Jepara Wooden Carving in the Digital Era

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Abstract: This paper is a study for redefinition of latest arts, in wooden carving. The equipment in work carving in today's is Computer Numerical Control (CNC). CNC can eliminates manual processes. Also, there was a diminishing interest in people's youth of Jepara in pursuing jobs as wood carvers. The presence of CNC is a solution that can replace human source. However, carving products produced by CNC machines are less attractive to the consumers. There is a contradiction, wich is this advanced technology can replace most of the production of art to be more effective, efficient, consistent, and precisely, but consumers actually want the unique and distinctive handiwork. This paper aims to uncover the creativity of entrepreneurs and wood carving artists responding to the tastes of markets and to get solutions to the existing problems. The method used is qualitative by getting data of literature and observation. The solution is to use CNC to speed up the production in initial engraving and then the carving process is continued with the hand skill manually. The product still expresses a distinctive creativity as a carving work done with hand skills, but can be done faster than using the full manual technique.

1 INTRODUCTION

Jepara is a city of carving, as a tagline shown that the existence of intelligence carves as an ancestral heritage is still preserved and developed in accordance by changing times. The carving brings blessing to those who pursue it in high persistence. Art as a living force (Marianto, 2017), has been practiced significantly by Jepara wood carvers. The superior products of the Jepara wood industry are on various beautiful carvings of furniture, reliefs, and other various interior accessories products. Jepara known as the center of the carving furniture industry (Pratiwi, Kenang, & Ruki, 2017). The advantages of Jepara wood products are mainly in fine carving and carpentry techniques (Eskak, 2013a).

Jepara is a heaven of wood carving hunters. It is a city located on the north coast of Central Java within an area of 949.80 km2. The city which has been known as the center of wooden furniture is at the position of 5º 43 '20.67' to 6º 47 '25.83' South Latitude and 110º 9 '48.02' to 110º 58 '37.40' East Longitude. Jepara borders the Java Sea in west and south side, Kudus and Pati Regencies in east side, and Demak in south side (Cemerlang, 2018). As Jepara is not crossed by the Pantura transportation route, which is the largest economic route on the island of Java. But, it is able to utilize the potential of its resources, and turn it into a regional economic power. This makes Jepara is able to align the economy with other regions, even in some other sectors Jepara is far more advanced than other regions (Prastiyan, 2017).

Eventhough it is an area with minimum potential natural resources and is not located on the main coastline, it has been able to align itself economically with other regions, one of them is due to the presence of wood carving industry. The Jepara wood carving industry has become one of the driving forces of the regional economy (Eskak, 2013a). Carving is the art technique of sculpting material with patterns and decorative structures, made in a concave or convex style, following the drawing plot with a chisel (Gustami, 2000). The material for traditional carving are wood and stone

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(Sunaryo, 2009). Bamboo (Eskak, 2016a) and coconut shell (Eskak, 2016b) can also be a media for carving. The traditional Jepara carved motif is a stylation or a vines formed, the stylation is a changing form styled and is generally patterned (Sunaryo, 2018). Its motifs also have the meaning of beautifying life in beauty with integrity, balance, and harmony in community. The goodness must be spread to all directions and places. The ancestors inherited many noble and meaningness values contained in artwork (Eskak & Salma, 2018).

The Jepara carving industry contributes about 10% of Indonesian furniture, and contributes to the district's economy by 27%. More than 12,000 furniture artisans operate in Jepara. The main competitor of Jepara's furniture trade is China, which it dominates trade by 16% of the world and prices are 20% cheaper than Indonesian furniture (Raharjo, Rubijanto, & Solechan, 2015). The price of Jepara wood carving products is more expensive, while it loses in competing with China, because of China's wood carving production process uses automation machines, so the output can be massive and have cheaper price. The higher price of Jepara carving products is due to the longer time production processes has taken, with high costs, and low output quantity in the contrary, less futuristic designs, and manual processes (Raharjo, Rubijanto, & Solechan, 2015). In contrast to the Chinese carving industry which has collaborated on an advanced technology and art, so that it can produce massively and has the lower prices.

