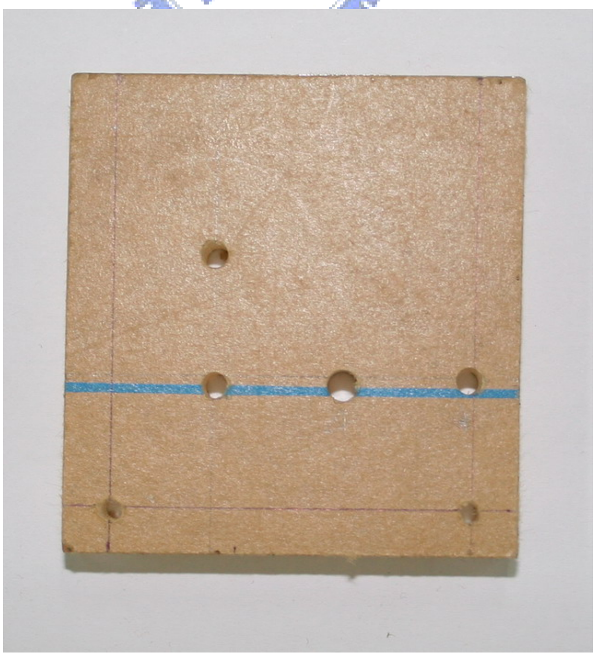


Fig. 5.27 Photo of motor support plate

Fig. 5.28 Photo of two acrylic plastic plates

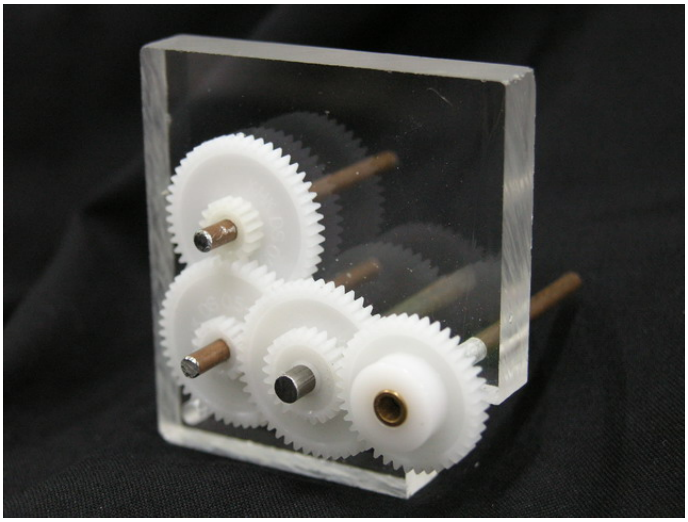


Fig. 5.29 Section 1 of gear train

