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The Study of Optimum Factors in Gold Plating Process to Enhance OTOP Knife Products for Ban Mai Knife Forgers Village, Lom Sak District, Phetchabun

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Abstract

This research aimed to study the optimum factors affecting the quality of gold plating process to enhance OTOP knife products of Ban Mai knife forgers village. This study focused on application of AISI 5160 steel and the 24k gold plating process.In the experiment, three samples of plating currents were observed; 10, 12, and 14 volts, each at 30, 60, 90, 120, 150 seconds, and 180 seconds, respectively. The study found that applying the electric currents in gold plating at 12 volts for 120 seconds gave the best results for the gold color and thickness, by giving the thickness of the gold surface at 33.82 micron and the color value between L*=88.72, a*=4.45 and b*=78.58. Moreover, the gold dispersion was consistent throughout the workpiece. From applying the electric currents in gold plating at 10 volts, it lessened the thickness of the gold plating which made the gold plating look uneven. From applying the electric currents in gold plating at 14 volts, it increased the thickness of the gold plating which resulted in a dull or burned finish from over-plating. In comparison, the cost of the knife before plating with gold costs only 30 baht per piece while the cost of the knife after plating with gold costs 99 baht per piece. In conclusion, the daily sales of a product increase from 50-60 items per day to 60-75 items per day, which also resulted in increased revenue and profitability from 1,500-1,800 baht per day to 5,940-7,425 baht per day on average.

Keywords : Gold Plating Process; OTOP Knife Products; Ban Mai Knife Forgers Village

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1. Introduction

Phetchabun province is situated in the lower north of the country. The area is mountainous with cool weather and lowland with slightly hot weather, it is suitable for various forms of cultivation such as field crops, horticulture crops, and also tourism agriculture, which is the main occupation of the population in the province [1]. However, another career that can generate income was natural and cultural tourism which is a learning center and continues to preserve the way of life of the previous generation in which tourists often buy stuff for using or as souvenirs to their home [2].

Ban Mai Knife Forgers Village (Tai Lom Knife), Lom Sak district, Phetchabun province has been the traditional forging knives group since their ancestors, for example, sharp knife, pocket knife, hiking knife, kitchen knife, cleaver knife, machete, pickaxe, hoe or rice sickle and other made to order knife which makes of medium carbon steel. Currently, those knives have been registered as the OTOP knife products of the province. Originally, they did not gather as a group, during an economic depression, they had been recommended by the government sector in gathering a knife forgers group to increase household's income apart from their agriculture time. The current members are around 70 people and the distribution is both in Phetchabun and other tourism sites including other province shops all over the country. The price is from 30 to 300 baht, depending on the type and size of the knives. However, there are many new knife forgers groups in the current time, the market competition is increasing. From the field trip, it was found that the knife forging group needs to develop new products for creating a distinctive point, expanding marketing channels, increasing the value of the product, and being able to access every group of all ages [3]. Phetchabun is one of the provinces which has various tourist attractions as well as other tourist attractions in Thailand. In these attractions, people of every age group who like traveling for food, atmosphere and shopping for souvenirs [4], [5].

Consequently, the researcher has an idea in developing OTOP knife products of Ban Mai Knife Forgers Village (Tai Lom Knife) by plating with gold to enhance the products to be a souvenir in tourist attractions [3] and add the value of products. The gold plating process is to enhance exquisiteness to various products and to upgrade the quality of products as well since gold is always luster and does not oxidize with oxygen, then it does not tarnish when exposed to air and also does not rust. Gold is therefore popular to be applied to cover materials or plating products that require more attractiveness [2]. This research is plating knives with 24k gold or 99.99% gold to comparative study the suitable factors in gold plating with medium carbon steel material and transfer knowledge including the technique of plating knives with gold to the knife forging group.

2. Research Methodology

2.1 Material and Variable in the Experiment

This study applied hot-rolled steel or spring steel AISI 5160 grade with carbon around 0.55-0.65 %C [6]. The workpiece was prepared by forging a knife length of 60 mm, a width of 10 mm, and a thickness of the edge 3 mm down to the edge of the knife as **Fig. 1.** Hardening for prevents rust and eases to the gold plating process. After that, it was polished with water sandpaper and scrubbed with a flannel cloth, along with 5 micron alumina powder, to get a shiny surface and apply the coating material or plating with 24k gold or 99.99% gold since it was popular in plating that gave a fine-looking surface and was not easily transformed.

