Journal of Inventive Engineering and Technology (JIET)
ISSN: 2705-3865
Volume-4, Issue-2, pp-43-51
www.jiengtech.com
Research Paper Open Access

Development of Working Drawings: Machine Design Perspective

Nwoke, O.N.[1*], Ndubuisi, P.D.I.[2], Okoro, U.I.[3], Igwe, L.U.[4], Alum, J.O.[5]

[1,2]Department of Mechatronics Engineering Technology, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria
[3]Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria
[4,5]Department of Mechanical Engineering Technology, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria

***Corresponding author: obinnanwk@yahoo.com**

ABSTRACT: *Machine design and equipment building has come to stay with man, and relevant technologies involved in the actualization of daunting tasks of machine design can only diversify in scope. This communication focuses on beaming light on functional engineering drawing as an essential means of technical communication in machine elements design, equipment design, and design implementation protocols via computer-aided design (CAD) technology; and by extension, the paper serves as a regimented scheme for the organization of most mechanical and mechatronics systems designs along with their CAD model outputs, offering valuable insight into generic design documentation of mechanical plants and sophisticated systems. Proficiency in handling CAD tools and its significance in research and development of creative technological outputs are summarily underscored as a factor which has the capacity of unlocking innovative potentials of engineering personnel that would drive accelerated technological leaps for improved and sustainable national development. In this contribution, a review of the varied classes of design is presented; criticality of 3D solid modeling is expounded; elements and key features of quality machine drawing are adumbrated; and a guideline that fosters clarity of machine configuration is marshaled out with illustrative scenarios.*

KEYWORDS*: 3D modeling, CAD, Machine building, Machine design, Working drawing.*

Date of Submission: 04-11-2023 Date of acceptance: 07-11-2023

I. INTRODUCTION

"A good design with bad presentation is doomed immediately; but a bad design with good presentation is doomed eventually" is a dictum in engineering design practice.

The above statement implies that accurate presentation of a design is crucial as it determines, to a large extent, acceptability of the design and overall success of machine design implementation and project delivery. In the academia, projects are undertaken by scholars with a view to contributing to knowledge thereby expanding knowledge-base and increasing its horizons and frontiers. The knowledge when harnessed and properly developed would lead to productions that would satisfy specific human needs.

Machines assist man in undertaking laborious and time consuming tasks in no mean dimensions; hence, continuous development of new designs of equipment and modification of existing models would suffice so long as improved performances of machines, more economic methods of production, and lower operating running costs are envisioned. Configurations of machines and various equipment are conveyed to machine building workshop operators via "working drawings". No word language can convey details of a machine design effectively, accurately, and concisely like its engineering graphics, of which computer aided design (CAD) has taken the centre stage due to its unmatched ubiquity (Nwoke et al, 2018). Readability and clarity of

www.jiengtech.com. All Rights Reserved. 2023.

such drawings are dependent upon so many factors amongst which 'Complexity of the equipment' is a key determinant.

Extensive study on the importance of drawing during the process of mechanical design was undertaken by Ullman, Wood, and Craig (1990) and their finding predicted continuing necessity for CAD tools, demonstrated positive trajectory cum outcome for CAD based engineering tasks, and posited requirements for future computer aided design tools and graphics education, including development of artificially intelligent CAD tools designed to give cognitive support to the designer.

Common streaks that runs through separate works of Craig (2010); Crawford (2018); French and Vierck (1970); Luzadder (1977); Ullman, Dietterich, and Stauffer (nd); and Brown (2000) are that efficient machine design protocols and proficient product development lines are critical components of viable technology-based economies. Robust technological platform is said to underpin the development of products, processes and systems that ensure human progress and wellbeing. CAD remains pivotal in the attainment of various technological feats and breakthrough witnessed in evolutionary and mind-bugling sophisticated machines and mechatronics systems.

Razzaq, Hasan, and Abbas (2021) explored how simulation derived model of Mechatronic machines could manage the most complex scheme of the machinery profile with a systematic approach by understanding the concept with precise machine design actions, dynamic behavior, and effective interaction with the various components of the machine. Razzaq et al concluded that mounting demands for machine tool product and their increasing technological complexity bring challenges for improved and innovative methods in the product development procedures, of which CAD has taken the centre stage.

