International Journal of Vocational and Technical Education Research
Vol.9, No.3 pp.1-23, 2023
Print ISSN: ISSN 2059-1187,
Online ISSN: ISSN 2059-1195
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

Design and Construction of a Locally Fabricated Serigraphy Machine for Curve/Flat Printing Substrates

Oluwasegun Daniel Olumola
Industrial Design Department, Kogi State Polytechnic, Lokoja, Nigeria

Tope Israel Ibiwoye, PhD
Industrial Design Department, Federal University of Technology, Akure, Nigeria

doi: https://doi.org/10.37745/ijvter.15/vol9n3123 Published June 12, 2023

Citation: Olumola O.D. and Ibiwoye T.I. (2023) Design and Construction of a Locally Fabricated Serigraphy Machine for Curve/Flat Printing Substrates, *International Journal of Vocational and Technical Education Research*, Vol.9, No.3 pp.1-23

ABSTRACT*: The study aimed at designing and producing a serigraphy machine that prints on both curve and flat surfaces. Various methods of printing such as dye sublimation, heat transfer and screen printing are employed to print on fabric and other allied printing substrates in Nigeria. However, screen printing is one of the oldest forms of printing and one of the most popular method. The "Development of a Locally Fabricated Serigraphy Printer for Curve and Flat Surfaces" has become imperative. The sketches were made based on the conceptual idea and were later drawn with the aid 3D application software (Autodesk Fusion 360) installed in the computer system. The 3D drawings were used as guide to construct the serigraphy machine in the workshop. The machine which is manually operated comes with an adjustable squeegee, an adjustable metallic frame which holds the screen during printing, and a spring attached to the frame holder which holds the frame taut during printing without the aid of an assistant. The squeegee can be stationed and moved manually depending on whether the printing being done on curved or flat substrates. The Serigraphy Printer for Curve and Flat Surfaces is 602.5mm long, 450mm wide and 510mm high its size and weight afford for ease of carriage. The adjustable metallic frame which holds the frame can be adjusted to suit any screen size; ranging from (500mm by 350mm) to (300mm by 22.86m). The main findings of the study were that the objective of developing a serigraphy machine from locally sourced material, that prints on both curve and flat surfaces was realised, also it was discovered that the printing did not leave room for rough prints. The study concluded that by recommending that the "Serigraphy Printer for Curve and Flat Surfaces" is adopted by the local printers to enhance their occupation, and schools to aid teaching.*

KEYWORDS: fabrication, development, screen printing, design, substrate, serigraphy, construction.

INTRODUCTION

The researchers having passed through the rigours of apprenticeship in the 1980s when the technology that is being enjoyed now was hard to come by in Nigeria, had always been panting for a way to solve some of these peculiar problems in serigraphy printing. Knowing that machineries are not easy to come by due to lots of variables, the researchers then began to research into how some of these problems can be solved by consistently fabricating machines that could bridge the gap. Such machines include the serigraphy mesh and lithography plate making machine, ruling machine for exercise book, light box, to mention but a few. It is therefore, the quest for a machine that can make screen printing (serigraphy) easier and interesting that birthed this scholarly work.

This research is an in-depth study of design and development of a serigraphy printer for curve and flat surfaces towards advancing indigenous printing technology in Nigeria. According to Raizman (2003) design usually satisfies certain goals and constraints taking into consideration the aesthetic, functions, economic, or socio-political considerations, and is expected to interact with certain environment. Habib (2021) states that development can be seen as the act of improving by expanding, enlarging or refining products through the use of labour, machines, tools, and chemical or biological processing or formulation. It is the essence of secondary sector of economy. The term development is a range of human activity, from handicraft to high-tech applied to industrial design. Therefore, development of a locally fabricated serigraphy printer for curved and flat surfaces is the act of developing a printer that will make the printing process easier for serigraphy printers in the course of their printing either on a flat or curved surface(s).

According to Daniel *et al*., (2009) serigraphy printing work has been a very lucrative trade, but over the years it has been facing challenges because of restrictions in the importation of machinery cum high exchange rate of naira to dollar causing a lot of problems to the business. This machine is a prototype, designed to use cheaper and locally sourced materials which makes it cheaper and affordable to end users, easy to operate with little instructions and without electricity, taking care of perennial power outage experience. It is also hoped that the serigraphy printing machine would be a useful teaching aid in the tertiary institutions and trade centers.

Statement of the Problem

Adeyeye (2020) noted that the printing industry development began as far back as 1854 with the excitement to bringing the Christian religion and education to Nigeria by foreign missionaries. Daniel *et al*., (2009) stated that serigraphy machine cannot be pushed aside in modem day printing as the perennial experiences of unstable power supply, and dwindling exchange rate of naira to dollar. Luke (2022) notes that the cost of available automated serigraphy printer is between $32,000 to $87,500 which translates to between ₦16,000,000 and ₦43,750,000 as at 8th June, 2021, excluding the payment of high duty on importation of foreign goods, other avoidable challenges like port theft, goods damage, demurrage fees and the like.

The design and development of locally made serigraphy printing machine for curved and flat surfaces has not really thrived in Nigeria and perhaps they do, but this is not adequately documented. A Portable T-shirt Printing Machine by Gbadegbe (2017) from metal pipes and metal plates is composed of an adjustable squeegee, leather padded table, an adjustable metallic frame which holds the screen during printing and a magnetic holder which holds the frame taut without the help of a second person. The squeegee can be moved manually by the help of a bearing and a hollow pipe. However, the portable printing machine is 100 percent mechanically driven and was not designed to print on curved surfaces.

The Pneumatic Multicolour Screen-Printing Machine by Kacharel (2016) is semi-automatic machine that make use of the principle of pneumatic pressure so as to create uniformly distributed pressure instead of unequal pressures while applying the ink. By introducing pneumatic pressure, work done by operator was reduced and good quality prints were achieved in a minimal time. Good as the operation of the Pneumatic Multicolour Screen-Printing Machine sounds, it still left a gap of inability to print on flat and curved surfaces.

Therefore, the features of the current design did not only make the development and usage of serigraphy curved and flat surface printer possible and easier, but also minimises cost. It is anticipated that the machine will support in class experimentation. According to Ifeanyi *et al*., (2021), the public institutions in Nigeria are under-funded, and this is affecting the development of the system. Thus, art education is struggling and needs an overhaul, there are poor facilities for teaching art, unavailability of materials, outdated and poor curricula as well as inadequate funding are some problems confronting the Nigerian arts education system (Ukazu, 2022).