Fig. 1. Work-piece preparation of Tai Lom Knife

The variables in this experiment was the amount of electric current used for gold plating (voltage difference) in direct current (DC) at 10, 12, and 14 volts, and the experiment time in the plating was at 30 seconds, 60 seconds, 90 seconds, 120 seconds, 150 seconds and 180 seconds per experiment and repeated each variable in 3 experiments [7]. After that, the gold surface thickness was examined with an optical microscope (OM) with a workpiece dimensioning program or the built-in Measure with a line command and examined the dispersion and color of gold from experts.

2.2 Methodology

The study of optimum factors in the gold plating process to enhance OTOP knife products for Ban Mai Knife Forgers Village. The researcher has designed an experiment material with safety and advised the gold plating performer to wear personal protective equipment (PPE) every time [7]. The gold plating process was one type of electroplating process in which electrical current was passed onto a workpiece in an electrolyte solution then causes the positive ion (Anode) in which a lure gets oxidation and runs to the cathode charge at the workpiece [8], where the reduction reaction was occurred and caused the thin layer of metal from the lure to be coated on the surface of the workpiece which the gold plating process consisted of the following six steps; [3].

Step 1: electroplating set up, prepare a power transformer with 30 amperes that can adjust the compression of 10, 12, and 14 volts and connect the positive electrode to the lure as well as the negative electrode to the workpiece [8], [9]. This study applied the lure in the alkaline copper pond and copper material with 30x40x10 mm in dimensions was applied and the lure in nickel pond, nickel-type material was applied with

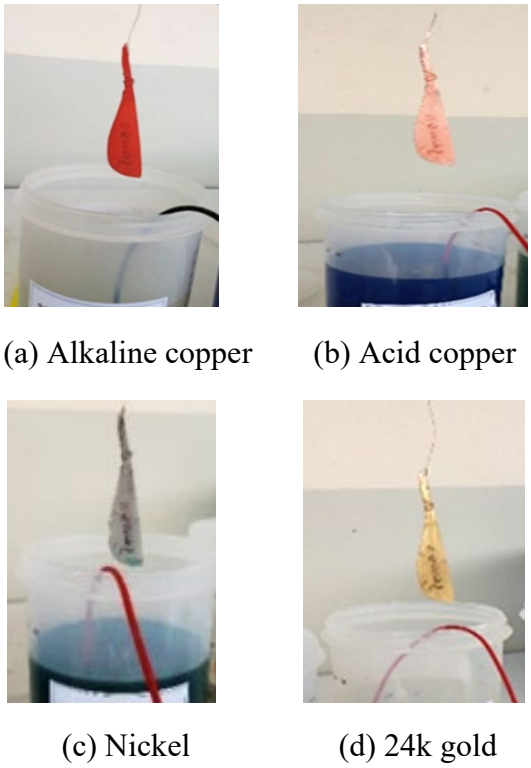
dimensions of 30x40x10 mm and the lure in the gold pond, a stainless steel sheet with dimensions of 30x30x3 mm was applied [10].

Step 2: workpiece surface preparation, the workpiece was washed with chemical sodium cyanide to clean the dirt that adheres on the workpiece such as green rust stains. With these stains, it can be cause the problem of not attaching to the plating.

Step 3: alkaline copper plating, the workpiece was plated in an alkaline copper pond. It contains 23 grams of sodium cyanide, 15 grams of copper cyanide, 15 grams of sodium carbonate, mixed with 1 liter of clean water to make the gold plated a thick layer of coating, shiny and long-lasting, does not deteriorate, as shown in **Fig. 2(a)**.

Step 4: acid copper plating, the workpiece was plated in an acid copper pond in which contains 250 grams of copper sulfate mixed with 1 liter of clean water mixed with 98% concentrated sulfuric acid 30 grams and mixed with Copper brighter 3 grams to make the workpiece to be polished. Do not add water to concentrated sulfuric acid as a dangerous splashing of acid will be occur. The color of the acid copper plating solution is blue as shown in **Fig. 2(b)**.

Step 5: nickel plating, the workpiece is plated in a nickel pond. It contains 250 grams of Nickel sulfate, 60 grams of Nickel chloride, 40 grams of Boric acid, 10 grams of Nickel additive, and Nickel brighter 10 grams works to contribute the plated parts a shiny luster. The color of the nickel plating solution is green, as shown in **Fig. 2(c)**.