An object of this paper is to present general guideline for the development and presentation of working drawings in a professional manner that would enhance better understanding of the machine configuration within shortest possible time while guaranteeing precise and efficient design implementation by the technical team. Pursuant to this objective, the following information should be captured on a typical working drawing for machine development: Title Block, Drawings, and Specifications (Joshua, 2023). Discussion on these key elements is expounded in section III of this presentation. It must be copiously reiterated that while implementing items and parameters of these key elements by the machine or mechanical system designer, central focus on **quality** of engineering drawing must be borne in mind. The yardsticks used in the definition of the overall quality of an engineering drawing according to Joshua (2023) are:

Accuracy: The drawing should accurately reflect the design intent and should not contain any errors.

Clarity: The drawing should be legible and understandable by all relevant parties, including end-users, engineers and manufacturing personnel.

Completeness: The drawing should include all the necessary information (dimensions, tolerances, notes, geometric definitions, etc.) to allow for successful product development, manufacture and assembly.

Consistency: The drawing should be consistent with industry standards and conventions and should be compatible with other drawings and documents; and

Simplicity: The drawing should be as simple as possible in order to minimize complexity, reduce costs and speed up product development.

In view of the quest to adroitly combine and manage the aforementioned indices for the production of quality engineering drawings, it has become pertinent to summarily review the different kinds of machine designs albeit briefly.

A. Dimensions of Machine Designs

Many mechanical designs and invention involves knowledge of various machine elements and an intelligent and creative combining of these elements into a component or assembly that fills a need. According to the works of Khurmi and Gupta (2005), Budynas and Nisbett (2010), Bhandar (2007), Rao (2013), Sharma and Purohit (2009), and Jack *et al* (2002), machine designs may be classified as rational design, empirical design, industrial design, optimum design, system design, element design, and/or computer aided design (CAD) regardless of whether the design is new, adaptive, or developmental in conceptual nature.

In most machine designs, rational and empirical design approaches (that is, aspects of designs that depends upon mathematical formulae from principles of mechanics and empirical formulae based on practice and past experience) serves as foundation for generating technical data for components and systems, under a given set of constraints. The derived technical data are used in developing the required CAD models. CAD, having taken the centre stage for modern design discussions shall be considered the tool of graphics development in the current work. In this context, further discussions on development of working drawings, vis-à-vis machine design, shall be centered on CAD modeling as the basis for the automatic or computer-assisted generation of model views required to actualize excellent and quality drawings for machine production purposes. In the light of the above, salient merits of 3D CAD modeling shall be *x*-rayed.

II. CRITICALITY OF 3D MODELING

Modeling in 3D has several advantages ranging from viewing of the model from any vantage point; automatically generating of orthographic projections of the 3-standard views and auxiliary 2D views of interest; automatic generation of sectioned views; creation of varied kinds of 2D and 3D drawings i.e., outline drawing (OL), OL with hidden lines visible, wireframe, realistic shading, etc; creation of realistic renderings; animation and motion studies; checking of interferences; extraction of manufacturing data; to virtual experimentation and failure analysis (i.e., Stress vs Strain, or Load vs Deformation analyses). If adroitly exploited, these advantages hastens the designers task delivery, increases his accuracy and productivity, leads to improved quality of drawing, facilitates easy design alterations, modification, and file sharing; and offers better design visualization through colors (Nwoke *et al*, 2018).

Machine designs could be very complex that even seasoned draughtsman may find it difficult to clearly understand some areas of the design from orthographic views alone. By using a 3D model, designers can view components and assemblies from any vantage point, quickly visualizing and appreciating their construction geometry and design intent. To increase clarity, graphic software makes it possible to zoom in close to a selected area of the model that may be crowded and confusing. There are tools for clipping, hiding, or changing of transparency of obstructing components, thereby improving perception and mitigating ambiguities. With this, it would be possible to see the inside of complex 3D solid models of mechanical systems thereby facilitating understanding of hidden features. With the creation of 3D model of a machine, virtual tour can be created, effects for rapid visualization implemented via material and colour assignment, interference between components detected, failure analysis conducted and potential failure prone zones forecasted professionally with exactitude.

