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Properties and Printing Performance of Light-weight Paper

Bachelor's Thesis 2014

ABSTRACT

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Properties and Printing Performance of Light-weight Paper, 45pages
Saimia University of Applied Sciences, Lappeenranta
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The purpose of this final thesis was to study light-weight papers' properties and try to find out the optimum printing performance.

The information was gathered from journal, literature, the internet. Printing part was guided by Dr. Han Wenjia. The printing performance test was carried out by Ding Na in the Qilu University of Technplogy's printing laboratory.

As a result of this project we can gain the suitable methods of increasing the light-weight physical performance. According to the test result, we select the best combination of color table and image from GATF or ISO400 standard image, which can be served as a reference tool for light-weight paper printing.

Keywords: Light-weight paper, print tone reproduction, selection of the image and chart.

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1 Introduction

Light-weight paper is a more humane kind of paper, which has high quality and is light-weight, inexpensive, has non-fluorescent brighteners, high mechanical pulp content, environmental comfort. Original color can be used to protect the readers, especially the elderly and children's eyes, enabling them to protect their eyesight from harm in reading and facilitating the reader to carry with natural characteristics. The weight of books printed on it is lighter than the weight of the books on plain paper, saving the cost of transport and mail-order. For printing books, its appearance as well as the feel, read, use, preservation can achieve the desired effect.

This thesis trying to find out various factors that can be affect the performance of light-weight paper through experiment and observe the printability affected by these performances. By analysis GATF Beta and ISO400 standard image have a role in process of controlling printing quality. The outcome of experiment can give a support to the best combination of the color table and image, then measure field density, dot gain or other parameters and analysis printability. Finally, select and design color table and image from GATF or ISO400 standard image, which can be served as a reference tool for light-weight paper printing. Based on the application of light paper in books printing in the domestic aspects, this thesis is studying the salient features of Light paper, analyzing its whiteness, smoothness; K & N ink absorption properties and the surface characteristics of this kind of paper.

The body of this thesis can be classified into four parts. First chapter describes the background, purpose and meaning of light-weight paper, and then makes rough outlines of book printing and publishing application in home country and abroad

The second chapter, based on light papers characteristics, first introduces the origin and development of light-weight paper, and then talks about the physical properties of the surface of light paper and the problems encountered in the production process as well as solutions. Finally, the thesis data collection and analysis the characteristics of paper are made. These also have become an important theoretical basis for further research.

The third chapter gives specific interpretation about tone reproduction for printing and color quality reproduction which based on print quality assessment and control targets. It also discussed the factor affecting these both targets.

Chapter IV presents a different tone color and standard color image by the experiment and collected experiment data, then makes tone curve and the printed dot gain curve by MATLAB, at last, we can give objective evaluation and subjective evaluation.

The fifth chapter gives the summary and outlook of the paper.

2 Light-weight paper

2.1 The properties of light-weight paper

Light-weight paper was originally made in Sweden Munkdel, which has a light-weight paper production normal name, as Mengken paper (light-weight paper), According to its property, it is a kind of small weightiness paper for printing but with relatively large bulk paper. Light-weight paper is usually represented by thickness factor number, such as 1.5, 1.7, 1.8, etc., which means divided by the thickness of the paper refers to the quantitative. Usually defining on light paper thickness factor is generally higher than 1.5，which is also known as light paper, plain paper. In Europe and Japan, and other economically developed countries, more than half of the books in bookstores are printed by this kind of paper. (Zheng 2010)

Light-weight paper is not complicated to produce, normally people take advantage of using traditional paper machine transformation to produce light paper by adjusting on the original structure and the pulping process. Through increasing mechanical pulp, reducing the amount of filler to achieve its bulky lightweight purpose the machine does not need to be very complicated transformed since mechanical pulp yield is high, up to 88 % to 90 %, which gives more efficient use of resources.

Light-weight paper seldom contains optical brighteners; mostly it looks like milk white, beige, white valley, soft color vision has a protective effect. Meanwhile, the texture and bulk are quite good, folding, opacity, original good printability. When it comes to printing, the most important property is that the comparative lower the density of the paper than ordinary printed books, light-weight paper printed

book light 1 /4 a 3 /4 than normal books, which also saves transport and postage costs.

Although light paper in price, technology, environmental protection and other aspects of the decision reflects the comprehensive advantages, but lightweight printing paper surface strength, absorbency, opacity three quality indicators for printing is very important, if not meet the quality of these indicators needs, it will seriously affect the normal operation of the printing press since the printing quality cannot achieve satisfactory results. Therefore, when converting the machine to achieve high quality, we should consider how to break the technical bottleneck restricting the index. (Zheng 2010)

2.1.1 Bulk and light weight

The bulk of the light-weight paper is quite good, which is the most important property of light-weight paper. Normally we select CTMP, BCTMP, and APMP pulp as raw materials, the fibers themselves stiff, the stiffness of light-weight paper is 14% to 40% higher than the same quantity of uncoated board paper. There is also increased opacity, which has a positive effect on the printing. It is not as the actual weight as it looks like, and easy to carry. Therefore, this paper can replace the original high quantitative equivalent thickness of paper, the actual production of the plant in terms of efficient freight and postage savings, thereby reducing costs. (Zheng 2010)

2.1.2 Natural color

The pulp of light-weight made by the chemical-mechanical pulp, non-fluorescent brighteners, due to the addition of a special creamy，which make it white or pale beige, compared to ordinary coated paper, offset printing paper, light-weight papers' color is a little dark, and pulp colors are similar, which gives a kind of

natural feeling especially for a long time reading books printed on light-weight paper since it is not likely to cause visual fatigue. Nowadays in China, with the rapid development of paper making, printing by light weight paper gradually and widely used in many parts of the school's educational books, children's publications and even magazines which for reducing the weight of paper and printed with benefit readers ways for a long time positive effects.

2.1.3 Good printability

Lightweight paper's surface is smooth and delicate, paper quality better, which depends on the structure of porous paper and ink absorption ability. The most basic requirement is that the printing paper in the printing process can go through the printing press smoothly; the paper cannot go with any fault. Light-weight printing paper can meet the requirements and have good printability, because no coating or the coating amount is low, so that light reflectance of the paper is not high and the ink absorbing capability is strong, it can adapt to the offset printing, letterpress printing, gravure printing and other traditional printing. Light paper is chlorine-free paper, and usually 10% pure chemical pulp paper-making, non-fluorescent brighteners and other ingredients are used in paper-making, so that the paper was slightly alkaline, you can save it even for thousands of years without deterioration. Light-weight uncoated paper, without treatment, mainly composed of fibrous calcium carbonate and water, do not pollute the environment, it can be regarded as a green product. (Wang 2005)

2.1.4 Drawbacks

Since the light-weight papers lack fibrous tissue and the thickness is relatively large, thus its tensile properties are also relatively narrow, and easily produce damp deformation. In addition, the rough surface of light-weight paper lead to

the printing plate friction easily and increasing the friction of paper. Normally, compared with ordinary light paper printing paper thickness, it would be under the same relative reduction in the thickness of the graphics capacity. These defects can be seen as drawbacks which need to be improved. (Yang 2011)