In addition, today there is a decline in the number of professional carvers, further to threatens the sustainability of the wood carving business in Jepara. The study and work carving interests of the younger generation has also wane off. If For this is left without a solution, the concern about the extinction of traditional art is close to reality (Eskak, 2013b), which it is truly unfortunate if the existence of classical archipelago carvings those are beautiful and comprise with high philosophies (Nizam, Nugraha, & Gustami, 2018) can not be preserved. Along with this feeling of concern, the existing conditions must still be addressed with various solutions. Jepara entrepreneurs, artisans and carvers need to take steps forward so that the survival of their businesses is maintained. The use of more technology is one of the solution can be taken to these problems.

The technology can help increase productivity while resolving the problem of the difficulty of finding a carving industry workforce. The use of carving machines is one of the solution. A sophisticated and reliable carving machine is a CNC machine. CNC is a computer machine that uses a numerical control system. CNC itself stands for Computer Numerical Control. The factory uses CNC to control their factory machines. At a glance, it is as if a normal computer controls the machines, but actually the computer runs using a unique software and special consoles. With CNC machines, factory machines are controlled with number controls. The computer programs are specifically designed to control machines and objects. The program uses the CNC machining language (called G-code). This program organizes features such as feed rate, coordination, location and speed. With CNC machining, computer can control the precise position and velocity of the machine (Mengenal Apa Itu Mesin CNC, 2019).

There are many benefits to use a CNC machine. This process is more rigorous than its manual machining. Besides that, it can also be repeated the same way many times. CNC machines are a series of machines with programmable intelligence work patterns for the execution of drilling system work (Guiping, Yazhou, & Guangwen, 2010). By seeing the specificity of CNC machine performance does not rule out the possibility that CNC machines can still function with a variety of materials including wood material. CNC machine components consist of two basic components, namely hard components in the form of machine physical devices and soft components in the form of programable devices or software executors (Iskra & Hernández, 2010).

Material working patterns using CNC are more commonly used for soft material types such as wood, so that the use of CNC machines currently dominates solid-shaped and wood-based work such as multiplexes, hardboards, medium-density fibreboard, and other types of wood particles. CNC is considered to be more capable of providing a high level of accuracy compared to other wood manual machines. CNC is currently being used for ornamental work on the surface (Iskra & Hernández, 2012). CNC can be used for mass production patterns. The current CNC development system has 3 axis and 4 axis pattern. The 3 axis pattern can be found in most furniture industries while the 4 axis pattern is still rarely found due to the price of CNC machines those are quite expensive. The CNC machine reading pattern is based on a code pattern called G Code contains coordinates of the object to be pointed by a blade driven by a CNC machine so that the level of accuracy can be achieved even in millimeters (Raju, Janardhana, Kumar, & Rao, 2011; Firstiawan, 2012). CNC is able to provide very

smooth levels of wood material execution on its surface (Darmawanto & Minardi, 2017).

The use of CNC can increase a company's competitiveness, because of the selling price of the products. However, the reality of the Jepara wood carving market is different to it. It is said that Jepara wood carvings do not compete with Chinese wood carvings, basically it turns out that the sculptures of Chinese Gods, altars, and Chinese cultural symbols created by residents of Jepara which are many buyers are interested in mainland China, Hong Kong, and Taiwan (Eskak & Sumarno, 2016). This is shows that Jepara carving lost in terms of mass production but won in the manual carving production. The advantages for Jepara wood carving are better than Chinese's in quality and durability (Soedarso, 2006). Some of Jepara carving companies have also used CNC machines, but their carving products are less attractive to the foreign markets, as the main market for wood carving products from Jepara. There is a contradiction, which a sophisticated technology can replace most of the art production processes to be more effective and efficient, but consumers actually demand a unique and particular results of handwork carving. This paper aims to uncover the creativity of wood carving artists in responding to the tastes of markets and getting solutions to the existing problems.

2 METHODS

This research categorized as qualitative research, by obtaining data from the literature and observations. Literature studies are carried out by reading relevant references and the observations are carried out in Jepara. Observation is sighting, but they are carried out carefully and deeply on an object or problem (Eskak, 2014). Qualitative research aims to explain phenomena through deep data collection. If the data collected is in-depth and can explain the phenomenon under this study, then there is no need to look for other sampling. The depth issue is more emphasized of or quality of the data rather than its quantity, and researchers actively participate in determining the type of data desired (Kriyantono, 2010). Data is analyzed qualitatively and interpretatively through several processes such as: data verification, data reduction, data presentation, and conclusion (Moleong, 2012).