CAD lends itself easily to reverse engineering (RE) technology of machines and mechanical systems, integrates well with flexible manufacturing systems, and is pivotal in the operation of 3D printing used in rapid prototyping (RP) schemes (Nwoke *et al*, 2021a; 2021b). These advantages put together makes 3D solid modeling of machines and mechanical systems worthwhile endeavor that results in tremendous time and cost savings as opposed to discovering and solving the problem later, say, after production or manufacturing.

III. EXTRACTION OF WORKING DRAWINGS

Working drawing refers to drawings for the proper construction (manufacturing, or production) of equipment. They are employed for the purpose of carrying out the various trades in accordance with the design, and for obtaining estimates of cost (Bhatt, 2012; Gill, 2013). Working drawings for machine development are usually extracted from 3D solid models of parts and assemblies. For the sake of clarity, development of working drawings of machines for effective workshop communication has a lot to do with the implementation of the following features in the guideline hereunder:

1) 3-Standard views: Outline drawing of Top/Plan view, Front/Approach elevation, and one other complementary elevation (Right or Left elevation/view) must be depicted in the graphic communication. The 3-standard views are essentially orthographic projections of the equipment. Model view of major components of an assembly should be depicted. Hidden details should be made visible for component drawing, and may be considered optionally for assemblies so long as readability will not be impeded. Wireframe or shaded/coloured display styles should not be considered here.

2) Dimensioning: Major dimensions (linear and angular) of features must be added; and chosen drawing scale indicated to enhance overall understanding of the drawing features within minimal time possible. Unit of

dimension (mm, inch, etc) should be legibly captured in the title block.

3) Annotation: Essential write-ups (e.g. title of elevations, views, names, revision notes et cetera) must be provided for reasons of good presentation and comprehension. Symbols of surface finish and tolerance for mating bodies/features may also be added where and when justified to improve clarity. Insertion of centre marks and centre lines where necessary is a good practice. Standard symbology should be adopted to minimize language dependence effect.

4) Axonometric views: Complex machine assembly drawings are often difficult to read if only 2D drawings are provided for workshop communication and machine production. Hence, 3D isometric views and other auxiliary views should be incorporated in the design package. Rendered or photo-realistic graphic images are often required as they facilitate smooth and seamless graphic communication of even sophisticated designs through visualization using colours.

5) Detail view: Details of tiny features of interest shall be provided. The object is to facilitate and enhance readability of tiny and obscured components, and ensure clear perception of clustered features or parts. Where standard parts are used (e.g. threaded fastners), ISO, METRIC or IMPERIAL designations for such parts should be provided.

6) Exploded view: Here, components parts of the machine assembly are separated from one another while maintaining their alignments. This has to be provided as a means of indicating relative positions of all components and sub-assemblies with respect to a fixed or reference component. Exploded view serves as an assembly guide. Field and industrial operators use same in dis-assembling/dismantling a machine during maintenance service or break-down repair operations.

7) Section view: Working drawings often incorporates sectioned views to ensure that enclosed components are revealed. This provides quick and direct access to the internal working mechanisms of the machine. This, as a matter of rule, must be incorporated into the design package, be it e-file or printed. Sectional views could be full, half, offset, revolved, removed, partial or broken section (Bhatt, 2012; Gill, 2013; Shah & Rana, 2009). With sophisticated 3D design software, this objective may be gotten by either changing transparency or outright hiding/clipping of the secluding parts.

8) Ballooned drawing: Ballooning of machine drawing facilitates swift components identification and makes reading easier as Bill of Material (BOM) is automatically generated for ballooned drawing, matching part (component) numbers with their names and probably their specifications and functions.

9) BEME: Bill of Engineering Measurements and Evaluations (BEME) is an essential part of design as cost burden of production of machines cannot be waived off knowing fully that it (i.e. manufacturing cost) represents a single critically significant factor that production managers rely upon for essential decision making. BEME is usually generated by incorporating columns of unit cost of items and amount into the auto-generated BOM.