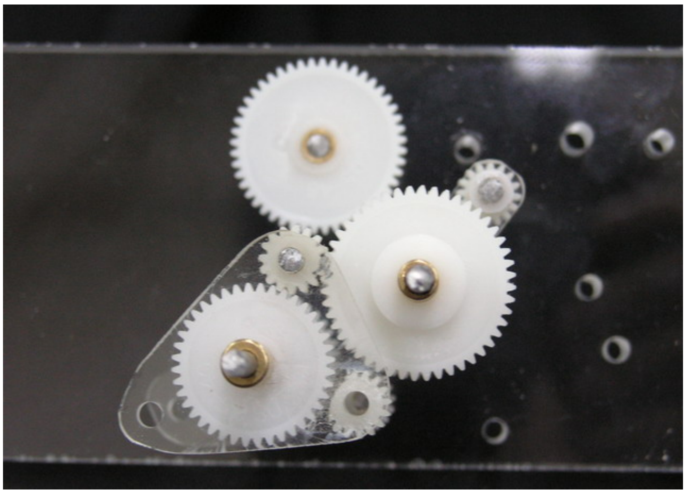


Fig. 5.30 Section 2 of gear train

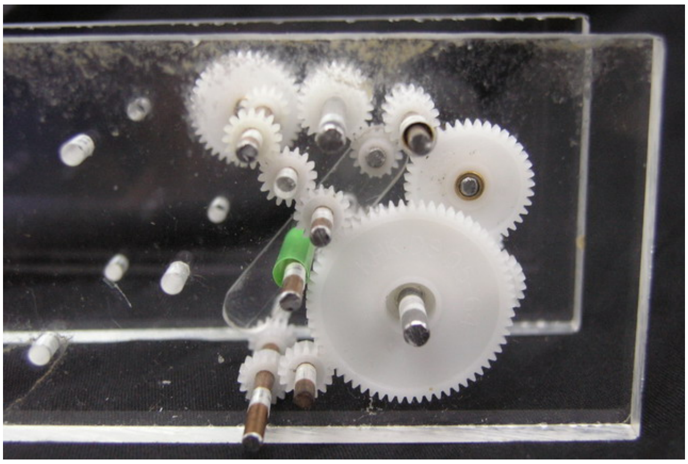
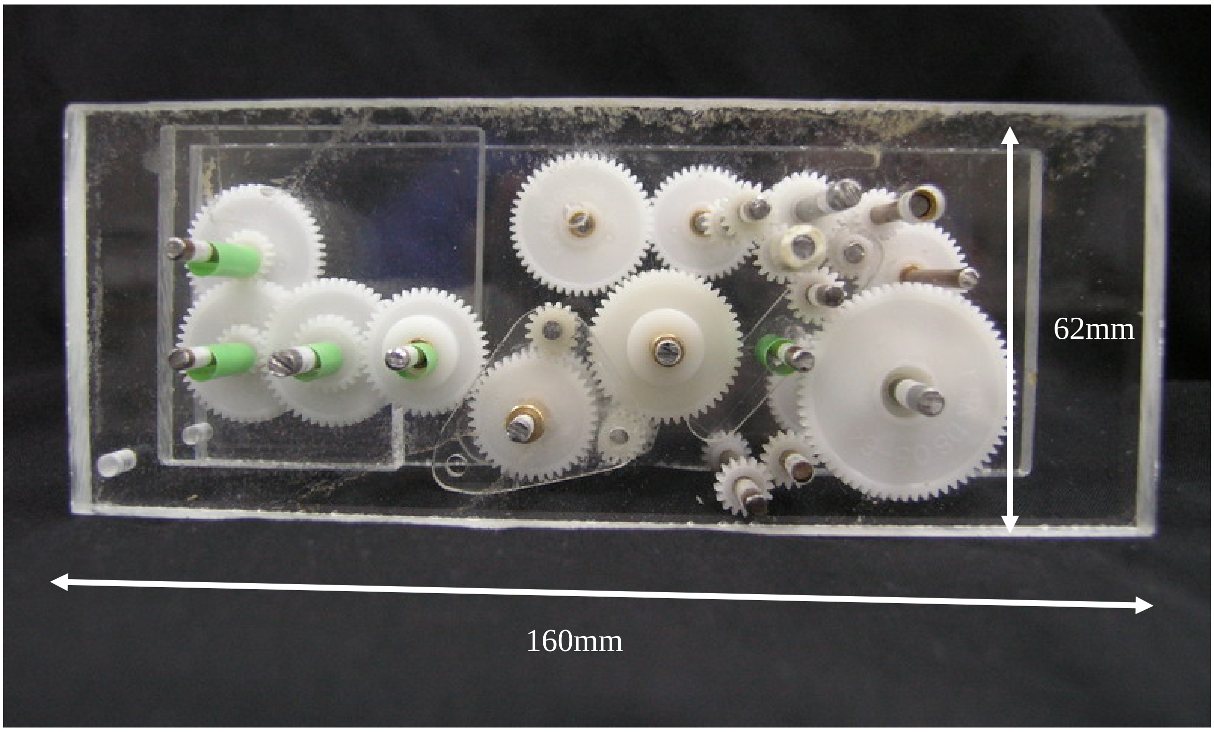
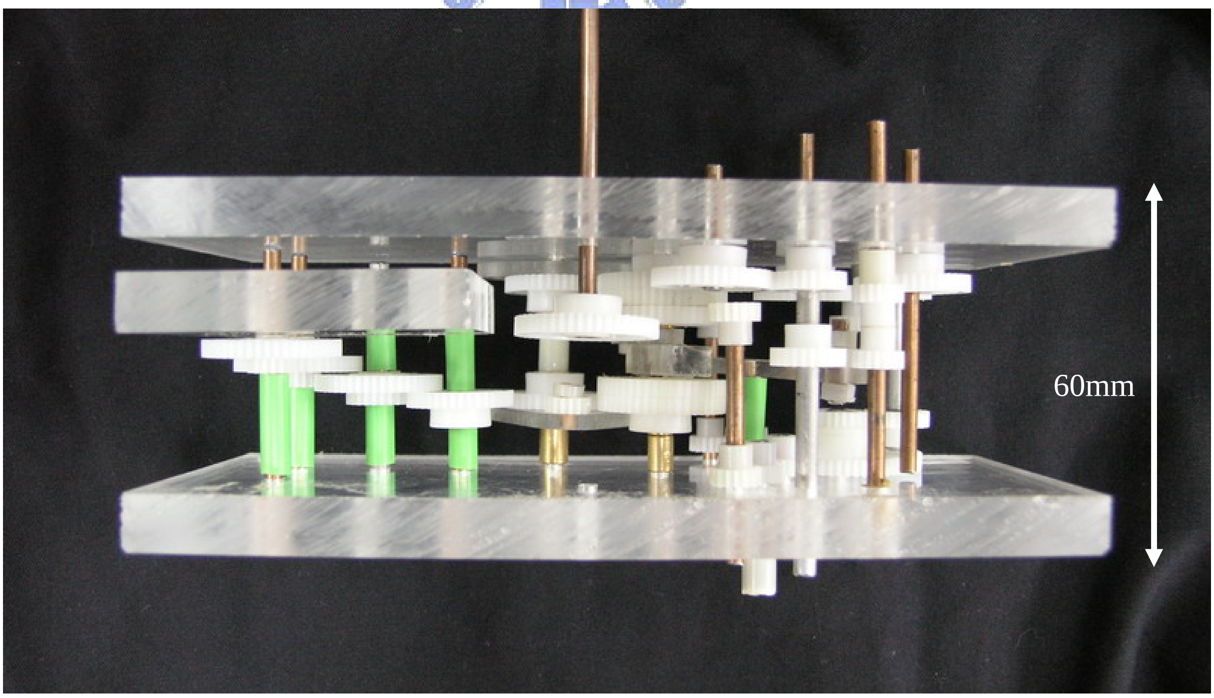