3 RESULTS AND DISCUSSION

3.1 Reverse Progress

Technological and community development are interrelated and influenced to each other in life, including in the Jepara wood carving industry. Today there is a significant decrease in the number of carvers resources, which threatens the sustainability of the wood carving industry. The younger generation interests has declined to practice and become a professional carvers. Learning to carve requires perseverance and a long enough time to become skilled. Today's younger generation is more likely to think and act pragmatically and instantaneously so they choose to work in cigarette factories, cables, clothing, and other factories which are now prevalent in Jepara (Purnomo, 2018). The regional government has been negligent by giving many permission to establish factories those are not in accordance with the regional superiority and culture of the Jepara community. The large factories have absorbed a lot of naturally talented human resources in the field of carving and it is not immediately taken care off by the government, so it can turn off the existing efforts of populist carving. The local governments should have better understandable according this matter and they are not solely tempted by the tax revenues from these factories.

The provision of carvers skilled in Jepara has 2 lines, those are traditional routes and formal education routes. The traditional path is taken first by becoming an assistant (*kenek*) for professional carvers while working (Hariyadi, 2010), and received wages from the learning process. At present days, it is difficult to find young people who want to learn to work on carving (Eskak & Sumarno, 2016). Jepara young generation generally prefer to work in other fields those are easier and faster to make income.

Pathways to sculpturing formal education learning can be passed by taking courses or conducting studies in vocational schools. The famous sculpturing course institute in Jepara in 1990s were *Nevada* and *Jenggala* Course. Formal education of carving can be taken at SMK Negeri 2 Jepara which has wood carving as one of its majors. It is become a favorite major to be chosen in the school that was formerly called the Jepara State Craft Industry Middle School (SMIK). Uniformizing by the national curriculum, the wood carving major has renamed by the wood craft design and production major. From its special major in accordance with the needs of the industry region has transformed into a national curriculum that no longer

fully learns to carve but to learn wooden crafts in general. This is has made an decreasing effect on the graduates ability and competence to carve. The last stronghold of defense of skilled carvers supply was already weakening. The Ministry of Education and Culture should consider wisely about the special needs those support the progress of regional industries, and not just do the appliance of uniformity which would reverse the existing local industries.

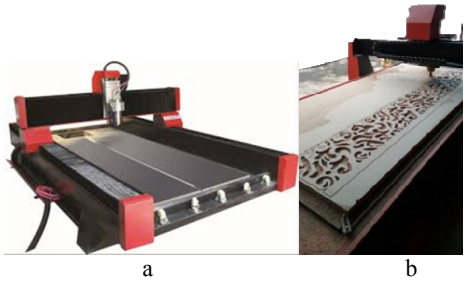
The impact of these policies was truly felt in difficulty search for carving workers. The wood carving industry that has raised and made Jepara into a famous national and international forums is experiencing production sluggishness, not just even a few but more than are out of business. The government should be present to provide for strengthening policies and refreshment so that the wood carving industry rises and triumphs again, instead of deflating and letting it die slowly. The government must immediately realize and revise the wrong direction of regional development programs. It can not be turned upside and down and belated to be realized, which it is to intend and work to develop the region, but it turns out to be as a setback.

3.2 Carving Automated CNC Machine

The development of advanced technology can help solve many human problems, one of which is a CNC that has the ability to automate the work of carving. The development of wood carving production from traditional manuals to CNC automation machines can be done with various social and economic considerations. CNC can be easily obtained in the market, but for small entrepreneurs the price is still quite expensive. For medium and large entrepreneurs, investment in CNC carving machines is very beneficial for the efficiency and effectiveness of production. Carving has the potential and opportunity to be developed into an industrial production business through coaching to answer the demands era, as well as to improve the welfare of society (Gustami, 2007). The creation of works of art needs to pay attention to the development and changes of the times because each era has different challenges and problems. The current development demands higher creativity in art creation with the ability to utilize in multiple scientific field. Gustami in (Eskak, 2013c) states that the obligation of today's young generation to anticipate this change so that later it can be realized as a new craft according to the soul of the times but it still reflects the national culture. Jepara's carving today, has undergone a shift in definition from the concept of manual traditional production to digital automation production. Redefinition of carving needs to be done so that the current generation is not confused and being as a technology stuttering. A simple or sophisticated machine is just a tool to work, but the core or the essence of art is still creativity. Today's carving can be interpreted as a technique of decorating wood by carving using manual, masinal, or digital programs.