The foregoing therefore necessitated the researcher's quest to embark on a study to develop a serigraphy printer that will print on both curved and flat surfaces. This machine was designed to prints on both curved and flat substrates thereby encouraging creativity and self-reliance. It is expected that the machine will serve as a teaching aid to students in tertiary institution that are often exposed to theories of serigraphy with little or no practical knowledge. This is also geared towards fulfilling industrial design objective of making functional design, thereby creatively defining product forms and features, which add value to product design.

The study therefore aimed at designing and developing a serigraphy printer that can print on curved substrate, using locally sourced materials, thereby promoting the art of screen printing thereby preventing screen printing from being moribund.

International Journal of Vocational and Technical Education Research
Vol.9, No.3 pp.1-23, 2023
Print ISSN: ISSN 2059-1187,
Online ISSN: ISSN 2059-1195
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

LITERATURE REVIEW

Serigraphy is the oldest form of printing, as its origins can be traced to prints such as woodcuts and block prints of the Song Dynasty (960–1279 AD), and later to the Japanese in the 15th century as a way of transferring designs to substrates (Laura, 2016). They began using simple stenciling techniques as a way to create imagery. As at this time stencils were cut out of paper and the mesh was woven from human hair with stiff brushes used to force ink through the mesh to the substrate (Laura, 2016). In the 17th century, silk screens were used in France as a way of printing on substrate. Stiff brushes were still being used as a way to push ink through the mesh. It was here that the practice of stretching silk over a frame to support stencils was initiated. Serigraphy was finally introduced to the West in the late 18th century, but became popular in the early 20th century, when silk mesh became more available and a profitable outlet was discovered (Baines, 2019). Laura (2016) considered 1938 New York group of artists experimenting with screen printing as artistic medium on substrate and coined the term serigraphy. While in the 1960s, Pop Artists, such as Peter Blake, Andy Warhol and Robert Rauschenberg used screen printing as an integral element in their practice, thus establishing and popularizing it as a medium of creating contemporary art. According to Sam (2020) serigraphy printing techniques has the ability to be able to print on different types of substrates and on different types of shapes, be it circular, conical, flat and cubic. It further noted that Printing can be done in specified places such as showcases, vehicles chairs, tables, shirts, face caps and doors, as it is reputable for its quality of not damaging the surfaces where it is printed.

Serigraphy, otherwise knowns as Screen Printing is arguably the most versatile of all printing processes. It can be used to print on a wide variety of substrates, including paper, paperboard, plastics, glass, metals, fabrics, and many other materials. Some common products from the screen-printing industry include posters, labels, decals, signage, and all types of textiles and electronic circuit boards. The advantage of screen printing over other print processes is that the press can print on substrates of any shape, thickness and size. A significant characteristic of screen printing is that a greater thickness of the ink can be applied to the substrate than is possible with other printing techniques. This allows for some very interesting effects that are not possible using other printing methods. Because of the simplicity of the application process, a wider range of inks and dyes are available for use in screen printing than for use in any other printing process.

According to Adu-Akwaboa (1994) screen printing is the process of transferring designs from screens onto a substrate with print paste. He further explains that before a design is printed, it is transferred onto a well stretched screen so that all but the design is covered by a resist material. Screen printing is basically a form of stencil printing. The screen consists of a synthetic fibre or metal gauze stretched over a frame. Parts of the screen have the holes blocked off and the printing paste is forced through the open areas by a rubber blade called a squeegee, the mesh is stuck to the printing table, which is covered with a resilient felt, wax cloth or rubber material. Screen is placed on the substrate in turn; the paste is then applied to one end of the screen and the squeegee drawn by hand through the paste and across the screen, forcing it through the open mesh areas onto the substrate beneath.

Configuration of Printer Adaptable for Flat and Curve Surfaces

Tomaz, *et al,* (2013) states selecting the most suitable work equipment is a key factor in creating the value of products; therefore, the design and selection of work equipment are increasingly focused on its adaptability. The adaptability of work equipment with regards to flexibility and responsiveness is defined by its universality, mobility, modularity, compatibility and economy.

Hernandez (2003) asserted that adaptability is the potential of the company to carry out both the purchase of low-cost goal-oriented work equipment and the reconfigurations of it. Reinhar, *et al,* (2002) and Zah, *et al,* (2004) understood adaptability to be an extension of flexibility. Nyhuis, *et al,* (2008) said that adaptability is associated with additional costs of investment and consumption of time; however, the costs only apply when changes are carried out. Wiendahl, *et al,* (2009) wrote that it is necessary to distinguish between five levels of adaptability: universality, mobility, modularity, compatibility and economy. As a carrier of value creation, work equipment is the key factor of production. Today, the design and selection of work equipment are increasingly oriented towards its adaptability, mostly because of unreliable market forecasts (Palcic, *et al*, 2010, Anisic, *et al,* 2008 and Bozickovic, *et al*, 2012).

The adaptability of work equipment is its ability to be adapted (at low cost) according to internal or external technological, structural, or organisational changes. In general, adaptability consists of the flexibility and responsiveness of work equipment; this can be classified under universality, mobility, modularity, compatibility and economy. Flexibility means that the work equipment is greater than needed with respect to the current functions, performance and accuracy. It allows the management of future, planned-in-advance scenarios. Additional functions are available and can be activated when needed. Work equipment must be able to adapt to new circumstances and new needs at low costs (Kusar, *et al*, 2010). The responsiveness of work equipment is the capability of reacting to new circumstances that were not foreseen in the planning phase. Such a responsiveness is carried out by using its capability of being reconfigured. The desired result of responsiveness is modular, reconfigured work equipment. When designing or selecting work equipment, it is necessary to take into account the requirements that must be met by it with regard to its technological functions and adaptability.

Configuring therefore the Flat and Curved Surface Printer to print on products such as a variety of plastic, glass, metal materials made of cylindrical, conical shape products, including wine bottles, medicine bottles, cosmetics bottles and other packaging bottles, mugs, thermos mugs, beer mugs, red mugs, glass tube, pen, ballpoint pen, fishing rod, bat and other small cylindrical products, requires a lot of time and creativity such as:

i. Constructing a printing plate frame with a spring to pull and lift the adjuster of the screen plate, the lift angle of the screen plate can be controlled by adjuster using knobs, the operation is easier. The spring tension a side of the machine should be as consistent as possible after installation, otherwise it may cause distortion of the printing screen frame.

ii. The screen installation was done in an easy way to ease mounting and removal of the screen frame. Just put the screen plate into the mesh holder through the front slide in the printing rack, and tighten the screen holder with the knobs.