Fig. 5.31 Section 3A and 3B of gear train



(a)



(b)

Fig. 5.32 (a) Front view (b) Top view of the whole prototype

Chapter 6 Analysis

6.1 Weight

After the embodiment design, the size of print module has been confirmed. Besides of the space and power consumption, weight is also a key factor for mobile. In the embodiment design the material of frame is SECC and thickness is 0.8mm. The material of gear is DURACON® M90-44 and the material of axis is steel.

- Density of SECC: $8225kg/m^3$
- Density of DURACON® M90-44: $1410kg/m^3$
- Density of Steel: $7860kg/m^3$

Here are some assumptions about the components which are assembled by different things, for example, the print head, motor and photo-interrupter. Table 6.1 shows the components weight and total weight which is calculated by the software, CATIA. The total weight of print module is about 308g.

6.2 Displacement of Paper and Ribbon

The displacement of paper and ribbon relates to the resolution of print head. Thermal print head used here is one of Kyocera's products; model no. is KPC-54-8PAO1-LO. Table 6.2 shows its specification. The dot density is 8 dots per millimeter which means the resolution is 203 dpi. Generally the step angle of stepping motor is 18 degrees for 1 pulse per second. The displacement of paper in a step should be less than the dot pitch so that while printing, the paper can be located by sensors precisely.

The number of teeth on the motor gear is 12 and there are three deceleration gears in section 1. The teeth ratio of two deceleration gears is 16:48, and the other is 24:48. As shown in Table 6.3, the speed ratio from motor to ribbon roller is 1:60, and 1:160 from motor to capstan roller because of there is another deceleration gear, and teeth ratio of which is 24:64. According to present design, the radius of capstan roller is 3mm. Therefore, the displacement of paper per step is,

$$\text{Paper displacement per step} = \frac{\theta_m \times \pi \times R}{180 \times D_r} = \frac{18 \times \pi \times 3}{180 \times 160} = 0.00589 \quad (mm)$$

θ_m: The step angle of motor

R: Radius of capstan roller

D_r: Deceleration ratio

6.3 Motor

Here the motor used in the print module is a stepping motor. While choosing the motor, the maximum and minimum torque and the rotating speed should be confirmed. If the standard of motor after calculation can not be manufactured by the present motor companies, it is not feasible. On the contrary, it is workable if the standard can be found.