The use of advanced technology is a necessity in traditional arts, including in carving. In this digital era, the art and culture space of the community changes with the development of information technology and media (Kusrini, 2015). The latest technology can be used to make carving works in accordance with the development of the era. In essence of carving is the technique not in its decorative design, this has always been the wrong thing to understand related to finished products which are often considered lay as carving because of their motifs (Darmawanto & Minardi, 2017). The developing technique of carving can be done by designing a machine that is specially set to be able to do the work of carving (Raharjo, Rubijanto, & Solechan, 2015).

It is not something difficult that the production of wood carving on an industrial scale can be done with CNC tools because it will increase the competitiveness of small industries (Making Indonesia 4.0 - Kementerian Perindustrian, 2016). Rapid industrial climate change demands market segmentation related to carving techniques that are compatible with economical counts so that art expression changes into commodity calculations. Art is actually a form of technique that is able to provide economic results for the actors (Adu-Agyem, Sabutey, & Mensah, 2013).



a b

Figure 1: a. CNC carving machine, b. Carving process

Carving ornaments still have a high selling value so that the development of design and design parameters can be made coding catalysts so as to

facilitate producers in making the same production. Traditional decorative motifs can be modernized according to the tastes of the present, so that consumer interest increases and producers can feel the economic impact (Salma & Eskak, 2012). The use of CNC can maintain production consistency, carving quantity, and uniformity.

3.3 Speed and Precision

To give a real picture of the effectiveness and efficiency use of CNC, it take for an example of the CNC application for carving the *krawangan* of calligraphy products. *Krawangan* is a technique to carve until it penetrates material (Eskak, 2016a). The CNC used has the following specifications: 3 axis, namely X, Y, and Z or can move left and right, back and forth and up and down. Movement of 400 x 500 x 400 mm. Axle track to adjust the movement of the wood carving router. The rail uses drawer rail slides, 30 mm in diameter and 600 mm in length. The carving platform uses an aluminum Profile 150 Series coated with a thickness of 2 mm. 230W / 11000 Spindle Motor as a router carve on the stand. The drive system uses a Screw ball Pitch 4 mm in length of 600 mm. Screw ball Pitch bearings use stainless steel Insert Ball bearings SUC202-10. Stepper motors - 1/2 ″ dual shafts with X, Y, and Z axis movements on ball screw. The voltage cable to the drive component is protected by a chain cable. Stepper Motor Driver M542 / M752, inventer, and Omron Automation. The inverter for motor spindle speed control uses a 2.7 kW 220V VFD inverter. S8VS-06024 AC-DC Omron Automation; 24V-2.5A as a power supply for wood carving machines. M542 / M752 Stepper Motor Driver for drive control interface, parallel serial cable interface. Core-2 desktop computers equipped with DSP or digital singal processing systems (Suwignyo & Yanto, 2018). These specifications can be seen in Figure 2.

Figure 2: Protable CNC carving machine

The CNC mentioned above will be used to test the manufacture of *krawangan* calligraphy carving products in Banjaran Village, Jepara Regency. The production of wood carving calligraphy in the village averages 20-30 daily sales at a price of Rp. 400,000 - Rp. 6,000,000 each, while for exports per month 1 container contains 4000-5000 pieces. Banjaran Village has 2 groups of artisans, that is: The Harjo Kaligrafi Cahaya Seni group. The problem faced is that the small production capacity and product precision are not maintained. The use of CNC succeeded in accelerating the process of carving and increasing the precision of significant carving products (Suwignyo & Yanto, 2018).

3.3.1 Speed of the Carving Process

Carved calligraphy with CNC has gained a significant working speed. Calligraphy design was carried out on the help of Computer Aided Design (CAD) with CorelDRAW. The size of the carving calligraphy is 25cm long and 45cm wide using a 3mm chisel. Software for running programs using Max3. The time of the process of carving calligraphy with variables into the feed rate of 50, 60 and 70 mm / rev. Cutting speed 30 m / min, 1 mm depth of cut, and 200 rpm spindle speed. The type of wood used is mahogany with a water content of 26% and density of 512 kgs / m3. The speed of the process of carving calligraphy with the feed rate variable is shown in Table 1, and the product results in Figure 3.