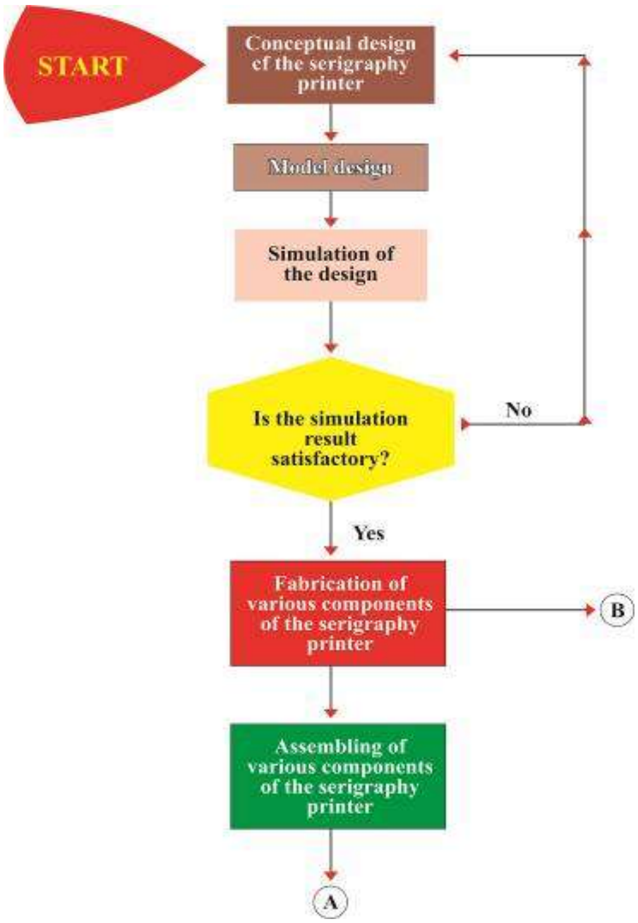
iii. Sliders are connected to the screen frame to make the screen frame slide back and forth; it is easy and smooth to push and pull.

iv. The back and forth sliding distance of the frame can be controlled by the cone on the mesh holder; The user can lock the mesh holder after adjusting the position of the screen and the substrate placement on the printing table.

v. The printing squeegee is configured in such a way that can be mounted and stabilised at a point while printing on curved surfaces and unmounted when printing on flat surfaces.

METHODOLOGY

A conceptual design was done followed by design analysis. Also, to ascertain that the design was adequate before fabrication, a simulation study was done. A conceptual design flow chart for the research methodology is presented in Figure 3.1.



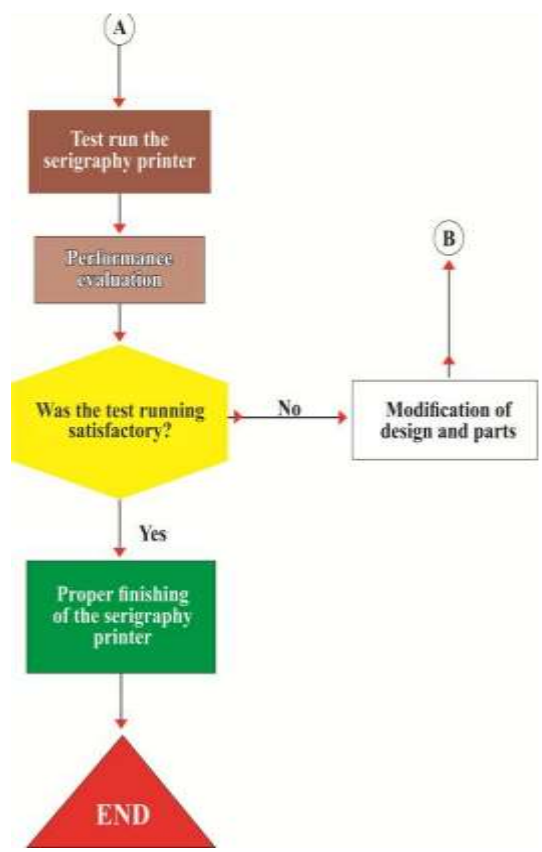


Figure 3.1: Design Methodology Flowchart for the development of printer

Figure 3.2: Continuation of Design Methodology Flowchart for the development of printer

Source: Researcher (2021)

Design Consideration

The materials and methods adopted in this research were appropriated in consideration of the following: availability of materials, properties of the materials selected such as rigidity, corrosion and wear resistance, hygiene of fabrication and overall weight of the machine and cost of fabrication in order to produce an efficient and reliable machine that will ensure the techno-economic status of the intended users.

Research Design

This type of design is a constructive research design which means that it develops solution to a problem that has to be solved through the development of a system.

One of the core features of the constructive research approach is that it produces an innovative construction meant to solve the initial real-world problem and dovetail into an attempt for implementing the developed construction and thereby test its practical applicability (Lukka, 2000). As this often relate to ideas, and also to tangible artefacts as in the case of the current study where a fabricated machine is developed to address real life problem. Figures 3.1 and 3.2 show the procedure in designing and developing the serigraphy printer. Adequate research of materials to back up the design was likewise done. Choosing the right bearing, spring, bolts and nuts, and others were accomplished.

PROCEDURE FOR DEVELOPMENT OF THE SERIGRAPHY MACHINE

The Procedure for the Production of the Machine are divided into two; The Design and Construction Process:

The Design Processes (Stage A)

This stage involves representing the concept of the serigraphy machine on paper via sketches, and then imputed and modified with the aid of computer software application. However, it is important to state the minimum computer system requirement that can run the graphic application software used for the design process. The Autodesk Fusion 360was used to systematically draw the different parts of the conceptualised serigraphy printing machine for ease of fabrication and coupling.

Computer System Requirement

The minimum Computer System Specification to carry out the design is as follows:

Autodesk Fusion 360 Application

Operating System:	Apple® macOS™ Big Sur 11.0*; Catalina 10.15; Mojave v10.14; High Sierra v10.13 Microsoft Windows 10 (64-bit)
CPU Type:	x86-based 64-bit processor (e.g. Intel Core i, AMD Ryzen series), 4 cores, 1.7 GHz or greater; 32-bit not supported ARM-based processors partially supported via Rosetta 2 only
Memory:	4 GB of RAM (integrated graphics recommend 6 GB or more)
Graphics Card:	Supported for DirectX 11 or greater Dedicated GPU with 1 GB or more of VRAM Integrated graphics with 6 GB or more of RAM
Disk Space:	3 GB of storage
Display Resolution:	1366 x 768 (1920 x 1080 or greater at 100% scale strongly recommended)
Pointing Device:	HID-compliant mouse or trackpad, optional Wacom® tablet and 3Dconnexion Space Mouse® support
Internet:	2.5 Mbps or faster download; 500 Kbps or faster upload

Dependencies:	.NET Framework 4.5, SSL 3.0, TLS 1.2+

Complex Modeling Recommendations

Recommended specs for complex modeling and processing

CPU Type:	3 GHz or greater, 6 or more cores
Memory:	8 GB RAM or greater
Graphics:	Dedicated GPU with 4 GB or more VRAM, DirectX 12 supported.