2.2 Main process of light-weight paper making

The process of light-weight paper making is not complicated, Basically, normal paper making machine can be adjusted based on the original material structure and the pulping process , and increase mechanical pulp , reducing the amount of filler so that can achieve its bulky lightweight purpose, but machine does not need to have complicated transformation. What is more, mechanical pulp yield is high, up to 88 % to 90 %, more efficient use of resources. Light paper in price, technology, environmental protection and other aspects of the comprehensive advantages of the decision has caused the paper become popular. (Yin 2013)

However, the properties of the printing paper surface strength, absorbency, opacity, the three quality indicators are significantly important to printing process. If the quality indicators are not necessarily meet, it will seriously affect the normal operation of the printer, and the printing quality cannot have satisfactory results. Therefore, when converting the machine to achieve light-weight papers, how to break the technical bottleneck should be take into consideration. (Yin 2003)

2.2.1 Brief description of pulp preparation

According to the impact of different fiber ratio on the physical properties of paper in the production of lightweight paper, selection of raw materials is very important, which is the key to achieve bulk requirements. The selection of raw materials

should be based on chemical -mechanical pulp. Light-weight paper pulp requires a low content of lignin, the relative density (typically 0.6 ~ 0.7 g/cm3). Thus, the fiber deformation, good evenness of paper, paper color is not easy turning yellow, and air permeability is easy to control. Normally, light-weight paper use the bleached Kraft pulp in general should adopt hardwood pulp -based, plus a small amount of bleached softwood Kraft pulp to increase strength. (Li 2010)

1) Normal softwood chemical pulp (NBKP). Bleached coniferous chemical wood pulp (NBKP) can be achieved by hydro pulper after pulping , pulp pool and high concentration cleaner , beating and other refiners processing into pulp storage tank, beating controlled at 30 ~ 35 ° SR.

2) The conventional mechanical softwood pulp. Softwood pulp can be prepared by the main processes of hydra-pulper pulping, pulp pool, the high concentration clean, beating and other treatment refiner into storage tank.

3) APMP pulp. After aspen CTMP pulp then send it into high concentration cleaner, beating and other refiners processed into pulp storage tank, beating controlled at 50 ~ 60 ° SR, the freeness generally controlled if raw materials used CTMP at 60 ~ 65 ° SR. Overall, according to dehydration paper quality and appropriate network portion of the well beating process, trying to ensure that in the bulk of the most important indicators of the premise of improving freeness is to enhance adhesion between the fibers.

4) White water recovery system. White-water recycle is most concentrated in the flow system, and the network under excess dilute concentrated Whitewater, Whitewater is sent multiple disc fiber recycling machine, Whitewater concentrate on pulp by adjusted for recovery after wire section spray, broke dilution and so on.

5) Pulp combination systems, softwood chemical pulp, mechanical pulp, softwood, poplar APMP pulp, pulp loss, as well as the general control of the white water recycling pulp slurry, after the automatic pulp combination, paper machine approach flow through the filters into the pulp combination system, with

a good pH values between 7.5 and 8.5, the overall degree of beating control 40 ~ 45 ° SR. (Jin 2012)

2.2.2 Wet-end chemistry

This part basically includes preparation of wet end chemicals and plastic material preparation system. Gluing the amount of 1 ~ 2g/m2 (single-sided), plasma temperature controlled at 40 degree for internal sizing, a good and easy way to produce filler deposition phenomenon. Filler (calcium carbonate) about 8% to 16% is added. According to the printing requirements of advanced lightweight paper and the storage characteristics, it first requires a high bulk, and precipitated calcium carbonate fillers can maximize bulk. If you are using precipitated calcium carbonate, the sizing can only use (alkaline) sizing agent.

Secondly, the use of paper sizing agents can increase the pH to neutral or alkaline so that the paper is advanced reduce the degree of back to yellow. It is important to note that most of the type of paper produced using mechanical pulp, and short fiber pulp machine, the low bonding strength between the fibers, such as low surface strength of the paper, printing cannot meet the high demand, and surface sizing is to improve the printability of paper. Advanced lightweight paper color not dazzling, but the light neutral paper sizing, the softer tone color, showing warm colors. (Wang 2005)

1) Gluing by AKD and ASA

Among the medium / alkaline sizing agent, the most popular reactive sizing agent is AKD and alkyne succinic anhydride (ASA). AKD sizing has higher ratio than ASA sizing, since AKD does not need on-site emulsification and hydrolysis tendency not as obvious as ASA, and the paper machine wet end cleaner, roller less sticky and fouling problems. Meanwhile, AKD neutral sizing is the biggest

advantage is that you can use calcium carbonate as a filler, making the whiteness of the paper, opacity, folding, surface strength, durability and printing performance were significantly improved, and making high levels of bleaching chemical Thermos-mechanical pulp (BCTMP) of light-weight papers' brittle significantly reduced. As sizing polyamide polyamine epichlorohydrin resin additive (PAE) in papermaking process is an efficient wet- strength agents, can significantly improve the effectiveness of AKD sizing, and has a retention effect, which can improve the adsorption of a large number of AKD the retention of the fines, In addition, it can also improve retention of AKD in the fiber of paper and dried to participate in the reaction of AKD sizing. (Liu 2008)

2) Filler's impact on gluing

Different types of fillers have different effect on the gluing of light-weight paper, filled calcium carbonate (GCC) is better than filled calcium carbonate (PCC) when gluing, which is due to the large specific surface area PCC, with a micro porous structure inside the particles. Drying the sheet partially melted AKD wax will penetrate into the pores and cannot react with the hydroxyl groups of cellulose, thus reducing the efficiency of the AKD sizing. The GCC has no internal porosity, so add filling GCC is better than filling PCC.

Research results show that the fine fibers and fillers with a larger surface area, which are mostly of AKD preferentially adsorbed on the surface of tiny fibers and fillers. Due to the special nature of light paper pulp production and its tiny mechanical pulp fibers and fillers PCC has relatively high specific surface area , so as to improve the retention of admit appropriate retention system must be used to increase fines and filler retention, otherwise it will be an accident that AKD with huge loss of fines and fillers. When fines and filler retention rate is 45 percent, then, AKD retention rate is about 45%; fines and filler retention increased to 90%, then, AKD retention rate of 90 %. Because of the long fibers remaining on AKD sizing is retained much higher efficiency than the tiny fibers AKD sizing efficiency, so the purpose of retention aid by adding AKD neutral

gluing system is not only to increase the fines and fillers retention, but also to improve the retention of AKD in the fiber, especially in the retention of long fibers. (Wang 2005)