(a) Alkaline copper (b) Acid copper

(c) Nickel (d) 24k gold

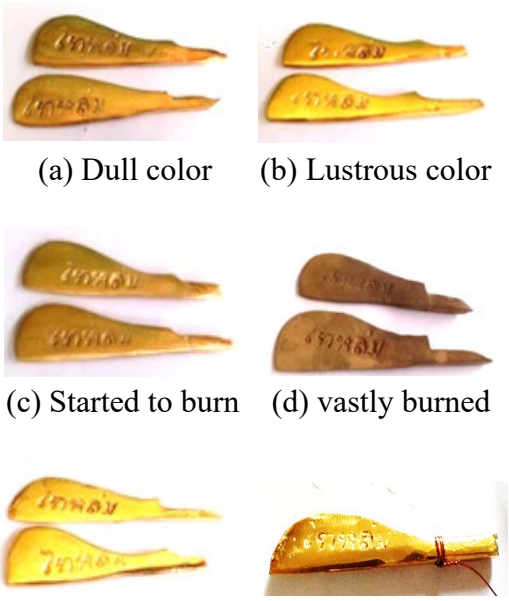
Fig. 2. Inspection of the microstructure of the gold plating process

Step 6: 24K gold plating, the workpiece is plated in a flash 24k gold pond and 250 grams of clean water to make the plated workpiece become a gold color. The solution has a clear white color as shown in **Fig. 2(d),** and washed with an anti-tarnishing liquid in which its function was to coat the plating workpiece for long-lasting durability. After finishing the gold plating process, the workpiece was waiting for the knife handle to complete the package.

3. Results and Discussion

3.1 Gold plated knife surface inspection

The Inspection of the knife surface after gold plating is the first process of colorimeter analysis. (CIE L*a*b* system).



(a) Dull color (b) Lustrous color

(c) Started to burn (d) vastly burned

(e) Most luster (f) Gold plated knife products

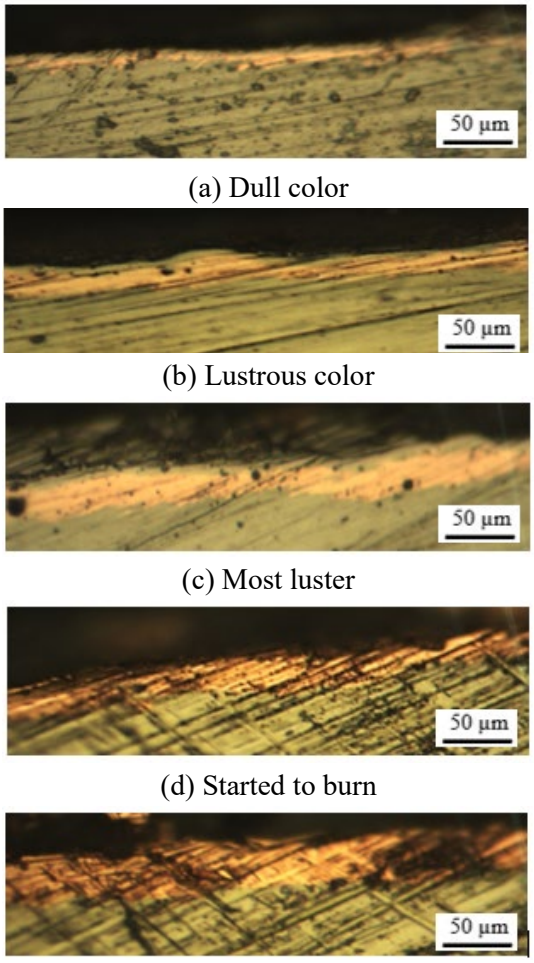
Fig. 3. The characteristics of the knife's surface of the gold plating process

From the examination, it was found that the surface of the knife which was gold plated, as shown in **Fig. 3(a)**, had a faded gold color due to the low electricity consumption and less time for gold plating, the color value is between L*=63.58 a*=14.31 b*=61.84. causing the thickness of the gold to be uneven throughout the workpiece [11]. From the examination, it was found that the knife's back area had a thinner gold coating than the knife's sharp edge area. From **Fig. 3(b)**, a shiny golden surface has appeared but there is no consistency throughout the workpiece since the time for plating gold is quite little [8], the color value is between L*=78.95 a*=15.75 b*=75.53. From **Fig. 3(c)**, a gold color surface has started to burn, the color value is between L*=50.82 a*=27.46 b*=56.91, and **Fig. 3(d)**, a gold color surface was vastly burned due to the excessive electrical current and time in the plating. It caused the gold surface to look tarnished and not shiny [10], [11], the color value is between L*=33.76 a*=17.35 b*=28.15. From **Fig. 3(e)**, a shiny gold which has been the best factor in gold plating since the surface of the knife from the gold plating is consistent, and shines throughout the workpiece, the color value is between L*=88.72 a*=4.45 b*=78.58. From **Fig. 3(f)**, was a ready-to-sell gold-plated knife [3], [9]. However, from the experiment, there was no porosity or other defects found were found in the area of gold.