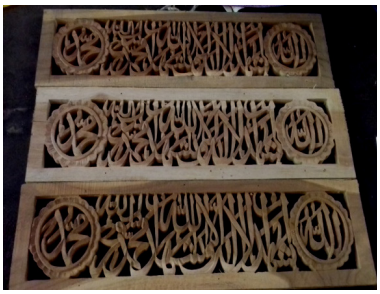


Figure 3: Carved products with variabel feed rate (Source: Suwignyo & Yanto, 2018)

The lowest feed rate is 50 mm / rev for the longest carving process time is 2:33 hours better than the manual carving process of 80%. Increasing the feed rate speeds up the process of carving at a 60 mm / rev feed rate which takes 2:12 hours. This can cut time by 2; 23 hours or 108% of the process of carving manual calligraphy. The fastest CNC carving process at the 80 mm / rev feed rate is shown in Table 1. The carving process time is 1:33 hours and is able to save time compared to the manual by 2:56 hours or 177%. The increase in the feed rate accelerates the process of carving calligraphy because the feeding process is higher and the completion time is faster. Savings in the process of carving calligraphy can increase productivity. Within 1 working day of 8-hour work, CNC engraving can produce 4-5 calligraphy carvings (Suwignyo & Yanto, 2018).

Table 1: Manual and CNC carving times

Carving Calligraphy Process	Time Process of Carving Calligraphy (hours)		
	50 mm/rev	60 mm/rev	70 mm/rev
Manual	4:35	4:35	4:35
Carving 1	2:35	2:09	1:33
Carving 2	2:28	2:14	1:30
Carving 3	2:37	2:14	1:36
Average	2:33	2:12	1:33

(Sumber: Suwignyo & Yanto, 2018)

3.3.2 Precision of Carving Results

CNC carving precision results show better results compared to its manual. Feed rate speed has a significant effect on product precision. Repetition of the process is done to accuracy test of the design. Table 2 shows a 73% manual carving precision, while a CNC carving with a 50 mm / rev feed rate reaches 93%, it has a difference of 20%. By increasing the feed rate to 60 mm / rev, precision has decreased to 90%. As the feed rate increases to 70 mm / rev, the precision decreases again to 85% (Suwignyo & Yanto, 2018).

Table 2: Level of precision of manual and CNC carving

Carving Calligraphy Process	Level of precision carving (%)		
	50 mm/rev	60 mm/rev	70 mm/rev
Manual	73	73	73
Carving 1	93	89	85
Carving 2	92	90	84
Carving 3	94	91	86
Average	93	90	85

(Sumber: Suwignyo & Yanto, 2018)

Increased feed rate speed carving wood calligraphy decreases to the precision of the product. High precision level is influenced by wood hardness and chisel feeding speed. A high feed rate makes the surface of the carving product rough and fibrous and decreases its precision (Rahman & Kadirgama, 2015). The difference in the products precision of the carved calligraphy with CNC machine feed rate variables is very small, but it affects the tidiness, surface cleanliness, and beauty of the products produced. Suwignyo & Yanto, 2018).

3.4 Quick Tips and Taste Tricks

The existence of a CNC carving machine is a solution that can replace human resources for the process of making wood carving products, but the carved products produced are less attractive to consumers. Overseas consumers as the main market for wood carving products from Jepara do not like products those are automatically processed with these CNC. The contradictory thing is that CNC technology can replace most of the production or work processes of art in a more effective, efficient, consistent and precise way, but consumers actually want a unique and distinctive handwork. Therefore wood carving artists need to be creative in addressing the market's tastes. Carving artists can use CNC to speed up the process of producing wood carvings.

Figure 4: Carved product of CNC carving machine from China (Wood Cnc Router, 2018)

Figure 5: Combined product of CNC and manual carving (Jepara)

The tread carved by a CNC is different from hand carving. The process of CNC carving uses a router system, not a chisel knife. The router system only works in the form of a straight one-way rotation from above. The machine is only able to work according to the program's instructions, not as creative as humans. CNC carving results can be seen in Figure 4. The carving works still feel stiff and empty of meaning. Carving artists can use CNC to speed up the production process, especially in the initial carving process, then continued with hand skills manuals. The artwork produced still expresses a distinctive creative expression as a pieces of work, but can be done faster than when it using manual techniques completely. CNC carving results that are enhanced by manual carving can be seen in Figure 5.