3) α - amylase

Surface gluing of light-weight paper is most commonly by oxidized starch gluing. The traditional high starch modified oxidation method has some problems such as high costs, degree of oxidation is difficult to control, environmental pollution and other shortcomings, but with the enzymatic conversion of starch technology, it can overcome the shortcomings of the traditional craft of oxidized starch present. It is an enzymatic conversion of starch with α - amylase on native starch modified products obtained, this modified method is a kind of simple operation, low cost, no pollution. Obtained by enzymatic conversion of starch low viscosity, good fluidity, high transparency, for gluing into the paper can significantly improve printability. α - amylase can effectively degrade the molecular chain of corn starch, thus significantly reducing the viscosity of the starch glue. Preparation of α - amylase using a high concentration of low viscosity for surface sizing starch glue on light-weight paper, the optimum preparation conditions were : α - amylase amount of 0.02%, temperature 80 ℃, (on dry starch) insulation 20min; rapid heating to 98 ℃, insulation 30min. The resulting product solids content 9.0%, 60 ℃ when the viscosity of 5.5 ~ 6.5mPa.s, to meet the requirements of machine operation. Enzymatic conversion of starch glue is usually for light paper surface sizing, and enhance effective, compared to traditional oxidized starch, the costs decreased significantly. (Feng 2012)

4) Cationic guar gum (CGG)

Guar gum is extracted from a plant of melon bean gum, which is a natural Tanggua poly guar galactosamine is soluble in cold water in comparison with cationic starch the molecular structure of the cellulose molecule is not similar and guar gum gelatinized easily and fiber molecules combine to produce effects

and enhanced retention and drainage nontoxic guar gum is a new kind of Eco-friendly paper additives.

Closed water circulation with the promotion of the accumulation of sulphate pulp and white water circulation system of unbleached anionic trash which would significantly increase many conventional paper additives such as polyacrylamide out of action and the extensive use of modified polyacrylamide bound starch slurry dehydration and improve the cohesion excessively to reduce the fiber formation and strength advantages of guar gum sheet is a fiber molecule, since the molecular structure is similar to guar gum occurs .It does not react with the anionic trash in the even number of anionic trash the situation remains the same presence can be effectively adsorbed onto the fibers play a role in anionic trash and not about the adsorption of guar gum fiber and filler retention aid used as a modified cationic guar tape has a positive charge with a negative charge easily with fiber electrostatic attraction and filler flocculation phenomenon can be generated within the pulp fibers and fillers which are wrapped in tiny micro flocculation group and not because of its relatively high molecular mass does not produce a significant over- flocculation retention effect without affecting the sheet formation .

CGG additive is preferably dispersed in water. It can be dispersed in water without gelatinization swelling. The time of dissolving is more than 30 minutes. To accelerate the dissolution speed stirring device requires the dissolution concentration of mass fraction of 0.1%. Recommended dosage is generally mass fraction of 0.03% to 0.08 %. Special attention is needed, CGG auxiliaries bubbling foam in the process of dissolution and are more difficult to get rid of thin, therefore it should be payed attention to. In the course there is a certain level of control additives cannot be carried out using anionic defoamers. Elimination bubble may cause flocculation phenomenon in the production preparation process which can only be properly adjusted by the manufacturers of the technology .

Lightweight paper anionic trash mainly from wet hardwood liquid dye brightener

fungicides and other types of active agents of these substances seriously affect the efficiency of the paper machine to play. So paper-making workshop need to strictly control the quality and pulp consumption of various chemicals in order to further improve the retention effect of reducing consumption in the slurry. It is appropriate to add some inexpensive aluminum chloride (PAC) and anionic trash control and efficient agent is a good idea after all. (Yang 2011)

Factories' actual production experience shows that the use of cationic guar gum and cationic polyacrylamide (CPAM) in the production of lightweight paper have better compatibility when the amount of CPAM and CGG are 0.4kg / t paper: pass retention an average of 75% concentration of it is about 0.2% in white water. After a paper evenness, it is better to use CGG and try to use effective control of the system and adversely affect the anion papermaking systems even refuse to cationic demand reached 1000equ / L system can maintain a high retention rate and thus greatly reduce the ashes of the cost of maintaining the cleanliness of production systems, to achieve energy saving purposes. In addition to bulk, the surface strength and tensile strength decreased slightly among other indicators such as smoothness and ash into the air permeability of the paper quality indicators using guar gum products have improved after the loose. However, the thickness of the surface strength and tensile strength has a lower performance, according to the main reason for this situation is due to the ash content increased. Guar gum products using essentially on the paper quality is not adversely affected. (Li 2010)

5) lignin - phenolic resin (LPF)

Lignin - phenolic resin. The lignin is a phenolic resole resin obtained by modifying the product, usually as adhesives for plywood production. The lignin is the second largest natural polymer material, which has wide range of sources, with a molecular weight, molecular structure of complex features. Lignin is a phenyl propane unit by an ether bond and the structure of the carbon - carbon bond formed by the polymer compound, the presence of functional groups and

linkages of the different nature of the different nature of the inter-cell unit, it is a certain chemical lignin activity. The structure containing a variety of functional phenolic hydroxyl group, a carbonyl group, a carboxyl group and a methyl group and something like that, which can be reacted with an electrophilic reagent, and can also be reacted with a nucleophilic reagent, which can be an oxidation reaction, the hydrogasification reaction and the graft copolymerization reaction. On its side chain will have alkylation, acylation, phenol reaction. Because of the characteristics with both aldehydes and phenols, and therefore the production of phenolic resin adhesive can be used to replace part of the reaction of phenol or formaldehyde, reducing the cost to a certain extent, reducing formaldehyde release, and have better performance.

When using lignin-phenolic resin for copy paper sheets, paper proceeds bulk higher than using starch and flour with phenolic resin and wood flour, since the reaction of phenol and formaldehyde during lignin reactive hydroxyl groups, aldehyde attended reaction, the resin is introduced in a large substituent group, the molecular weight of the reaction product increases, and gradually cross-linked macromolecular network structure is formed. Because of the free hydroxyl groups present on the macromolecular product, after adding pulp fibers can be formed with the hydroxyl hydrogen bonding between the fibers to form a tight binding. What is more, fibers can remain on the paper sheet, while increasing the strength plays the effect, then adding flour to improve its bulk of the paper, the wood meal can be left in the sheet which improves bulk. (Li 2010)

No matter what lignin - phenolic resin or starch flour was used in papermaking, paper tensile strength increased more than the simple use of the copy machine pulp. Pulp wood meal replacement would affect paper strength. And tensile strength decreased when starch flour with more obvious. Lignin - phenolic resin itself is dark red -brown, adding the syrup if excessive dosage, which have an impact on the whiteness of the paper. It should be not added too much. Studies have shown that while using 100% mechanical pulp copy paper sheets in lignin -

phenolic resin addition level of 1.5% , 20% wood flour dosage is better : to improve the papermaking Deo thickness 36.9% decrease in tensile index 12.9%, whiteness dropped 1.3%. Compared with starch flour furnish with light paper and 100% chemical-mechanical pulp for paper-making light-weight paper with lignin - phenolic resin with pulp wood powder to add bulk to improve the paper has a significant effect , but it will affect the anti- tensile strength, it is not excessively added, the strength of the paper required to be considered. (Ma 2010)

2.3 Problems and solutions

2.3.1 Selection of raw materials

In the production of light-weight paper, selection of raw materials is very important. The reason why in the same thickness situation that relative to the quality of many of offset paper to light, mainly because of mechanical pulp works, people reach an consensus that ATMP, CTMP, BCTMP are the main raw material for light-weight. In principle, it is better with the amount of mechanical pulp, many manufacturers in China are fully using mechanical pulp for paper-making of light-weight paper. Usually in the choice of materials to BCTMP hardwood pulp -based, with the amount of 50% of hardwood pulp, as some indicators added in order to ensure the strength of the paper, adding softwood pulp, bleached grass comes into the mix for about 20% of the pulp.