Design Procedure Outlined

i. Conceptualization: this is based on the problem with printing on curved surfaces and elimination of rough edges.

ii. Sketches for the proposed machine were made as shown in Fig 3.3, and 3.4,

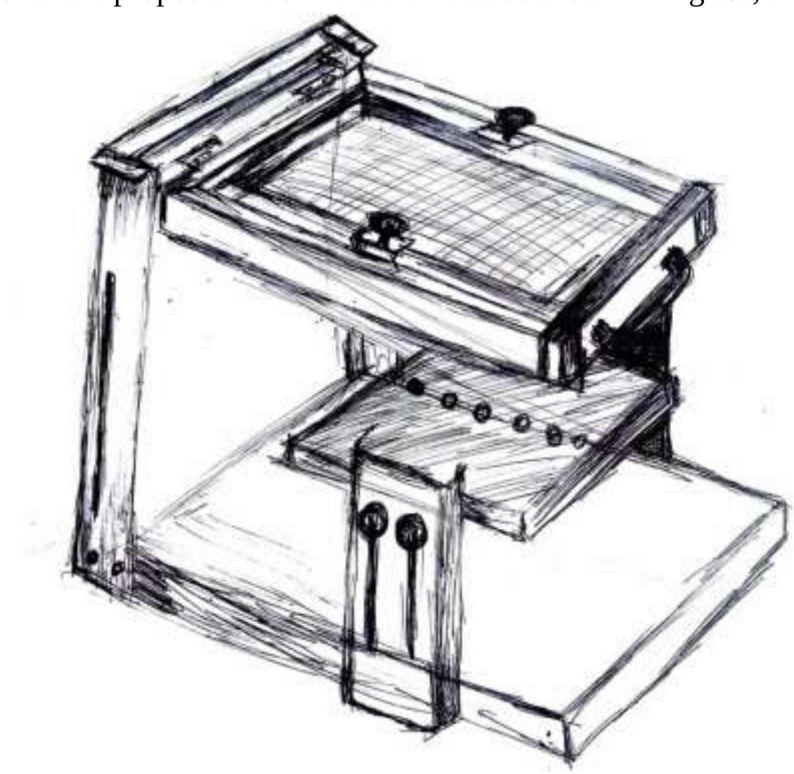


Fig. 3.3: Initial rough sketch of curved/flat surface serigraphy printer
Source: Researcher 2021

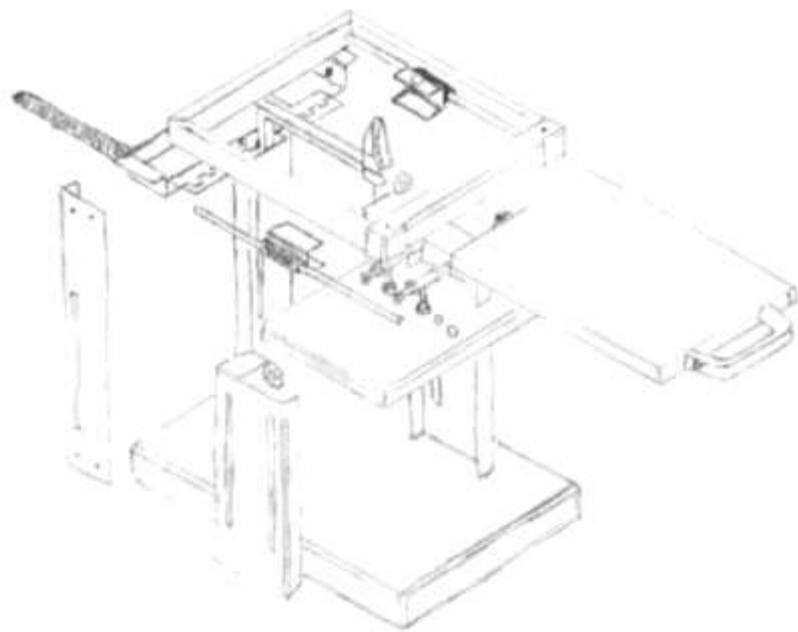


Fig. 3.4: Rough sketches of the curved/flat surface serigraphy printer
Source: Researcher 2021

iii. Transfer sketches into computer for schematic drawings as shown in 3.5, 3.6

iv. Outline the steps used on system to analyse: break the parts into unit to enable fabrication as in Fig. 3.5 and 3.6

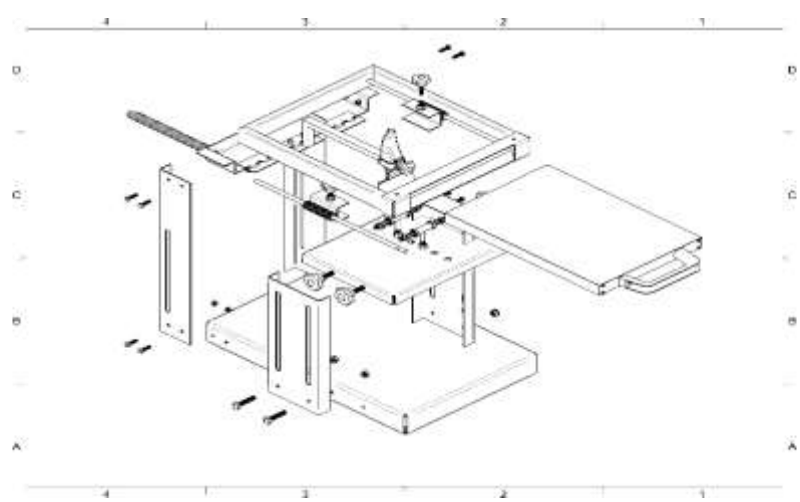


Figure 3.5: Schematic drawings of the curved/flat surface serigraphy printer
Source: Researcher 2021