6.3.1 Pulse Rate of Stepping Motor

According to the test of ALPS product, PTMTL-25, while printing a sheet whose length is 85mm, the time for printing is about 15 seconds and 7 seconds for drawing sheet into printer. Use these data as the reference to calculate the rotating speed.

<u>Drawing sheet into printer</u>

The linear speed for drawing paper into printer = $\frac{85mm}{7s} = 12.14\ (mm/s)$

Pulse rate of stepping motor= $\frac{12.14mm}{0.00589mm} = 2061\ (PPS)$

<u>Printing</u>

The linear speed for printing = $\frac{85mm}{15s} = 5.67\ (mm/s)$

Pulse rate of stepping motor= $\frac{5.67mm}{0.00589mm} = 963\ (PPS)$

6.3.2 Torque

According to Table 6.2, the pressure for printing is about 12.7 N. Here assume that, first, the friction coefficient of rubber on the capstan roller and platen roller is 0.35. Second, the tangent force to draw paper into printer is 0.2 kg. Third, the efficiency of gear transmitting is 95%. Therefore, the torque the motor needs can be calculated by the following equation.

$$\text{The torque of motor} = \frac{F_t \times R}{D_r \times (0.95)^n} = \frac{T}{D_r \times (0.95)^n}$$

<u>F_t: Tangent force to draw paper by capstan roller</u>

<u>R: Radius of capstan roller</u>

<u>D_r: Deceleration ratio</u>

<u>n: The number of gears used for transmitting power</u>

T: Torque resistance

Drawing sheet into printer

$$\text{The torque of motor} = \frac{200 \times 0.3}{160 \times (0.95)^{14}} = 0.769\ (gf\text{-}cm)$$

Printing

$$\text{Tangent force to draw paper while printing} = \frac{12.7 \times 0.35 \times 1000}{9.8} = 453.57\ (gf)$$

$$\text{The torque of motor} = \frac{453.57 \times 0.3}{160 \times (0.95)^{13}} = 1.656\ (gf\text{-}cm)$$

Press thermal print head

When pressing thermal print head, print head cam will rotate and press pressure plate to supply required pressure. As shown in Fig. 6.1, the length from heater line to supporting axis is about 22.38 mm. The original angle between pressure plate and the thermal print head is 10 degrees. Therefore, the spring coefficient k of spring set A which supplies the force for print head is,

$$k = \frac{1296g \times 2.238cm \times 180\deg rees}{10\deg rees \times \pi \times 2} = 8309\ (gf\text{-}cm/rad).$$

Because the contact point between the print head cam and pressure plate is variable, it is difficult to calculate the torque resistance on the print head cam. Therefore, here use the software, ADAMS, to build a simple mechanism to simulate the movement, as shown in Fig.

6.2. The rotating speed of cam is 150 degrees per second which means the pulse rat of stepping motor is 500 PPS. The print head cam will rotate counterclockwise to press the pressure plate. Fig. 6.3 shows the simulation result, the real line is the result of present design. Point A is the maximum of torque resistance the cam must overcome. The value is 481.434 N-mm, equaling to 4912.59 gf-cm. After the speed ratio, 1:60, and the gear efficiency of gear transmitting, 95%,

$$\text{The torque of motor} = \frac{4912 gf - cm}{60 \times (0.95)^8} = 123.42\ (gf\text{-}cm)$$

It is too large for a small stepping motor. Therefore, the design of cam is not feasible.

If the cam can rotate clockwise, the torque that the print head cam can supply will be larger because the contact point is farer from the rotating axis of torsion spring than the contact point when the print head cam rotates counterclockwise. The dotted line in Fig. 6.3 is the result while print head cam rotates clockwise. Point B is the maximum value which is 145.4 N-mm, equaling to 1483.67 gf-cm. After the speed ratio and gear efficiency of gear transmitting,

$$\text{The torque of motor} = \frac{1483.67 gf - cm}{60 \times (0.95)^8} = 37.27\ (gf\text{-}cm)$$

This value is smaller than the previous one and is feasible to find the small stepping motor. Here the way to change the rotating direction of print head cam is to add one more gear in the gear train and the torque that the motor needs will become 39.23 gf-cm.