2.3.2 Pulp beating

During this section should be noted in the beating pulp processing, pulp should be pay attention when handling wet weight freeness and fiber length, because

usually hardwood pulp accounted for 50 percentages or more, it will inevitably result in more fines in the pulp. If severe beating again, which will cause damage to the fiber strength, the wet weight of the pulp will also become lower. The paper will not only lead to reduction in the strength but also the stiffness of the paper will be reduced accordingly. So when dealing with long fibers, with beater beating, requires freeness control 24SR, wet weight of 10 g. After a diameter of 450 mm plate mill, the processing time required to control and the beating of it is around 55 ~ 60SR, and the wet weight is 8 ~ 10 g. Short fibers cannot under heavy knife beating, only slightly ease, requiring a diameter of 450 mm plate mill through ease, beating controlled at 35 ~ 40SR, wet weight of about 4 g, into a pulp freeness at 40 ~ 45SR, wet weight between 3 to 5g. (Yin 2013)

2.3.3 The amount of filler

In order to ensure the quality of the paper , in the selection process of gluing by using AKD neutral gluing and adding cationic starch slurry, the slurry of fine ingredients to improve retention and reduce churn. In order to make the paper with good stiffness, pulp stiffness agent is added to improve the stiffness of the paper. During the process we should pay attention to the amount of calcium carbonate cannot be too high, and the ash into a paper which cannot be too high, because of excessive retention of filler paper thickness is reduced, thus affecting the bulk of paper. On light paper, in order to ensure its bulk, it should be possible to add a small amount of filler to ensure controlled ashes of 6% -8 %. (Yang 2011)

2.3.4 Pressure Control

The main indicator of light-weight paper are bulk and opacity of the paper, in the production process should be pay attention to pressure points which cannot be over- pressurized. Further selection machine press section felts is also important

that the quantitative requirements is 1250 g / cm2, it is a good dewatering the web. In surface gluing place, not only to control the paper sizing machines into the water, but also on the pressure sizing machines were controlled to ensure that the paper machine at the surface gluing inhaled more glue to improve the surface strength of the paper. When paper passes the calendar, do not try to pressure it on purpose, since pressure itself on it. If necessary, that ensure the bulk can try to without the pressure. (Kang 2008)

2.3.5 Avoid flounced, tidal fold

A notable feature of lightweight paper is higher bulk than the that of writing paper, while the cutting process is prone honeycomb, and after packing pressed creases. Because of this case, the method is mainly used: first, a paper dust content of between 6% and 8%, in order to improve the stability of the paper shape. Second, try to strengthen banner quantitative stability so that can control moisture. Third, under the paper at the thick mat rewinding, is conducive to maintaining bulk, so it does not deformed easily.

2.3.6 Surface intensity weakness

Improving the paper surface light intensity is a more complex process, specifically debugging from the following methods: Using surface-enhanced starch, and increasing the amount of retention aid. Keep the fines content, the charge retention aids rely on colloid action, fines and filler are characterized by a combination of molecular surface of the paper web portion to improve the retention of fine fibers. For improving freeness, which need to ensure a certain amount of fibers having wire broom and fine fibrosis. It is trying to improve the drying of temperature curve, paper prone to vibrate the first drying stage, there is need for strict control of steam pressure at this stage, that is to strictly control the

temperature of this period. If the rapid initial drying temperature, the adhesive sheet may result in the dryer surface, the surface of the sheet to be destroyed also increased lint resistance. Therefore, the more prudent approach in the sheet after entering is that the drying zone temperature should be relaxed. (Wang 2012)

2.4 Light-weight paper print -related properties

2.4.1 Smoothness

Smoothness of the paper is a way to evaluate the degree of surface unevenness of the technical specifications, the paper surface is flat and smooth uniform physical extent that. Under certain vacuum conditions, so that a volume of air from the sheet surface of the test sample at a constant pressure with a smooth glass flowing the time required to measure the surface, expressed in seconds per unit.

The higher the smoothness, the better the paper. Paper smoothness can be better contact with paper and printing plates which is between uniform and complete. Conversely, poor smoothness of paper, ink transfer uneven, inadequate, and the face amount of ink on paper permeability, the coloring effect is poor, and tend to make printing ink blur, light hair. So, fine printing products, network cable finer, smaller diameter outlets, and the better smoothness of paper should be used for printing, so as to make the original good reproducibility. Analyzing paper smoothness and printability which are measured by the method of determining the smoothness of the paper facing the air flow by measuring the frictional resistance. It is can also be determined by measuring the friction between sheets of paper. (Yang 2004)

2.4.2 Brightness

Whiteness of the paper, the problem actually depends on optical scope. This is because the paper is made of cellulose, filler consisting of air, for that it forming the fiber - air interface lot - filler, fiber - air and filler. When a beam of light is exposed to the paper, the occurrence of three phenomena: (1) reflection (scattering) , (2) transmission , (3) absorption. That is to say after the beam of light is irradiated to the paper, part of the light reflected back into the interior of that part of the sheet, on portion of the light is absorbed by the fiber addition, the transmittance of only a small portion of the back to the paper. Scattering (including reflection) back to this part of the light, which is what we usually forms the whiteness of the paper. The higher the whiteness of the paper, the more accurate performance characteristics of the color ink out, this is due to the synthesized white color light should be reflected back through the transparent ink subtractive. Therefore, the whiteness of the paper is almost all of the colored light reflection, so that printing ink has pleasing, good visual effect. The white paper is lower, since it only absorbs part of shade, we cannot truly part of the performance contrasts of light and shade, but also likely to cause a color cast. (Yang 2004)

2.4.3 Gloss

Paper Gloss is the reflection from the mirror surface of the paper, expressed as a percentage. The higher the gloss of the paper, the more it can be like a mirror -like surface reflecting light, the more it can show the appearance of the characteristic bright. In fact, in addition to the specular surface of the paper, but also there is added diffuse, the sheet gloss decreases. On high gloss paper, printing ink is also more vivid, ink has visual effects, too. We can say that the smoother the paper, the higher the gloss. Gloss and smoothness of the paper

are closely related, but paper's glossy surface is not necessarily smooth surface. From the point of view features gloss is paper, the characteristics of printed pieces to choose the right paper for printing, have a very practical significance. The layout of text books and text-based, should use the general gloss paper, in order to avoid reflections, the eye for a long time to see that does not produce fatigue. And prints with a pattern based layout, should be used high gloss paper, making printing ink evenly, thick, bright. (Jiang 2003)

2.4.4 K&N ink absorption

Printing absorption of paper is mainly to measure the capillary absorption capacity of situation. Current measurement methods are mainly oil suction method and K&N test. Oil suction method is mainly measuring the paper of certain solvents or oil absorption capacity of the paper describes the capillary absorption. The ink absorbing capacity of the paper can be controlled and predict the quality of the printing paper. K&N ink is a non-drying ink as a white colored pigment dispersed in oil formed. This test method has been set for the country (GB12911-91). This standard applies to offset, gravure used white or nearly white coated paper, uncoated paper and paperboard. K&N ink absorption and permeability are tasted by using standard ink test the capabilities of the ink absorption.