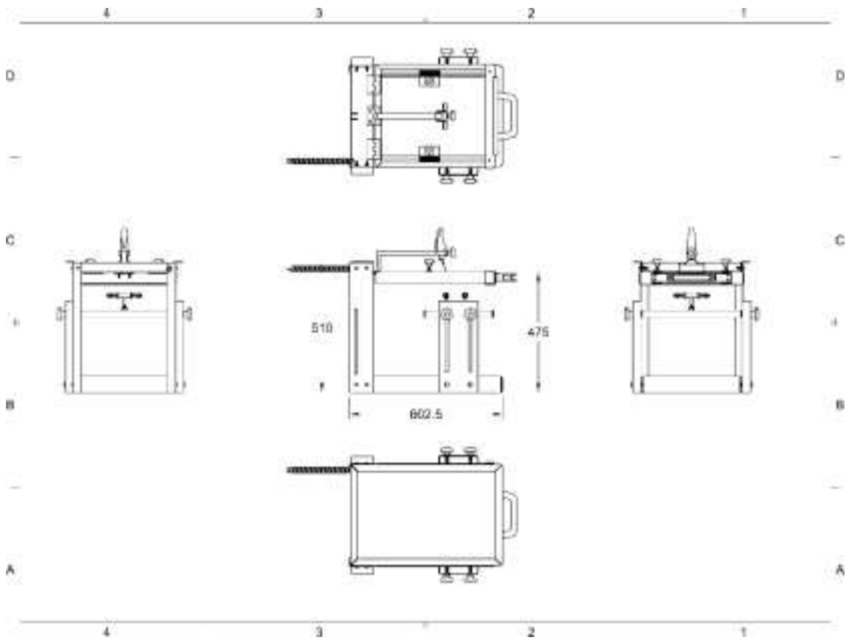


Figure 3.6: Schematic drawings of vital parts of the serigraphy printer

Source: Researcher 2021

To create a 2D drawing from a design in Fusion 360 that can be printed or exported.
The following steps were followed to create a 2D drawing from a 3D design:

1. Open the design.
2. Click Model and select Drawing from Design.
3. Select options in the Create Drawing dialog box. The drawing file can be created from a full assembly or individual components/bodies.
4. Select the appropriate drawing, template, standard, units, and sheet size options.
5. Use tools in the drawing workspace to place views and annotations in the drawing workspace.

Note: A drawing cannot be created with only sketch elements or surface bodies. The drawing will not auto-populate.

6. To Print or export the drawing, any of the two methods can be adopted:
   - Select File > Print and choose the preferred output format.
   - Select the OUTPUT drop-down on the toolbar ribbon and select the preferred output format.

Vol.9, No.3 pp.1-23, 2023
Print ISSN: ISSN 2059-1187,
Online ISSN: ISSN 2059-1195
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

Step-By-Step Design Process/Procedure

Gather all necessary data and information needed for the design of the system:

At this stage of the work the researcher brought together all the design data needed for the fabrication work from his sketches to the computer application drawings and followed them step by steps to complete the set objective as shown in Fig. 3.5, and Fig. 3.6 respectively

Fig. 3.7 shows the rollers drawing for printing curved surfaces and 3.8 reveals the positioning of the squeegee while printing on curved surface. Figs. 3.9, 3.10, & 3.11, show the mesh and how its holder looks like with their dimensions.

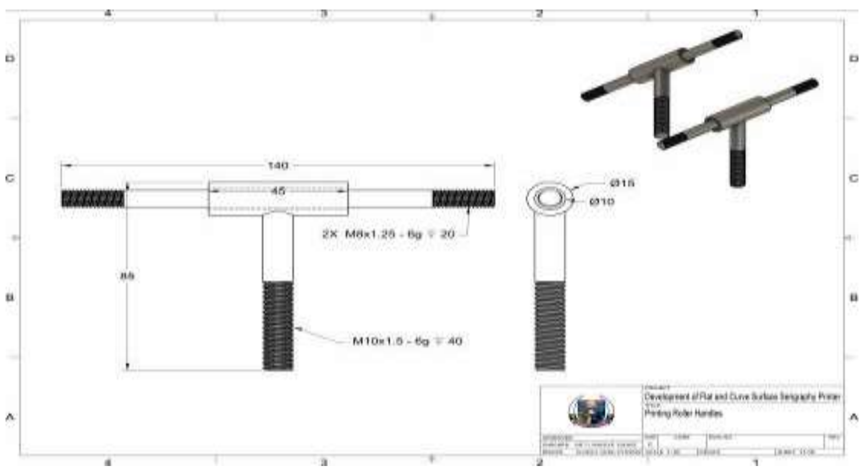


Figure 3.7: Detailed Drawings of the roller holder for the printer with dimension

Source: Researcher (2021)

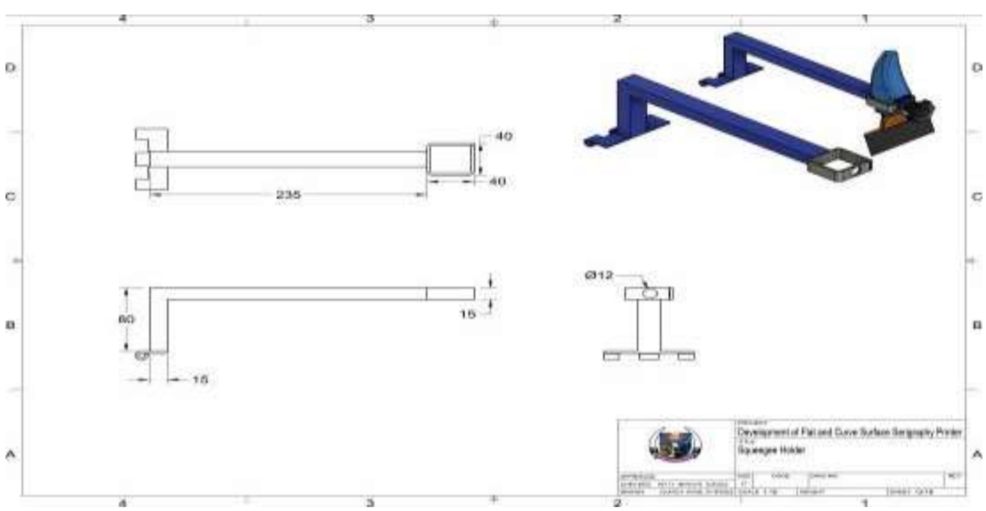


Figure 3.8: Detailed Drawings of the printers' squeegee and the holder

Source: Researcher (2021)