After these calculations, the requirements for the stepping motor are defined. The maximum torque is 39.23 gf-cm while the pulse rate is 500 PPS. The minimum torque is 0.769 gf-cm while the pulse rate is 2061 PPS.

6.4 Action Analysis

The key part in present design is section 2 of gear train, the mechanism for power switch and step change. Generally gear is used for transmitting power. But here the function of power switch is applied by the engagement or disengagement of planet gear. In this mechanism, because both the rotating arm and planet gear can rotate freely, it is hard to ensure which component will rotate so that here discuss the cases.

There are one force and two resistances that will effect the movement of these components,

1. F: rotating force
2. R_p: resistance of planet gear rotating
3. R_a: resistance of rotating arm rotating

Case 1: If $R_p < R_a$

As shown in Fig. 6.4 (a), while F is larger than R_p, the planet gear starts rotating but the rotating arm does not.

Case 2: If $R_p > R_a$

As shown in Fig. 6.4 (b), while F is larger than R_a, the rotating arm starts rotating but the planet gear does not.

In the present design, it only needs case 2 because R_a will become larger than R_p after the planet gear engages the step-change cam gear or power transmitting gear. Therefore, here the way to ensure that the mechanism always working in case 2 is to increase the resistance of planet gear rotating.

There are two ways to increase the resistance. First one is to increase the friction between the gear bore for axis and the axis. Second is to increase the friction between the planet gear and the rotating arm. But first way is more difficult than second one so that here uses second way. As shown in Fig. 6.5, a spring is added between rotating arm plate and gear axis to supply a lateral force to planet gear so that the friction between gear and rotating arm will increase.

6.5 Remarks

1. The weight of present design is about 308g.
2. The maximum torque is 39.23 gf-cm while the pulse rate is 500 PPS and the minimum is 0.769 gf-cm while the pulse rate is 2061 PPS. One more gear must be added into the gear train to change the rotating direction of print head cam.
3. In order to ensure the movement of section 2, increasing the resistance on the planet gear is necessary. Here use a spring to increase the lateral friction between planet gear and the rotating arm.

Table 6.1 The weights of print module

Component		Weight
Frame	Printer frame	89g
	upper cover	70g
	motor support plate	5g
	Axis support plate	16g
Ribbon cassette		19g
Thermal print head module(with spring, frame and cam)		35g
Motor		15g
Platen roller		25g
Capstan roller		8g
Passive paper roller		7g
Gear train(including axis)		14.94g
Others		4.06g
Total		**308g**

Table 6.2 Specification of thermal print head

Model No.	KPC-54-8PAO1-LO
Effective print width	54 ± 0.2mm
Number of heater elements	432 dots/HEAD
Dot density	8.0 dot/mm
Subsequent scanning density	8.0 line/mm
Dot pitch	0.125mm
Partial pressure onto platen	2.9 N/cm max
Platen pressure	12.7 ± 2.9 N/HEAD

Table 6.3 Simulation result of rotation angle after deceleration

Time (S)	Angle of motor (Degree)	Angle of ribbon roller (Degree)	Angle of capstan roller (Degree)
0	0	-3105	-1164.38
1	1800	-3075	-1153.13
2	3600	-3045	-1141.88
3	5400	-3015	-1130.63
4	7200	-2985	-1119.38
5	9000	-2955	-1108.13
6	10800	-2925	-1096.88
7	12600	-2895	-1085.63
8	14400	-2865	-1074.38
9	16200	-2835	-1063.13
10	18000	-2805	-1051.88
Total angle of rotation	18000	300	112.5