Calculated as follows:

$$K \& N = 100 - arc \log(2 - D)$$
$$D = D_1 - D_0$$

NB： D_1 –the sample surface of the light ink density region

D_0 –Ink-coated surface of the optical density of sample values prior to inking

2.4.5 Paper surface efficiency

The paper surface condition and absorbency, which will change the role of the three primary colors and gray ink, which causing the ink mixing color change, affecting the tone reproduction. However, a different paper, the performance of these two is different in somehow. Even an ink printing with the same condition, a great difference in color reproduction may sometimes appear substantially. This is the combined effect gloss paper and absorbent combined effect. The combined effect of the efficiency of the paper is the paper surface efficiency.
The relationship is:

$$PSE = \frac{(100 - A) + PG}{2}$$

NB: A-- Ink Absorptivity; PG--Paper Gloss

When the paper's absorbency is high, by using high gloss to compensate it, low gloss paper, it must be compensated with low absorption, in order to obtain the same color reproduction. (Wikipedia)

2.4.6 Printing permeability

Printing permeability means that paper printed surface has permeability oil absorption. It indicates the paper is ink absorption capacity, which is directly related to the extent of absorption of the ink. It is made of paper fibers and capillary permeability filler determined. Surface sizing of the absorbent may be changed, which affects the coloring effect and the ink density of the ink. The permeability of the paper can be printed on a printability tester measured: at a certain pressure at a constant speed so that a certain amount of the enrichment of the ink vehicle or in contact with the paper, to produce a blot, using the inverse

of the length of blotting represents the absorption capacity of the paper, the paper surface of the absorbent and the smoother the surface, the worse the performance, the smaller the value. Conversely, the higher the surface roughness is and the more absorption capacity of the paper, thus, the greater the value. Conversion formula such as:

$$P = \frac{1000}{L}(m \wedge 1)$$

(2-3)

Where:

P is the permeability of the printing paper;

L is the length of traces of oil (unit: mm);

3 Two indicators of the impact on printing quality

Print quality is evaluated with respect to the original to be reproduced. It is the combined effect of the various visual characteristics of printed matter. Half tone printing should be required to be faithful to the original in terms of tone reproduction and color reproduction. Such as uniform ink appearance, good gloss, dot deformation, overlay accuracy, and no ghosting, telegraphing, a variety of thick stick, back rub dirty or mechanical traces. The tone of the printed image and the color production are two important control factors. When the tone of original is copied well, the image will show a satisfactory contrast and get important details of original. Due to limitations of the printing conditions, the best copy cannot exceed the maximum printing density, so the colorful halftone images must be compressed based original tone, so that it can be adapted to the limited density range of ink and paper combination. Since using a variety of color to copy, so color reproduction involved many variables in process of printing.

Such as printing field density, dot gain, paper and printing features. There are two main criteria to measure the extent of copying original, namely tone (level) reproduction and color reproduction. Tone reproduction is how the relationship between light and dark are transferred to the print. Field density and dot gain have great influence on the tone reproduction. Color reproduction refers to all colors on the original being completely consistent to the visuals printed on the document. (Wu 2008)

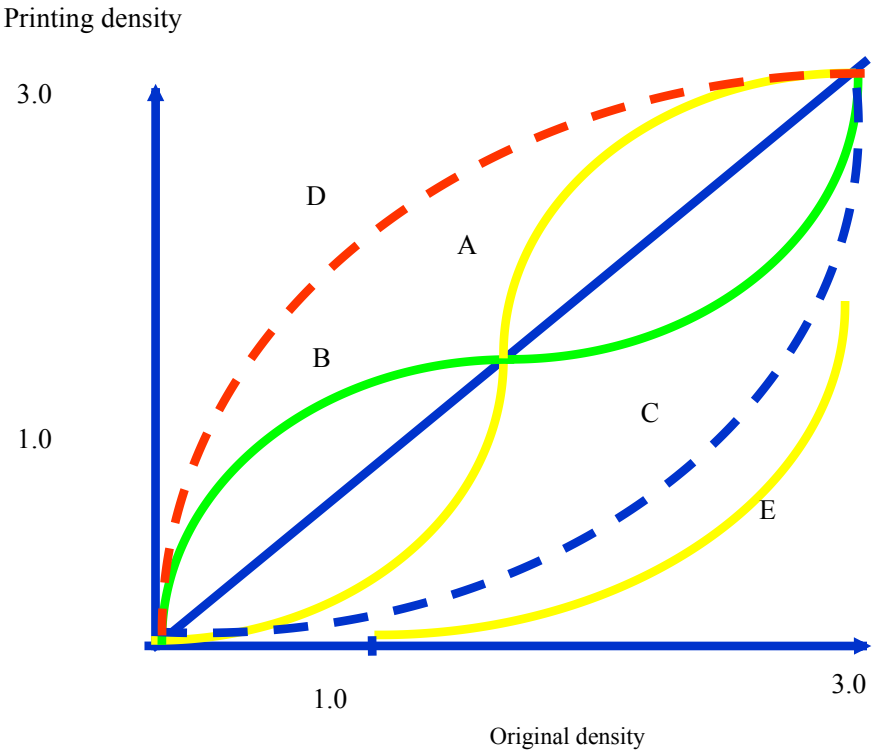
3.1 Print tone reproduction

Tone refers to the density level from the lightest to the darkest part on the original or copy images; it also refers to the evolution from the lightest to the darkest part of the level on the original or copy images. Specifically, the more levels copied and identified from the original, the better performance of the original in the tone or density range based on the original. Tone and level are two terminologies to express the replication of image. The former is a more general statement, and the latter is a more specific terms after the appearance of electronic color scanner. Tone reproduction always refers to correspondence between copied levels and corresponding levels of the original. Tone value can be expressed by network coverage and density values. (Yan 2004)

Level is defined as density level grade which can be distinguished visually.

When the tone of the original is copied well, the image will show a satisfactory contrast, getting important details on the original, and helping to balance the whole picture. When tone copy is not correct, the printed image looks not sharp and there is lack of natural luster or bright tone does not shine, which leads to important part giving the "flat" feeling and less color saturation. Sometimes, poor tone reproduction may have other reasons, like some parts are lack of saturation, so that leading to a large number of color aberration. This deviation cannot be corrected only through color correcting device. Because the color correction

range if needs is beyond the capabilities of the device.