4 CLOSING

4.1 Conclusion

The creative industry needs to pay attention to the development and changes of the times because every era has different challenges and problems. The development era demands an increasingly high artistic creativity with the ability to utilize multiple scientific fields. The carving today, has undergone a shift in definition from the concept of manual traditional production to digital automation production. A simple or sophisticated machine is just a tool to work, the essence of art is creativity. Today's carving can be interpreted as a technique of decorating wood by carving using manual, masinal, or digital programs. Entrepreneurs and carving artists can use CNC to accelerate the process of wood carving, while respond to the increase difficulty of workforce seeking. CNC carvings that still feel stiff and empty of meaning, can be given a touch of hand carved so that the results are more flexible, lively and soulful.

4.2 Suggestions

The policies issued by the government should really be through in-depth studies of the specificities and needs of the region, not to aim at advancing but instead of to reverse the existing conditions. This has happened to the Jepara wood carving industry sector. The government should be present to provide policies for strengthening and invigorating it so that the wood carving industry rises and triumphs again.

REFERENCES

Adu-Agyem, J., Sabutey, G. T., & Mensah, E. , 2013. New trends in the Ahwiaa wood carving industry in Ghana: Implications for art education and socio-economicgrowth. *International Journal of Business and Management Review*, *1*(3), 166–187.

Darmawanto, E., & Minardi, J., 2017. Pengembangan Produk Ukir Berbasis Desain 3 Dimensi Menggunakan Mesin Cnc Untuk Industri Mebel. *DISPROTEK*, *8*(2), 82–101.

Eskak, E., & Salma, I. R., 2018. Menggali Nilai-nilai Solidaritas Dalam Motif Batik Indonesia. *Jantra*, *13*(2), 240–255.

Eskak, E., 2013a. Krisis Bahan Baku Seni Kerajinan Kayu Di Jepara Dan Solusi Pemecahannya. *Dinamika Kerajinan Dan Batik*, *30*(2), 73–84. http://dx.doi.org/10.22322/dkb.v30i2.1112

Eskak, E., 2013b. Mendorong Kreativitas Dan Cinta Batik Pada Generasi Muda Kritik Seni Karya Pemenang Lomba Desain Batik Bbkb 2012. *Dinamika Kerajinan Dan Batik*, *30*(1), 1–10. http://dx.doi.org/10.22322/dkb.v30i1

Eskak, E., 2013c. *Rupa Karsa: Eksplrorasi Limbah Dalam Seni*. Tesis Pascasarjana. Institut Seni Indonesia Yogyakarta.

Eskak, E., 2014. Metode Pembangkitan Ide Kreatif

Dalam Penciptaan Seni. *Corak*, *2*(2), 167–174. https://doi.org/DOI: 10.24821/corak.v2i2.2338

Eskak, E., 2016a. Bambu Ater (Gigantochloa Atter) Sebagai Bahan Substitusi Kayu Pada Ukiran Asmat. *Dinamika Kerajinan dan Batik*, *33*(1), 55–66. http://dx.doi.org/10.22322/dkb.v33i1.1039.g1175

Eskak, E., 2016b. Identifikasi Pola Laminasi Tempurung Kelapa. *Dinamika Kerajinan Dan Batik*, *32*(2), 107–116. http://dx.doi.org/10.22322/dkb.v32i2.1366

Eskak, E. dan Sumarno., 2016. Peningkatan Nilai Tambah Pada Cacat Batang Kayu Dengan Kreasi Seni. *Dinamika Kerajinan Dan Batik*, *33*(2), 133–143. http://dx.doi.org/10.22322/dkb.v33i2.1649.g1656

Firstiawan, N., 2012. Optimasi Parameter Proses Pemesinan CNC Milling Terhadap Kekasaran Permukaan Kayu Jati Dengan Metode Taguchi. *Jurnal Nosel*, *1*(2).

Guiping, W., Yazhou, J., & Guangwen, Z., 2010. Evaluation method and application of CNC machine tool's green degree based on Fuzzy-EAHP. *Journal of Mechanical Engineering*, *46*(3), 141–147.

Gustami, SP., 2000. *Seni Kerajinan Furniture Ukir Jepara, Kajian Estetik Melalui Pendekatan Multidisiplin*. Yogyakarta: Penerbit Kanisius.

Gustami, S., 2007. *Butir-Butir Mutiara Estetika Timur: Ide Dasar Penciptaan Seni Kriya Indonesia*. Yogyakarta: Pratista.

Hariyadi, K., 2010. *Macan Kurung Belakang Gunung*. Jepara: Pemerintah Kabupaten Jepara.