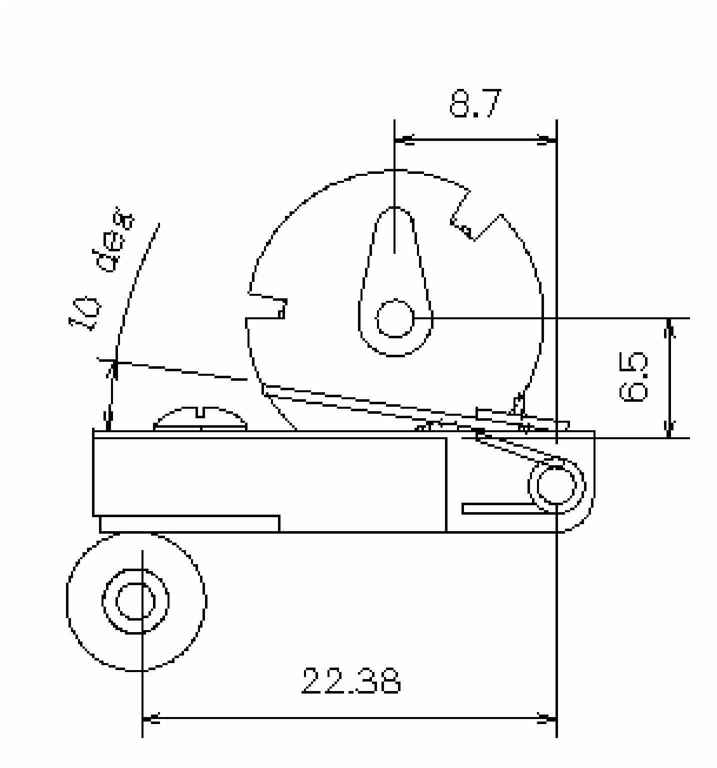


Fig. 6.1 The position of print head module

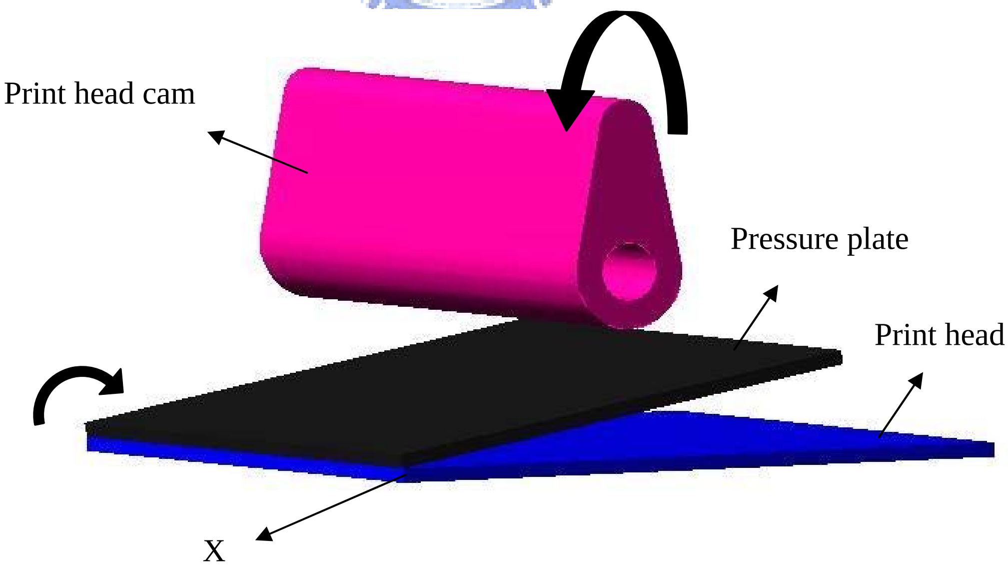


Fig. 6.2 The simulation model

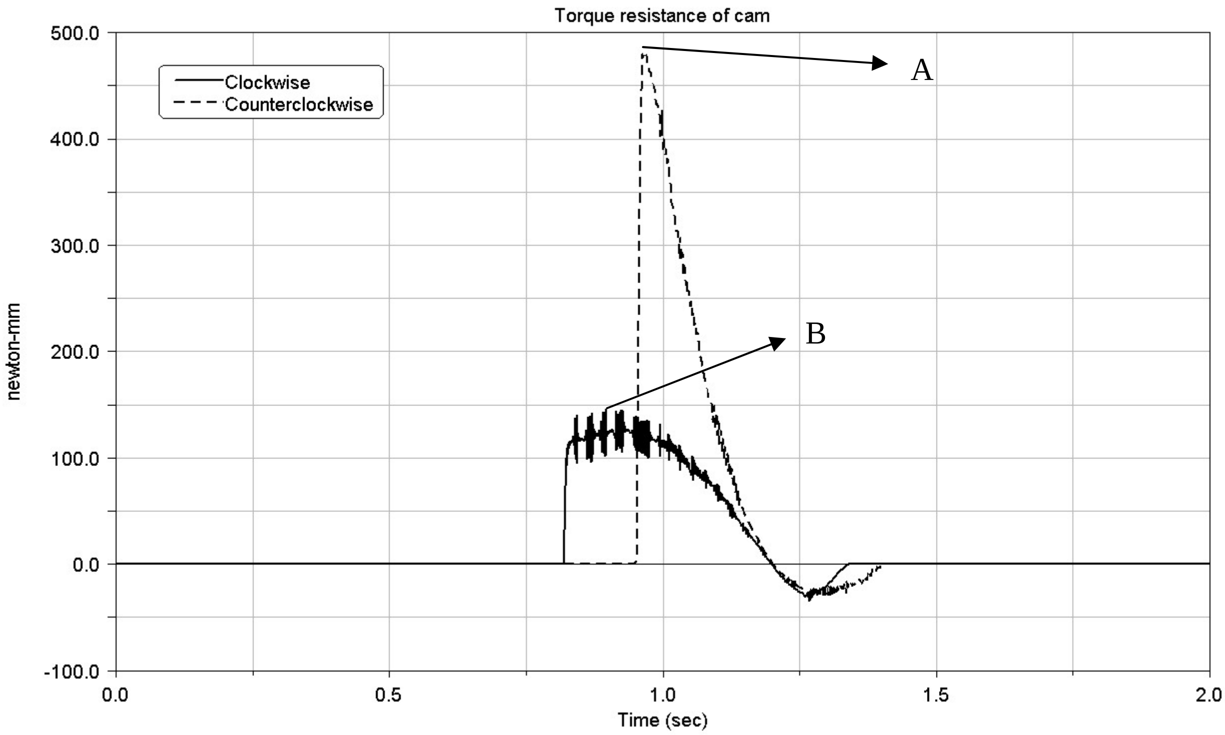


Fig. 6.3 Simulation result of print head module

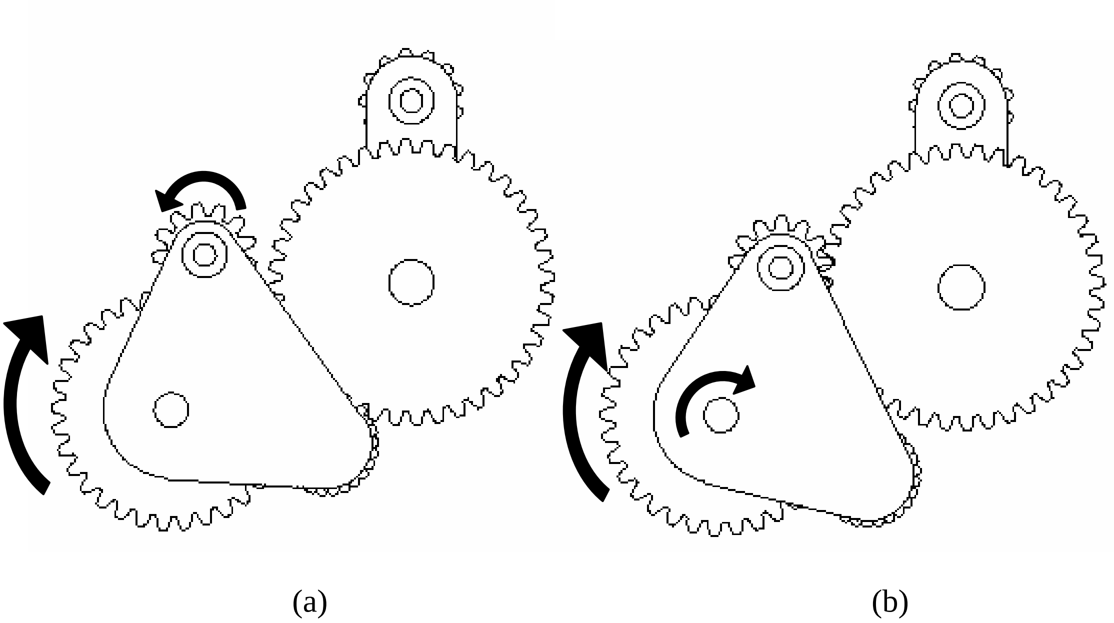


Fig. 6.4 The two cases of planet gear

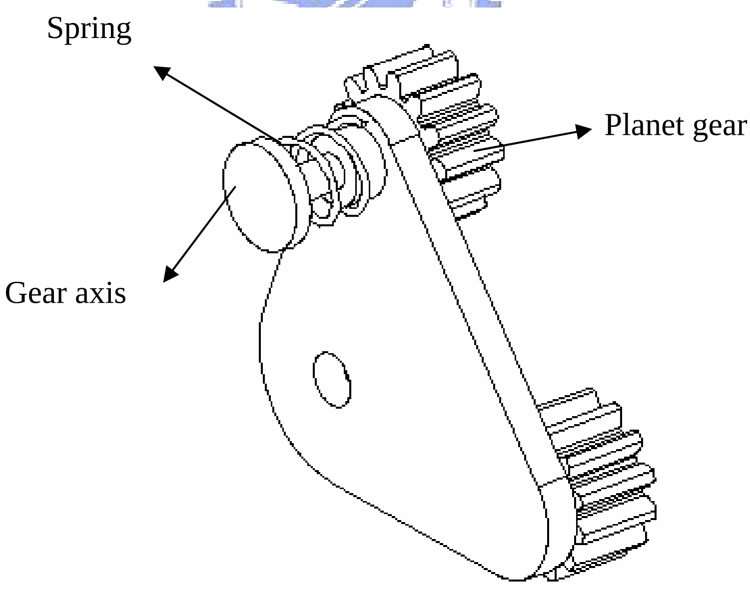


Fig. 6.5 Way to increase the resistance of planet gear

Chapter 7 Conclusions

7.1 Conclusions

1. TRIZ provides principles to designers, and these principles are related to design parameters. Therefore, these principles are usually suitable to solve the problem. It is different from designer's checklist method that developed by themselves. Therefore, using checklist method needs more creativity.

2. Compare these concepts in this study, concept 5 uses only one motor and need not any other electrical device to support the action. For the requirement of power saving, design of concept 5 can print more pages than other concepts with the same power.