Picture 3-1 Printing tone reproduction curve (Ding 2014)

This diagram can be understood as following:

A: Compress bright tone and shadow, stretch mid-tone

B: Stretch bright tones and shadow, compress mid-tone

C: Compress mid-tone and bright tone, stretch shadow

D: Stretch mid-tone and bright tone, compress shadow

E: Black edition tone curve

Tone reproduction is the most important parameter for the ultimate effect of the printed copy. But the best tone reproduction is relative, because the tone reproduction often comes from a subjective decision made by the operator In the process of production.

When it comes to a certain original, it cannot accurately understand the actual effect of tonal adjustment before playing proofs or printing sheet .Best tone reproduction not only has something with production of color separations, but also with some other process factors. It includes ink, the kind and quality of paper trapping and paste version parameters. It should be standardized through the organization of production, and the impact of these factors quantified on the tone reproduction process, and then compensate deviation in the production of color separation films.

3.2 The impact on tone reputation

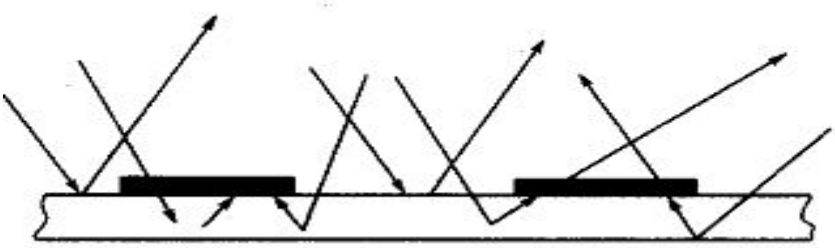
3.2.1 Field density

Field density refers to color density without a bank on the surface of substrate that is 100% dot density. Field density is the most important parameters during inspection and control of print quality, which can reflect the tone range of printed copy and the amount of ink. Thus it can realize the regulation and control of the printing process. The state of field is determined by the three parts, these are the degree of ink layer coverage; the average thickness of ink on paper. And the surface condition of the ink layer. (To avoid confusion with the network coverage, the degree of coverage by the ink layer on paper is called field coverage.)

There are related books founded that spot coverage is a major factor affecting the size of the field density in the lower range of values of the spot density. If spot coverage reached its saturation, the impact of the ink layer thickness increases. With increasing the thickness of the thinner portion of the ink layer, ink layer tends to be uniform, and thus the spot density increases. After further to the higher range of spot density, smoothness on the surface wound have an impact on the spot field. (Liu 2004)

3.2.2 Dot gain

In the printing process, dot gain is effect on replication is larger than other variables. Dot gain is an increase in the size when it is printed from the halftone negatives to printed paper. When printing black-white and color halftone images, dot gain will change the screen contrast, and cause the loss of image detail and clarity. Multicolor printing dot gain included two kinds: the mechanical dot gain and optical dot gain. Mechanical dot gain is an expansion phenomenon of the printed dot size at the pressure of printing. In the printing process, the mechanical dot gain occurs in the vicinity of the dot. Owing to printing failure, dot gain may be irregular such as ghosting or dot gain because of slider. Optical dot gain is due to complex optical phenomena surrounding dot area. The perimeter of dot is changing as well as the amount of increasing dot. That is dot coverage and the number of dot cable will all affect the expansion of dot.



Dot radial variation of different sizes is usually the same, so bright tone, mid-tone and shadows have the same amount of dot radial changes. But the longer the perimeter dot, the larger amount of dot increases. Therefore the terrible dot gain occurred about 50%. (Baike)

3.2.3 Relative contrast

In printing terms, relative contrast is used to determine criteria for proofing and the amount of printing ink. It is called Kite K, which is to control the indicator from

mid-tone to shadow on the image. In fact, it is not only able to control proofing and the amount of printing ink, but also indirectly control the entire copied curve.

$$K = \frac{D_V - D_R}{D_V}$$

D_V – Field density of printing.

D_R – Dot density from mid-tone to shadow.

Providing the correct original tone, D_V is correct, D_R is high, then the difference of these two parameters become little. The screen will be nausea; dark, gray, and dark tone is in the absence of level changes. The reasons may be long exposure time, too much ink, too much printing pressure, bad accuracy, wrong operation caused by the irrational. It may also be the result of several factors together, so serious dot gain is reduced K value. D_R is correct, D_V is high, then the difference of these two parameters become also little. The screen will thin, flat, gray, and there is the same lack of color change. The reasons may be short exposure time, too little ink, too small printing pressure, bad accuracy, wrong operation caused by the irrational and other reasons work together increases exceedingly. In this sense, control of the K value is equal to the control of the shape of the curve, as well as the tone of the screen. (Wikipedia)

According to the literature and domestic existing conditions, using the same density meter to measure and calculate with the same paper, ink, and beta, we can get that yellow K value is less than 0.4, substantially between 0.3 and 0.35. Magenta and cyan have almost the same K values 0.4~0.45, black is the highest between 0.45 to 0.5 .According to China's conditions and test results, in the process of making ”flat print quality requirements and test methods", K values were given two sets of data. And each gave a range of data, as shown in Table

color	Fine print	General print
0.25~0.35	0.20~0.30	
M.C.B	0.35~0.45	0.30~0.40

Table 3-2 K range of relative contrast

(Lab in Qilu University of Technology Ding Na 2014)

3.2.4 Trapping rate

Ink overprint refers to the amount of ink of second printing which is transferred to the previous ink when compared with the amount of ink printed directly on the substrate material. The meaning of trapping rate control is to avoid the wet-on-wet or wet-on-dry and low trapping rate to meet the requirements of tone reproduction. Trapping rate T is a value between 0% to 100% .The higher trapping rate is, the better overprinting is. When T = 100%, it indicates that the trapping rate of printing is excellent like the effect printed directly on the substrate. If T = 0, it indicates that there have been technological problems that the extreme "wet" is not printed on or "dry" is not printed on. It must be avoided and resolved at the moment. The formula of trapping rate is:

$$T = \frac{D_{1+2} - D_2}{D_2} \times 100\%$$

3.3 Color reputation

Color reproduction has three different concepts: One is the color reproduction in the physical meaning which requires the spectral distribution of color reproduction is exactly the same with the original color on each color point. The print is available for viewing visual. (Meyer J. 1989) It is difficult to achieve the same spectral color reproduction of the physical sense, and there is not much need to do that. The second is to reproduce the sense of colorimetric, making the reproduction identical with the original color image. That is the same color with different spectral distribution. This is an objective measurement to evaluate printed quality. Third is the psychological sense of color reproduction. There may be some difference with the original color on the Chroma in printing process, but the color effect is likely to achieve visual psychological satisfaction because of subjective evaluation factor. Making a proper evaluation of print must be used to measure the physical parameters to establish objective evaluation criteria for quality standards. Because color copy means and equipment performance are not imperfect, and the way of printing reproduction is not deficiency itself, realistic printing science and technology cannot reproduce the original color or all colors of the original scene faithfully. So this poses some difficulties to an objective evaluation of the quality of color reproduction. Only can color reputation be measured by comparing the results of chromaticity from the extent of closeness between printed color and originals. Similar and dissimilar color reputation has the incorporation of people's color vision requires, that is the psychological level of mental reproduction. The main factors about color

reputation are discussed in the following chapters.