3.2 Microstructure inspection

Microstructure inspection with Optical Microscope (OM) is examined to determine the deep penetration characteristics of the gold plating which affects the color of the gold surface, dispersion, and consistency of the gold skin. The depth of penetration was measured using an ocular micrometer, compared with the stage micrometer scale, which was measured 3 times and averaged.

From the examination, it was found that from **Fig. 4(a)**, the deep penetration with faded skin color which was approximately 12.06 microns and **Fig. 4(b)**, a deep penetration with a shiny surface color which has a deep penetration of approximately 22.87 microns due to the use of slightly little electric current and time of plating [10] and from the observation, the deep



(a) Dull color

(b) Lustrous color

(c) Most luster

(d) Started to burn

(e) Extremely burn

Fig. 4. The inspection of the microstructure of the gold plating process

penetration is uneven throughout the workpiece. From **Fig. 4(c)**, the deep penetration characteristics with shiny surface color with approximately 33.82 microns, which is the best variable of the deep penetration from gold plating. The deep penetration was consistent and the color is fine-looking throughout the work.

From **Fig. 4(d)**, the deep penetration with the color of the skin starting to burn which was approximately 39.19 microns and **Fig. 4(e)**, the deep penetration with intense burnt color which was about 44.52 microns, it was found that the penetration of the gold deeper than other experimental factors, but the appearance of the gold was burnt from the use of electricity and time in plating for a long time, causing gold's dull skin and unbeauty [11]. Generally, the thickness of jewelry gold plating is 2.5-5 microns, but the gold plating for this research is about 12.06-44.52 microns because the material is spring steel and has a rougher surface preparation than gold plating decorations Therefore, it can penetrate more deeply into the material.

3.3 Results from the study of factors from applied electric currents comparing with plating time

The important factors in the gold plating process were electric current and plating time which affected the reduction reaction causing a thin layer of metal from the lure to be coated on the surface of the workpiece. It also affected the thickness of the gold-coated on the surface of the workpiece, the dispersion of gold over the surface, and also the color of the gold. From the results of the experiment, the researcher has separated the color of the gold material into 5 levels, namely, faded color, that is the coating of gold on the surface of the work is less and uneven. Gloss color was a coating of gold on the workpiece surface which was fair and uneven throughout the workpiece. The shiny color was the coating of gold material on

the workpiece surface that is sensible and consistent throughout the workpiece. The starting-to-burn color was the coating of gold material that was consistently distributed throughout the workpiece, but the thickness of the gold is beyond the standard. The over-burnt color was the coating of gold on the workpiece that was consistent, but the thickness of the gold is extremely high, causing burns [12] since the use of time and electric current in the plating was excessive.

Table 1 Result of the use of electric current for gold plating at 10 volts

Experiment time	Gold surface thickness (Micron)	Uniform distribution of gold (Percent)	Gold luster (Percent)
30 seconds	09.89	29	Dull color
60 seconds	12.06	37	Dull color
90 seconds	16.19	53	Dull color
120 seconds	19.01	68	Dull color
150 seconds	21.33	80	Lustrous color
180 seconds	26.15	92	Lustrous color

From **Table 1**, as a result of the use of electric current for gold plating at 10 volts, it was found that the gold plating time to achieve the most lustrous color and thickness was 180 seconds, the thickness of gold is 26.15 microns. Due to its low electricity consumption, the gold plating process takes much time for gold plating as well [11]. From experimental factors, it was found that the dispersion of gold was not consistent throughout the workpiece, which is 92 percent. However, the experiment showed that less plating time will affect the thickness of the gold surface and the dispersion of gold material as well [12], which affected the dull color of the gold.

Table 2 Result of the use of the electric current in gold plating at 12 volts

Experiment time	Gold surface thickness (Micron)	Uniform distribution of gold (Percent)	Gold luster (Percent)
30 seconds	17.51	59	Dull color
60 seconds	22.87	84	Lustrous color
90 seconds	26.96	93	Lustrous color
120 seconds	33.82	100	Most luster
150 seconds	39.61	100	Started to burn
180 seconds	43.31	100	Extremely burn

From **Table 2**, as a result of the use of the electric current in gold plating at 12 volts in gold plating, it was found that the proper gold plating time for luster and

thickness was 120 seconds and the thickness of the gold surface is 33.82 microns. From the experimental factors, it was found that the dispersion of gold was evenly over the workpiece at 100 percent, which was considered as the best result of the experimental factor and also found that at the time of plating in more than 120 seconds the appearance of gold began to burn and it will be burnt intensely at 43.31 microns due to the excessive reduction reacting time [7], [9]. Besides, from the experiment, it can be seen that the less amount of time the gold plate is on, the more it affects the thickness of the gold surface, the dispersion, the skin penetration of gold [11], [12] and the dull color of the gold.