10) Title block: This captures important information regarding each drawing such as Name of company or organization, job title, drawing number, date, name of designer or draughtsman, scale, copyright, projection symbol, measurement units, reference to standards, sheet number, number of sheets and issue information, according to Manual of British Standards in Engineering Drawing and Design (Parker, 1991). Material specification, tolerances, revision notes, and few other information may be optionally accommodated within the title block for a component (i.e., part) or light assembly drawing (Vardhan, 2021). This information helps in the overall organization of jobs done and provides track record of other essential details that may be needed for any post-design/post-manufacturing activity.

11) Specification: Specifications are the written documents that go with the construction documents and describe the materials as well as the installation methods. They consist of precisely written documentation that describes a project to be constructed, with supplementing drawings and qualities of materials. Material specification is an integral part of design (Meyer, 2002). In design, materials selection can be a complex, iterative process (Brett & Stork Technimet Inc., 2002). Through this document (specification), qualities of materials to be used must be specified categorically, alongside relevant design codes and standards (Kenneth,

2001; Rajput, 2015). This serves as backbone for excellent design implementation, and a reference document in the event of catastrophic failure and ensuing failure investigation or analysis.

12) Design Integrity Test (DIT): Analyzing failures is a critical process in determining the physical root causes of problems. The process is complex, draws upon many different technical disciplines, and uses a variety of observation, inspection, and laboratory techniques (James et al, 2002). Early assessment of resilience of load bearing structures of a designed mechanical system could be useful in guarding against certain failure modes by defining allowable stresses and placing limits on working loads.

Computer-based simulation results of parts and assemblies of the designed machine is often required in modern design technology to insure that stresses, strains, and deformations suffered by the system under contemplated service conditions does not exceed allowable limits. This kind of virtual experimentation provides first-hand assessment of system load versus deformation characteristics. To guard against abuse of machine and concomitant failure, a suitable factor of safety (FOS) must be applied.

Fig.1 depicts an orthographic projection of a rotodynamic pump in 3rd angle projection. Here, standard 3 views are captured in addition to an isometric view. Encumbrances of the machine can easily be seen from the 3 principal dimensions indicated. In Fig.2, the piezo-electric burner and oven rack may not be copiously visible even with the partial opening of the gate. With appropriate scaling, well-visible detail of components can be provided as shown in Detail A.

Fig.3 is illustrative of a design explosion scheme using a knuckle joint assembly scenario. Ballooning of a machine drawing portrayed in Fig.4 is essentially useful for parts listing, machine descriptive essay and assay, and other technical and cost related significance. Sectioning, typically represented in Fig.5, is of strong engineering significance to machine designers and equipment building engineers, as far technical communication of machine configuration is concerned. Sectioning of 3D components and assemblies is also possible as seen in Fig.8 wherein a 3D assembly of a one-directional flow valve is sectioned in contrast to the sectional view implemented for the orthographic drawing of Fig.5.