3.3.1 Ink performance

Color of print is made of all kinds of ink. Ink quality and its various performances have a direct impact on color reproduction. Ink color intensity, and hue error, gray, coloration efficiency are the main factors affecting the color reproduction. In order to meet the requirements of color printing and get good color reproduction, ink must also have a high degree of tinting strength, fine pigment particles, good transparency and adequate stability.

3.3.2 Ink layer thickness

The extent of color saturation has a great relationship with the thickness of the ink in addition to depending on the spectral characteristics of the ink itself, that is degree of selection and absorption of ink and the ink color strength. Owing to the difference of ink layer thickness, the color saturation is not the same when using the same ink to print. Color saturation can be improved by increasing the printing ink layer thickness. But color saturation gradually slowed down as the ink layer thickness increased to a certain extent. Finally, there is no increase but a trend towards to a horizontal line. (Kasson 1995)

3.3.3 Paper performance

Different types of paper have a great difference in the ability of the ink color reputation. Printing on different paper by using the same ink layer thickness with the same ink, the resulted color effect is also not the same. Physical and chemical characteristics of the paper have a great impact on the reproduction of color, such as paper whiteness, smoothness, absorbency, gloss, opacity, and the

pH, moisture content.

3.3.4 Sequence of printing color

Printing color sequence has a direct effect on the color reproduction of copies. If printing color sequence is not identical, the color of the screen will be a significant difference with the same printing plate, the same series of color ink, the same kind of paper and the same printed parameters. Reflectance of yellow is maximum, followed by magenta and cyan ink; black ink is minimal in this colorful ink. Higher reflectance indicates more bright color brightness. If the yellow ink is at the bottom, black ink at the top, it is difficult to reflect color ink at the bottom to surface of the ink sufficiently after receiving the selection and absorption of light. Therefore, printing color sequence should be arranged in accordance with the transparency of printing paper, ink used the print gloss and other factors to ensure the best print color reproduction. (McCann 2007)

3.3.5 Dot coverage

Dot coverage is a decisive parameter for printing quality. Changes in dot coverage are not only causing wrong tone reproduction, but also change the results of the hue most obviously. Even if only dot gain of one color occurs, it will produce a different hue as well as an impact on the color over print, ultimately affecting print color show.

Chapter IV gives the evaluation of the color reproduction of print quality

4 Test of printing on light-weigh paper

4.1 Objective evaluation by experiments

Several different tonal colors Y, M, C, K, and different percentages overprinted dot R, G, B, for processing, and then output these colors on light-weight paper by digital printing press. Measure the density and dot gain with density meter and spectrophotometer. collecting data and then drawing printed tone reproduction curve and dot gain curve by MATLAB. Thus we can make an objective evaluation of the quality of light-weight paper.

A) Experiment device:

X-rite528 Densitometer

Eye-one、X-rite939 Spectrophotometer

B) Experiment materials

(1) Paper: different specifications of light paper coated on one side

(2) Ink: Yellow ink, magenta ink, cyan ink (Nanjing Amity Printing Co., Ltd.)

C) Analysis of printing parametric

	COLOR	0	10	20	30	40	50	60	70	80	90	100
Light-weight paper	C	0	0.02	0.08	0.16	0.22	0.37	0.51	0.67	0.82	1.01	1.14
	M	0	0.02	0.08	0.14	0.21	0.39	0.52	0.66	0.85	1.13	1.25
	Y	0	0.02	0.09	0.17	0.27	0.47	0.63	0.76	0.95	1.19	1.27

	K	0	0.02	0.09	0.17	0.24	0.43	0.6	0.74	0.87	1.06	1.32

Figure 4-1 density of different tone printed copy (Ding 2014.)

According to the measurement data, draw print tone reproduction curves were drew by MATLAB.

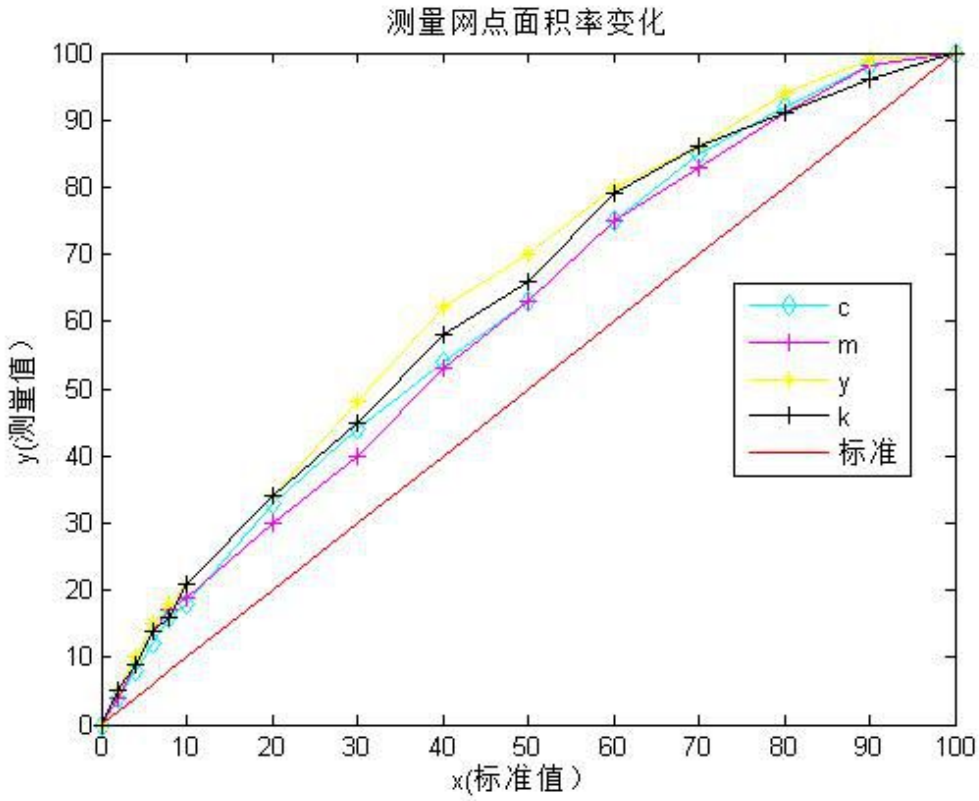


Table 4-2 Printing tone reproduction curve

(Ding 2014)

	Color	0	10	20	30	40	50	60	70	80	90	100
Sample	C	0	-0.01	0.01	0.01	-0.01	0.02	0	0	0	0	0
	M	0	-0.02	0	0	0	-0.02	0	-0.01	0	0.01	0

	Y	0	-0.02	0	0	0	-0、02	0	-0.01	0	0.01	0
	K	0	0	-0.01	0	0	0.03	0	0.01	-0.01	-0.01	-0.01

Figure 4-3dot gain tone of different printing

(Ding 2014)