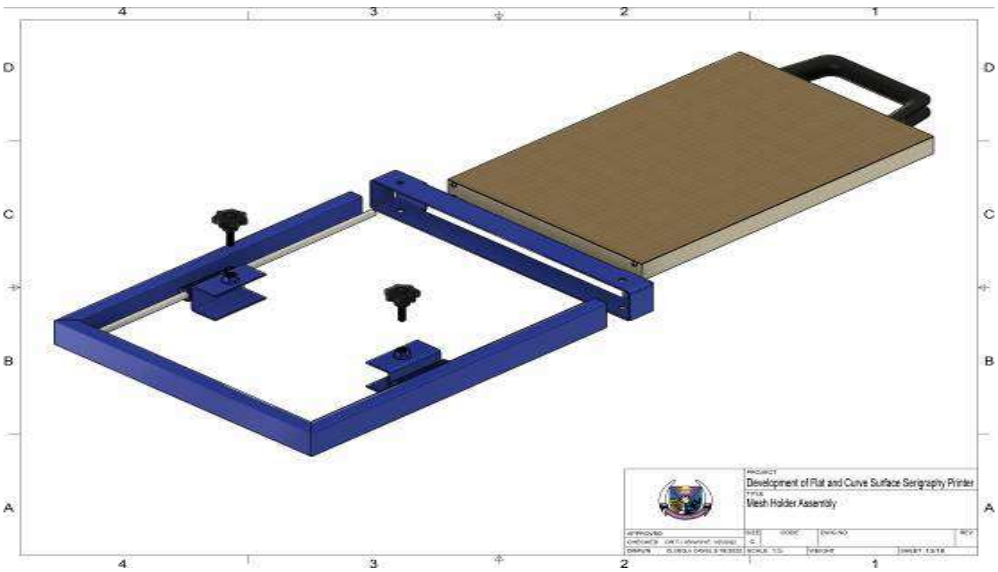


Figure 3.9: Drawings of the mesh and the holders in frame for the printer

Source: Researcher (2021)

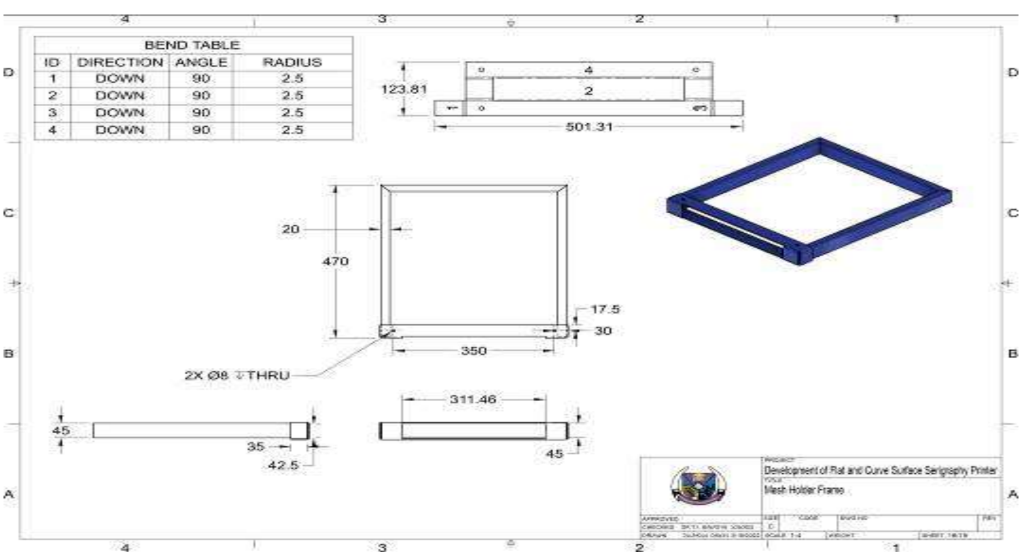


Figure 3.10: Detailed Drawings of the mesh holder for curved surfaces

Source: Researcher (2021)

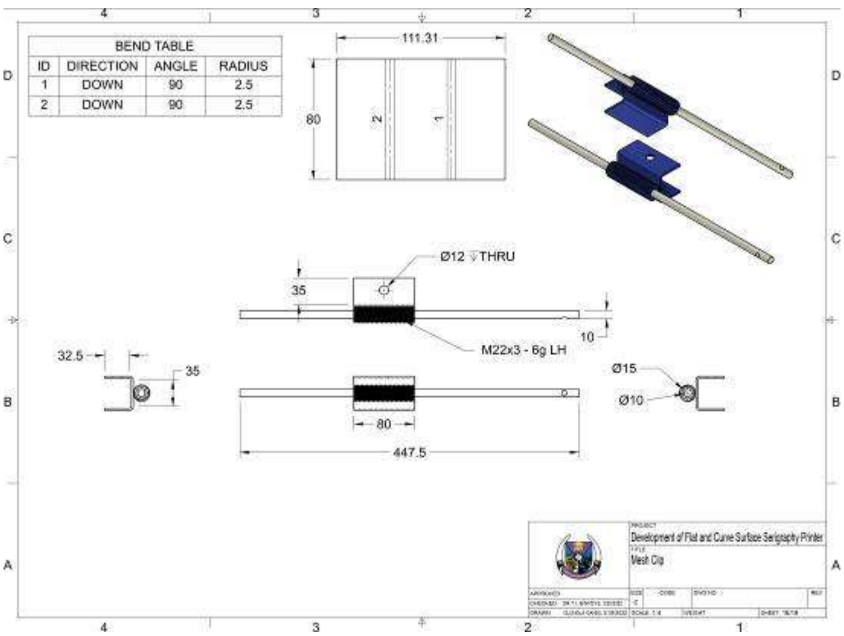


Figure 3.11: Detailed Drawings of the mesh holders with dimensions

Source: Researcher (2021)

RESULTS AND DISCUSSION

The result or outcome of the study is expressed in terms of the implementation of the design of the serigraphy printing machine. Following the design which generated a number of working drawings, the construction was able to follow a step by step procedure to fabricate the machine. Thereafter the discussion as to whether the result or outcome of the fabrication was able to address the objective set for the study is also followed.

The Construction/Fabrication Process (Stage B)

Rogers, (2001) states that the development of an innovation is the process of putting together a new idea in a form that is expected to meet the need of an expected audience or potential adopters. Fabrication process however represents a transformation of an invention into a form that will be more acceptable to potential adopters. Developing a serigraphy printer for curved and flat surfaces Using almost a hundred percentage locally sourced material was a labourious but interesting adventure. There are various aspects which require meticulous study, care was taken to understand the problems, and they were addressed accordingly.