Iskra, P., & Hernández, R. E., 2010. Toward a process monitoring and control of a CNC wood router: Development of an adaptive control system for routing white birch. *Wood and Fiber Science*, *42*(4), 523–535.

Iskra, P., & Hernández, R. E., 2012. Toward a Process Monitoring of CNC Wood Router: Sensor Selection and Surface Roughness Prediction. *Wood Science and Technology*, *46*(1–3), 115–128.

Kriyantono, R., 2010. *Teknik Praktis Riset Komunikasi*. Jakarta: Kencana Prenada Media Group.

Kusrini, 2015. Potret Diri Digital dalam Seni dan Budaya Visual. *Journal of Urban Society's Arts*, *2*(2), 2(2111–122. https://doi.org/https://doi.org/10.24821.

Making Indonesia 4.0 - Kementerian Perindustrian. (2016). Retrieved February 20, 2019, from www.kemenperin.go.id/download/18384

Marianto, M. D., 2017. *Art and Life Force in a Quantum Perspektive*. Yogyakarta: Scritto Book Publisher.

Mengenal Apa Itu Mesin CNC?, 2019. Retrieved January 26, 2019, from http://technopark.surakarta.go.id/id/media-publik/sains-dan-edukasi/539-mengenal-apa-itu-mesin-cnc

Moleong, L. J., 2012. *Metodologi Penelitian Kualitatif*. Bandung: Remaja Rosdakarya.

Nizam, A., Nugraha, W., Ch. R., & Gustami, SP., 2018. Eksistensi Ragam Hias Sulur Gelung Teratai. *Journal of Urban Society's Arts*, *5*(1), 37–48.

Prastiyan, D., 2017. *Dinamika Industri Kerajinan Seni Ukir Jepara 1989-2008*. Universitas Negeri Yogyakarta.

Pratiwi, A. P., Kenang, K. K., & Ruki, U. A., 2017. Analisa Perkembangan Motif Ukiran Di Jepara Pada Abad Ke-16 Hingga Abad Ke-17. 2. *Kreasi*, *2*(2), 5–25.

Purnomo, A., 2018. Nilai Investasi Tembus Rp 74 Triliun. *Suara Merdeka News*. Semarang.

Raharjo, S.S., Rubijanto, J.P., & S., 2015. Rancang Bangun Mesin Ukir Otomatis Ibm Mebel Ukir Kayu Di Desa Banjar Agung Bangsri Kabupaten Jepara. In *Prosiding SNST ke-6 Tahun* (pp. 79–83). Semarang: Fakultas Teknik Universitas Wahid Hasyim.

Raju, K. V. M. K., Janardhana, G. R., Kumar, P. N., & Rao, V. D. P., 2011. Optimization of cutting conditions for surface roughness in CNC end milling. *International Journal of Precision Engineering and Manufacturing*, *12*(3), 383.

Salma, I. R., dan Eskak, E., 2012. Redesain Motif Batik Tradisional Berorientasi Pasar. In *Semnas Teknoin: Pengembangan Teknologi Manufaktur untuk Menunjang Penguatan Daya Saing Bangsa*. Yogyakarta: Fakultas Teknik Industri UII Yogyakarta.

Soedarso., S., 2006. *Tinjauan Seni: Sebuah Pengantar untuk Apresiasi Seni*. Yogyakarta: BP ISI Yogyakarta.

Sunaryo, A., 2009. *Ornamen Nusantara: Kajian Khusus Tentang Ornamen Indonesia*. Semarang: Dahara Prize.

Sunaryo, A., 2018. *Seni Rupa Nusantara: Pengantar Kajian dan Apresiasi Seni*. Semarang: Dahara Prize.

Suwignyo, J., & Yanto, T., 2018. Studi Penerapan Mesin Ukir Kaligrafi Kayu Untuk Meningkatkan Produksi Dan Kepresisian

Produk Di Desa Banjaran Kecamatan Bangsri Kabupaten Jepara. In *Prosiding Seminar Pengabdian Kepada Masyarakat 4.0: Peningkatan Kualitas Pemberdayaan Masyarakat Memasuki Era Revolusi Industri*. Palembang: UNISRI. Retrieved from http://ejurnal.unisri.ac.id/index.php/sndms/article/view/2443%0A2018

Wood Cnc Router, 2018. Retrieved from http://id.qilicncrouter.com/wood-cnc-router/1530-cnc-router-woodworking-series-cnc-wood.html