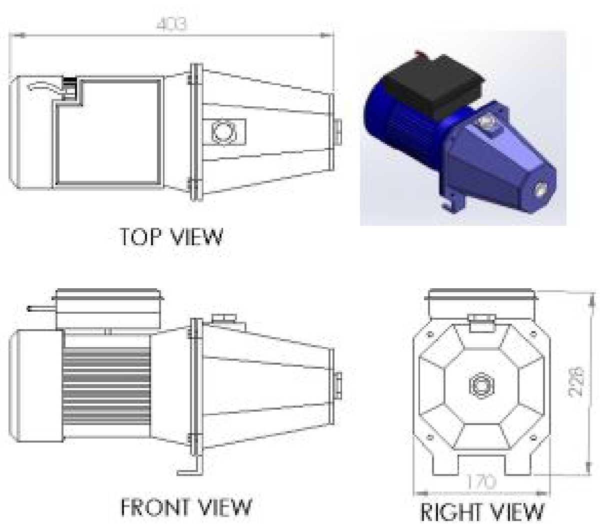


Fig.1: Standard 3 view of a rotodynamic pump

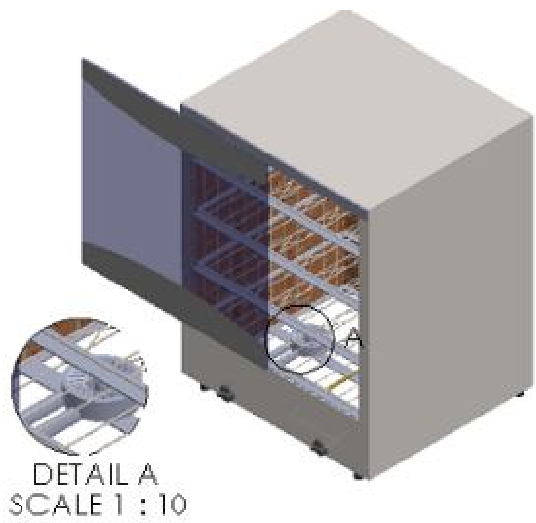
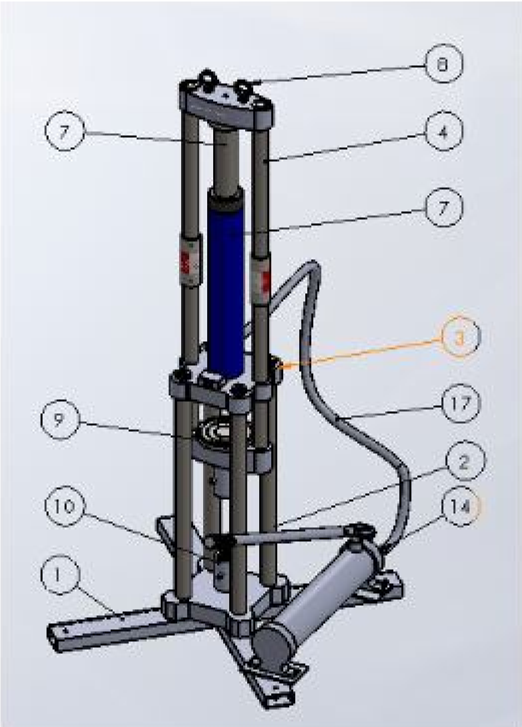