The main processes involved in developing the serigraphy printer for curved and flat surfaces are highlighted as follow:

1) building of the body,
2) taking mold and casting of the knobs,
3) fastening of all the parts together,
4) spraying the component parts,
5) building of the rollers, squeegee & mesh, and
6) testing the serigraphy printer for curved and flat surfaces. The materials for creating various parts were selected taking such factors as weight, strength, turning and the like into consideration.

Step by step Approach to the Production of Serigraphy Printing Machine

1. Prepare and get all the materials such as metals, rods, and pipes for the machine design. As shown in plate 4.3 the researcher is obtaining rods and pipes from condemned shock absorbers, as they are known for strength. Plate 4.4 shows the selected plate that were used in constructing the machine, print table, and the body.

Plate 4.3: Smoothening of rods to form mesh rail   Plate 4.4: Marking out plates to be folded

Source: The Researcher's field work (2022)

Bend plates and drill holes for screwing instead of welding. The drawings in Figures. 3.5, 3.6, 3.7, 3.8, 3.9, 3.10 & 3.11 were used as guide for the bending, and drilling of holes on the selected plates as shown in Plates 4.5, 4.6, and 4.7. These folded and burrowed metal plates were used for the bend tables which and helped to achieve one of the desired objectives of the study.

International Journal of Vocational and Technical Education Research
Vol.9, No.3 pp.1-23, 2023
Print ISSN: ISSN 2059-1187,
Online ISSN: ISSN 2059-1195
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

Plate 4.5: Folding of the areas marked out accordingly

Plate 4.6: Drilling and smoothing of the metal plates before coupling

Source: The Researcher's field work (2022)

Bring all necessary components together and screw. The 3D drawing in Fig 4.1 guided the assemblage all the components of the machine

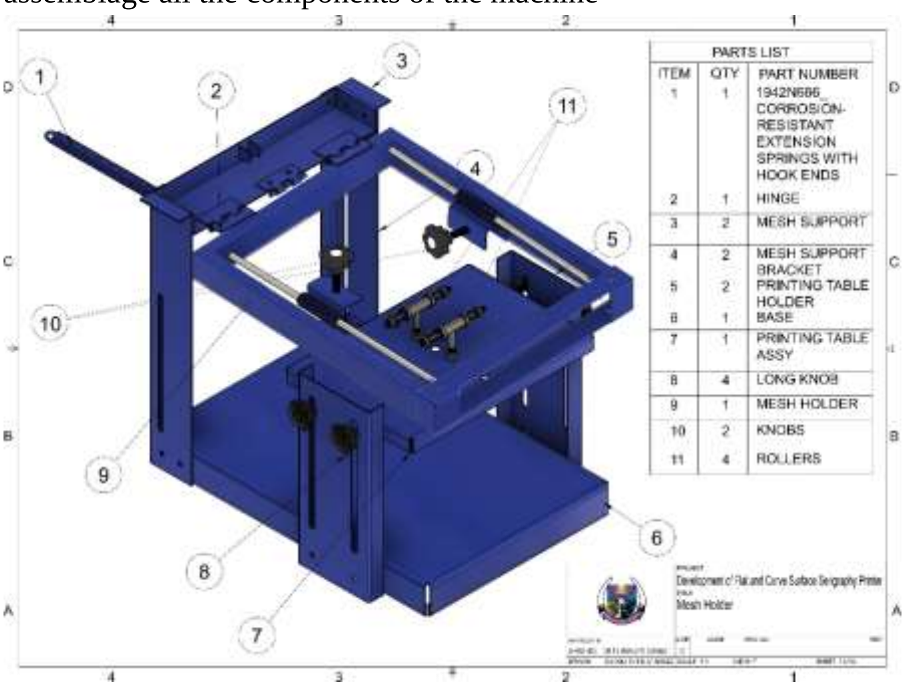


Figure 4.1: 3D Model of the Serigraphy Printer for flat and curved surfaces with labeling.

Source: Researcher (2021)

Plate 4.7: The base folded down accordingly
Source: The Researcher's field work (2022)

Plate 4.8: Assembling of all the components together accordingly
Source: The Researcher's field work (2022)

Plate 4.9: Smoothing the coupled machine Plate 4.10: Spraying the machine

Source: The Researcher's field work (2022)

Plates 3.8 and 3.9 show the smoothening process and spraying of the machine respectively.

Constructing, Evaluating and Test-running the final design.

Plate 4.11: Installation of the mesh and the substrate to print on.

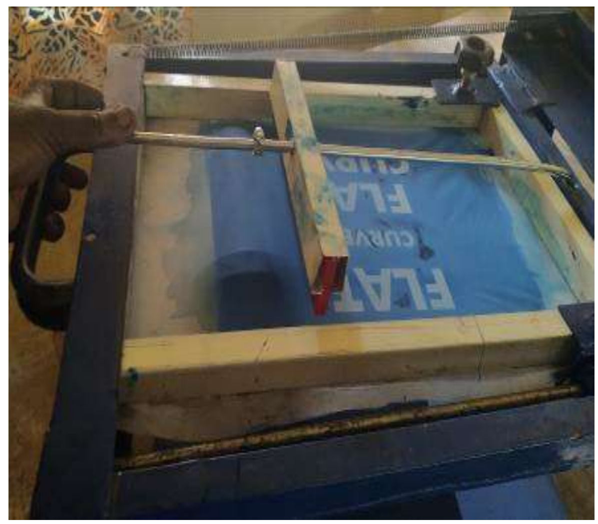


Plate 4.12: The aerial view of the installed mesh and the substrate to print on.

Source: The Researcher's field work (2022)

Evaluation

Major materials for the development of serigraphy machine were locally sourced, other materials that were not readily available such as the knobs were fabricated using locally sourced raw materials. The serigraphy printer was successfully designed to print on curved and flat substrates using special bearings as shown in Figure 4.1, Plates 4.6 & 4.8. Also, it is developed to work without electricity taking care of perennial power failure. The printing was effortlessly done on both curved and flat substrates, and the prints came out successful without rough prints. This makes the fabrication and evaluation a successful one having fulfilled the objective of the research.

Plate 4.13 Mixing Resin, catalyst and direct image tonner waste to form knobs

Plate 4.14: Purring already mixed resin, catalyst and direct image waste in the mould

Source: The Researcher's field work (2022)

Plate 4.15: The Knobs formed from the mould

Source: The Researcher's field work (2022)

Performance Evaluation

After the design and fabrication of the machine, the workability, performance and speed of the machine was examined to ensure that the prints are seamless according to the design analysis. The machine was tested and evaluated as shown in Plates 4.16 and 4.17. The result obtained with the condition under which the machine was evaluated was very good. Thus, the machine could be adjudged to have successfully fulfilled the purpose for which it was designed.