3. The size of the present print module design is 107.4mm* 81.6mm* 26.8mm and its weight is about 308g. For the mobile requirement, it is lighter and smaller than general printers and near to ALPS products.

4. Compared with the design of ALPS, as shown in Table 7.1, there are two advantages, first, the design of ALPS needs to detect paper first, and then draw the paper back for printing. Therefore, it needs 4 steps to complete the whole printing process. Second, while step changes from drawing paper in to printing, or reverse, the cam gear needs to rotate more than 270 degrees. These will spend more time to finish the printing process, but the present design only needs 3 steps and can detect the paper while drawing paper into printer at the first time. Furthermore, it only needs to rotate about 120 degrees from the step of drawing paper in to printing, and 240 degrees for the next color printing.

Therefore, the present design will save more time than ALPS products while printing.

7.2 Future Works

1. Search more related information. Patent is one of the important sources for the product design. Read more patents to make the database more complete. Other production related to printer can also be searched, such as the borderless printing, to increase the functions of printer.

2. Reduce the size of the present design. Here the study uses TRIZ to generate concepts about motor reduction. TRIZ or other optimum methods may be used to improve the size or weight of the present design.

3. Propose more new concepts. Use TRIZ or other innovative tools to find other better concept which can also use only one motor and the size is smaller.

4. Real size prototype. In the study, the size of prototype is twice to the embodiment design. Fabricate the whole mobile print module with real size to see if there is any other problem in the design.

Table 7.1 Comparison

	ALPS	Present design
Size	96.6 x 17.4 x 61.1 mm^3	107.4 x 26.8 x 81.6 mm^3
Motor	1	1
Steps	4	3
Gear	17	26
Rotating angle	> 270°	120° & 240°
Rotation 1	Paper change & change	Power output
Rotation 2	Paper out	Change

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