Table 3 Result of the use of the electric current in gold plating at 14 volts

Experiment time	Gold surface thickness (Micron)	Uniform distribution of gold (Percent)	Gold luster (Percent)
30 seconds	35.63	100	Started to burn
60 seconds	39.19	100	Started to burn
90 seconds	44.52	100	Extremely burn
120 seconds	49.14	100	Extremely burn

From **Table 3**, as a result of the use of the electric current in gold plating at 14 volts, it was found that the gold surface in plating in all experimental factors started to burn and extremely burn and this factor had the maximum experiment time by taking 120 seconds due to the longer time would cause more burns to the gold surface. It was found that the gold surface from plating began to burn at the thickness of the gold surface at 35.63 microns onwards [11], [12] which the burnt surface makes it look dull and cannot be sold [7].

3.4 Results from transferring knowledge in plating technique with gold

The knowledge transfer and knife plating technique with gold to the Ban Mai Knife Forgers Village of Lom Sak district, Phetchabun province had 25 participants with experiences in Tai Lom knife plating from 5-8 years. The evaluation was focused on 2 aspects of satisfaction evaluation [3] shown in **Table 4**, it found that overall satisfaction was at 4.39, the standard deviation was 0.66 which was at a high level. When analyzed in each aspect, it was found that the highest average score was satisfaction which was 4.46, the standard deviation was 0.64, which was in the high level. When assessed in each question, it was found that the item with the highest average was the researcher having easy-to-understand techniques and methods for transferring knowledge that mean was 4.61, the standard deviation of 0.65 which was in the highest level. However, when summarizing the overall assessment of knowledge transfer and gold knife plating techniques, it was

found that no item was lower than the specified Key Results (KRs) criteria of the project [1] and shows that OTOP knife plating products with gold for Ban Mai Knife Forgers Village can significantly meet the needs of the target audience.

Table 4 Satisfaction results from knowledge transfer in the gold plating process

Assessment details	$(\bar{x})$	(S.D.)	Results
The process of knowledge transfer			
Researchers have easy-to-understand techniques and methods for transferring knowledge.	4.61	0.65	Very good
The researcher can ask and answer questions.	4.11	0.66	High level
Researchers use a variety of media to transfer knowledge.	4.32	0.76	High level
The researcher used the time for training and demonstration appropriately.	4.25	0.62	High level
Average	**4.32**	**0.68**	High level
Satisfaction			
Satisfaction with the shape of the product.	4.42	0.5	High level
Used a product of gold plated knives to be used to increase productivity.	4.46	0.61	High level
Used a knife product with gold plating to add value.	4.36	0.83	High level
The product has a beautiful golden color.	4.52	0.61	Very good
The product is durable and can be used for a long time. (Gold does not peel off)	4.4	0.61	High level
The product price is reasonable.	4.5	0.65	High level
It is modern, novel, different from the original product.	4.58	0.67	Very good
Average	**4.46**	**0.64**	High level
Total average	**4.39**	**0.66**	High level

4. Conclusion

The objective of this research is to increase productivity and create product value from the gold plating process to enhance the OTOP knife products for Ban Mai Knife Forgers Village. The best experiment factor was the electric current in gold plating at 12 volts and the plating time in making shiny color and proper thickness was 120 seconds, the thickness of the gold surface was at 33.82 microns and the dispersion of gold was consistent at 100%. However, when transferring gold plating knowledge to the knife forging group and conducting products to increase productivity and add value to the products, it was found that from the original product of Tai Lom knife before plating, the selling price is 30 baht per piece, after the product is developed, it can be sold for 99 baht per piece. Moreover, tourists have tended to buy souvenirs in a large amount per time, causing to increase the production

capacity in both the tourist season and the normal season from about 50-60 pieces per day on average to about 60-75 pieces per day on average and also gain the average income from 1,500-1,800 baht per day to 5,940-7,425 baht per day on average. The results from knowledge transfer in gold plating techniques showed that the average satisfaction was 4.39 and the standard deviation was 0.66, the score was at a high level. In general, there are no items that fall below the criteria from the project key results indicators.

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