International Journal of Vocational and Technical Education Research
Vol.9, No.3 pp.1-23, 2023
Print ISSN: ISSN 2059-1187,
Online ISSN: ISSN 2059-1195
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development-UK

Plate 4.16: The view of a successful of print on curved surface from the mesh

Plate 4.17: The display of the printing on Curved surface from the mesh

Source: The Researcher's field work (2022)

It is important to state again that the main objective set for the study was to use locally sourced materials to design and produce a serigraphy printing machine that can print on both curved and flat surfaces. The target was designing the machine to print on curved and flat substrates, and whether the objective was realised or not was predicated upon the evaluation of the test-prints done with the printer both on curved and flat surfaces. The results however showed that the printer printed excellently on both the curved and flat surfaces, see Plates 4.16 & 4.17.

Configuring the Flat and Curved Surface Printer to perform dual operation will not be out of place to print on products such as a variety of plastic, glass, metal materials made of cylindrical, conical shape products, including wine bottles, medicine bottles, cosmetics bottles and other packaging bottles, mugs, thermos mugs, beer mugs, red mugs, cloths and so on. Glass tube, pen, ballpoint pen, fishing rod, bat and other small cylindrical products were painstaking observed and developed by working with turner to precisely turn the rollers and setting the bearing appropriately. Objective three could therefore said to be achieved as stated.

CONCLUSION

The main findings of the study were that the locally designed and produced serigraphy machine was able to print on both the curve and flat surfaces without rough prints. This is a novel feat, as most of the available portable serigraphy machines either print on flat or curved surface. The other notable achievement by this study was that the rough prints that often characterise some curved surface prints were eliminated, and finally, as set out by the study, the design and construction were done locally using locally sourced materials. The study therefore recommends that the "Serigraphy Printer for Curve and Flat Surfaces" be adopted by the local printers to enhance their occupation, and also by schools and vocational training centres to aid teaching.

REFERENCES

Adeyeye, O. (2020). "Evaluation of Developments in Offset Lithography Printing Industry in South West Nigeria". (Ph.D. Seminar)

Adu-Akwaboa, S. (1994) "Art for Schools and Colleges", Kumasi Samarg Publications, p70

Anisic, Z., Krsmanović, C. (2008). Assembly initiated production as a prerequisite for mass customization and effective manufacturing, Strojniski vestnik - Journal of Mechanical Engineering, vol. 54, no. 9, p. 607-618.

Baines, J. (2019). "A History of Screen Printing: Tracing Our Industry's Roots". Oxford: Oxford University Press.

Bozickovic, R., Radosevic, M., Cosic, I., Sokovic, M., Rikalovic. A. (2012). Integration of Simulation and Lean Tools in Effective Production Systems – Case Study, Strojniski vestnik - Journal of Mechanical Engineering, vol. 58, no. 11, p. 642-652, DOI: DOI:10.5545/sv-jme.2012.387.

Daniel, O. O., Haruna, A. A. and Atanu, B. U. (2009). "Lithographic Plate and Serigraphic Mesh Making Machine". p. 10, 12, 27

Gbadegbe R. S. (2017). "A Portable T-Shirt Printing Machine". Journal of Art and Design Studies.

Habib Alshuwaikhat (2021) "Problems of Implementation of Urban Development Plan in Developing Countries" King Fahd University of Petroleum & Minerals

Hernandez, R. (2003). Systematik der Wandlungsfahigkeit in der Fabrikplanung. VDI Verlag, Dusseldorf. (in German)

Ifeanyi O. D, Ogunode N. J. and Ajape T. S. (2021). Shortage of funds in the Nigerian Public Universities: causes effects and ways forward. Innovative Technologica Methodical Research Journal, Vol. 2 issue 7

Kacharel, S. A. (2016). Pneumatic Multicolour Screen-Printing Machine**.** *International Journal for Scientific Research & Development*. Vol. 4, Issue 03

Kusar, J., Berlec, T., Zefran, F., Starbek, M. (2010). Reduction of machine setup time. Strojniski vestnik - Journal of Mechanical Engineering, vol. 56, no. 12, p. 833-845.

Laura, M. (2016). "Leicester Print Workshop" Architectural Journal of Research and Development. Vol. 10, Issue 06

Lukka, K. (2000) The Key Issues of Applying the Constructive Approach to Field Research. In proponent, T. (ed.) (2000) Management Expertise for the New Millennium. In commemoration of the 50th Anniversary of the Turku School of Economics and Business Administration. Publication of the Turku School of Economics and Business Administration, A, 2000, 113-128

Luke, G. (2022). "Research and Market Challenges for the Printing Industry". Global Industry Analysis Inc, Guinness Centre Taylors Lane, Dublin 8, Ireland.

Nyhuis, P., Heinen, T., Reinhart, G., Rimpau, C. (2008). Wandlungsfähige Produktions systeme. Werkstattstechnik, vol. 98, no. 1/2, p. 85-91. (in German)

Palcic, I., Buchmeister, B., Polajnar, A. (2010). Analysis of innovation concepts in Slovenian manufacturing companies. Strojniski vestnik - Journal of Mechanical Engineering, vol. 56, no. 12, p. 803-810.

Raizman, D. S. (12 November 2003). https://books.google.com/books/about/History Of Modern Design. html?id = fkZJAQAAIAAJ The History of Modern Design', Pearson. (isbn|978-0131830400).

Reinhart, G., Berlak, J., Effert, C., Selke, C. (2002). Wandlungsfähige Fabrikgestaltung. Zeitschrift für wirtschaftlichen Fabrikbetrieb (ZWF), vol. 97, no. 1/2, p. 18-23. (in German)

Rogers, E. M. 2001. International Encyclopedia of the Social and Behavioral Sciences

Sam, K. (2020): "Print Expo 2020" Innovations in Raw Materials Research for Local Serigraphy Production, www.printexponigeria.org/wednesday/mar 4.

Tomaz, B., Janez, K., Lidija, R., and Marko, S., (2013) "Selecting the Most Adaptable Work Equipment" Journal of Mechanical Engineering, vol. 3, Issue 1.

Ukazu, I., 2022 "Why fine art education is struggling and needs an overhaul" Institute of Management and Technology (IMT), Enugu State.

Wiendahl, H.P., Reichardt, J., Nyhuis, P. (2009). Handbuch Fabrikplanung: Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktions stätten, Hanser Verlag, München. (in German), DOI:10.3139/9783446423237.