Fig.2: Detail view



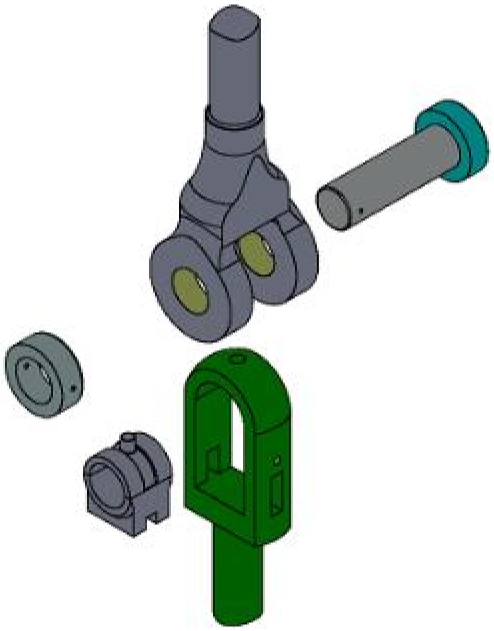


Fig.3: Exploded view of a knuckle joint assy *Fig.4: Ballooned Drwg of a UTM*

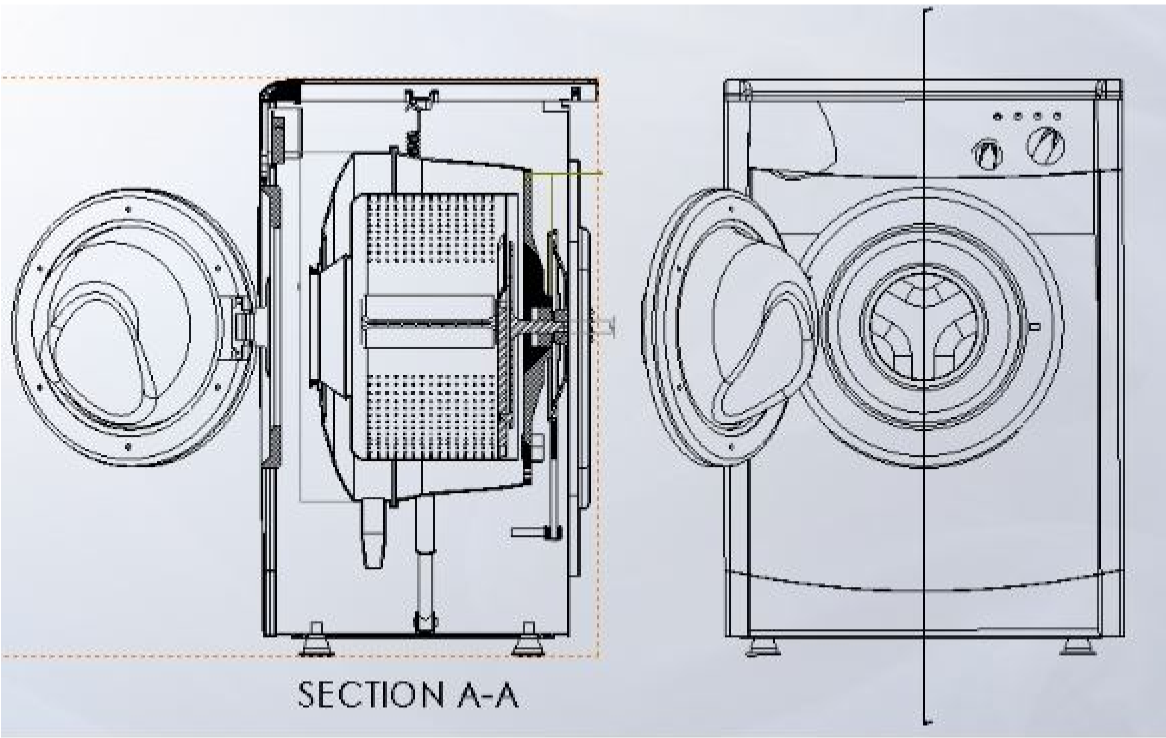


Fig.5: Sectioned view of a front loader washing machine

In Fig.6, two (2) covering panels are suppressed or hidden to reveal arrangement of the internal components of the model automatic hand washing machine. Figs. 5, 6, and 8 permits gaining insight to hitherto obscured components of the referenced machines. Fig.7 depicts a typical result of Finite Element Analysis (FEA) obtained via Load versus Deformation simulation on a designed blade of a turbo-machine. Virtual experiments

www.jiengtech.com. All Rights Reserved. 2023.

of this nature are accurate, reliable, and are widely deployed in hi-tech system designs. A very important aspect in teaching CAD is the choice of software (Asperl, 2005; Field, 2004; and Terence et al, 2018). Conversely, choice of suitable software for specific application area(s) in diverse fields of mechanical design would assist the designer in maximizing the benefits of CAD. Hence, deployment of suitable context-sensitive, high-definition graphic software packages with simulation capabilities to the design of efficient layout of manufacturing processes and machine design tasks could ultimately lead to more economical product manufacturing (Sharma, 2007; Ronald, 2012).

From the foregoing discussion, it would be inferred that well-articulated and packaged drawing of a machine, equipment, or a mechanical system is essentially useful in ensuring continuity of machine production even when the designers and original workshop men are 'gone'. Such document ensures consistency in quality of production of machine elements and machinery; and facilitates rapid design alterations that may lead to overall improvements in machine performance or improved industrial design concerned with optimization of production line.