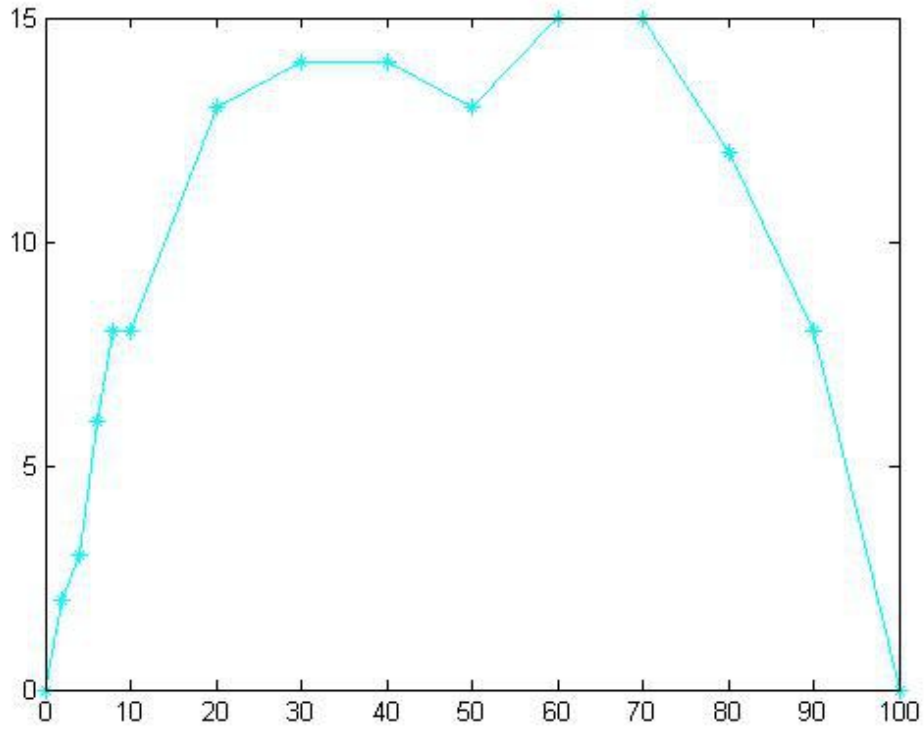


Figure 4-4cyan dot gain curve (Ding 2014)

A dot expanding curve was drew by using MATLAB by setting an example of Cyan(C). We can see that 50% dot gain of cyan (C) is the most serious. To ensure the quality of printing, we should compensate the dots of 50% by PHOTOSHOP in the process of preprinting to ensure a clear reputation of printing tone and color. (Li 2004.)

4.2 Subjective evaluation of image quality

4.2.1 Structure and composition of GATF Beta.

Figure4-5 GATF Beta Test Form

No.	Project	Requirement	Place
1	Around area	Two parts ,four color, width **5mm**	Side area, from center to side.

2	control strip	**Control of dingle-row dragged sight single row.**	Entire axial region domain to heart.
3	**Detection of ink spots**	**100%+50%KCMY,100% 十 50%CM、YM、YC**	Plate axial area **2.95x2.95cm**
4	Three color control strip	**50%K,50C,40M,40Y**	Axial plate
5	Four color wedge	**One part**	Next to the field
6	Picture	Bright、full-color、neutral gray、skin color	Blank area
7	Color correction	Different color correction	Blank area
8	Converting strip	**Two parts**	From the four corners to center
9	others	The largest amount of ink, resolution test target	Blank Areas

10	IT8.7/3	——	Under the ink apot test strips

Figure4-6 Analysis and description (Ding 2014)

4.2.2 Analysis and Research on ISO400 standard image

ISO400 Standard image 1-3

ISO400 Standard image 4-5

ISO400 Standard image 6-7

ISO400 Standard image 8

Analysis and description as follows

Names	Direction	Characteristics
N1 Portrait	Vertical	Used to evaluate a model of human skin tone reproduction character close-up image
N 2Cafe	Vertical	Images with complex geometry, for evaluating the effect of image processing

N3 Basket	Level	There are fruit baskets, cloth and wood image for detailed assessment of brown textured copy reconcile
N4 Beer	Level	There glassware and silver with images used to evaluate the high light colored skin tones and features
N5 Bicycle	Vertical	There are bicycles, icons, and other rich and detailed resolution levels of image clarity and image processing for effect evaluation copy
N6 Flower	Level	There gradient background orchid image for evaluating high light and dark tone to replicate the effect gradient region
N7 Musician	Level	Image of three women, used to evaluate the different levels of color harmony to replicate the effect subtle image
N8 Candle	Level	Darkened room scene images containing various items used to assess the darkened color, especially dark green and dark brown to replicate the effect

Figure4-7 Analysis and description (Ding Na 2014)

4.3 Making an objective evaluation of output image

Based on standard indicators of GATF test standard version and ISO400 standard color images, we output both of them by digital printing press, and then make a subjective evaluation in order to achieve the monitoring and control of print quality (Ding 2014)

4.4 Experiment device

Epson digital electrostatic printing press

Experiment materials

(1) Paper: different specifications of light paper coated on one side

(2) Ink: Yellow ink, magenta ink, cyan ink (Nanjing Amity Printing Co., Ltd.)

4.5 Making an subjective evaluation of output image

The apparent quality of the printed product is a kind of evaluated index based on subjective psychology, which directly affects the appearance of printed matter and determines whether it is eligible or not. The apparent quality of the printed product is printed on the basis of subjective evaluation index, which directly affects the appearance of printed matter, printed or otherwise determines eligibility. For example, (1) sheet neat appearance, wrinkles, oily, prints and fingerprints. (2) Sheet back clean, no dirty marks. (3) The text is clear, complete, not lacking pen off the program. (4) Overlay accuracy. (5) Outlets clean, clear, no glitches. (6) Clear tonal gradation, and partially darkened stage, bright tone without loss of part. (7) Ink bright, does not restore the color cast.

The choice of color images and output indicators to observe from the above images look clean, bright ink color copy reproduction not cast, clear tone level, and level the phenomenon does not appear that the printed color reproduction is good. (Ding 2014)

5. CONCLUSION

With the continuous development of lightweight paper manufacturing technology, it has been widely concerned in major production companies, and increasingly used to develop positive prospects for light-weight paper.

by using light-weight paper in printed books, which greatly reduces the weight of books in the past years which with traditional paper printing, thus largely reducing the heavy burden of books packaging, transport, storage, marketing and other aspects. The light-weight paper is more suitable for single color or with four-color photo-text books in color printing, which is helpful for the shortcomings in light-weight paper which, printed by normal four-color printing aspects.

This thesis describes the paper by studying the various properties of light -weight paper assessed. It is obviously that by studying the light weight paper we can gain that factors such as bulky lightweight, high stiffness and compare with the same quantity of offset paper, which has significant impacts on printing methods and especially plays a very active role in practices .However, there are still many limitations during the light-weight paper printing process, thus, the study of light-weight paper printability has a very important significance.

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