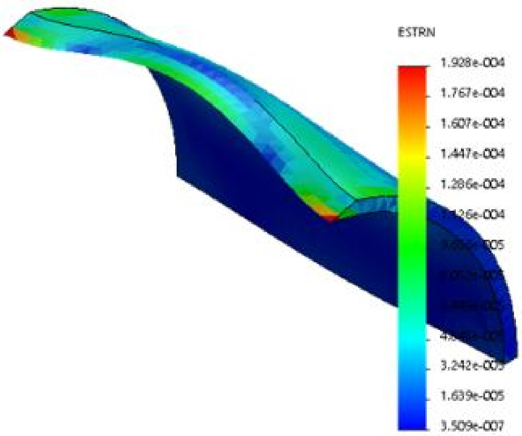


Fig.6: Hand washing machine *Fig.7: Excerpt of Load simulation result*

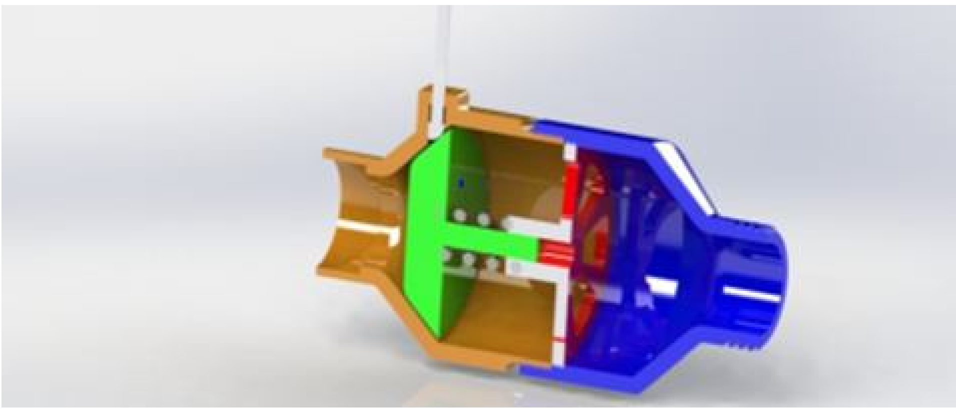


Fig.8: Sectioned view of a 3D Assembly of a One-Directional Flow Valve

www.jiengtech.com. All Rights Reserved. 2023.

IV. CONCLUSION

Creation of machine design is an arduous task that requires creativity, rational thinking and well-balanced judgment in addition to sound inter-disciplinary versatility as mechanical engineering designs are often ingrained and interwoven in many innovations and challenges in many fields. Machine manufacturing or Production Company would loose sight of critical machine details on the event of incapacitation, dismissal, resignation, or death of a design engineer if well-organized, robust and comprehensive equipment details are not documented. Hence, the informed need to develop well-encompassing machine drawings that would be easily interpreted and implemented in a case of any of the aforementioned eventualities. Results of CAD dependent engineering studies, including but not limited to virtual experiments, simulation, and machine performance studies, when subsumed in the designed package forms an embodiment of necessary details for future referencing, either within the industry or by scholars in the academia.

References

Asperl, A. (2005). How to teach CAD: Computer-Aided Design and Applications. *International Journal of Educational Technology in Higher Education, 2*(4), 459–468.

Bhandar, V.B. (2007). *Design of Machine Elements*, Tata McGraw Hill.

Bhatt, N.D. (2012). *Engineering Drawing*, Charotar Publishing House PVT LTD, 313-350.

Brett, A.M, & Stork Technimet Inc. (2002). Materials Selection for Failure Prevention *in ASM Metal Handbook Vol 11*. ASM International Metals Handbook, USA, 65-99.

Brown, J.K. (2000). Design Plans, Working Drawings, National Styles: Engineering Practice in Great Britain and the United States, 1775-1945. *Technology and Culture*, 41(2), 195-238. Available from: The Johns Hopkins University Press. https://www.jstor.org/stable/25147498

Budynas, R, & Nisbett, K. (2010). *Shigley's Mechanical Engineering Design* (9th ed). McGraw Hill Series.

Craig, K. (2010). Fundamental Principles of Mechanical Design. https://mae.ufl.edu/designlab/DFMA%20Tips/Fundamental_Design_Principles_KCraig.pdf; [accessed 18 February 2023], 1.

Crawford, J. (2018). Five machine design challenges and how motion controls help, Thomson industries Inc. https://www.controleng.com/articles/five-machine-design-challenges-and-how-motion-controls-help/

Field, D.A. (2004). Education and training for CAD in the auto industry. *Computer-Aided Design, ScienceDirect (Elsevier), 36*(14), 1431–1437.

French**,** T.E, **&** Vierck C.J. **(**1970**).** Graphic Science & Design. https://www.amazon.com/Graphic-Science-Design-Thomas-French/dp/0070223017.

Gill, P.S. (2013). *A Textbook of Machine Drawing*. Katason Books, New Delhi, 401-406.

Jack, A.C., Henry, R.B., & George, H.S. (2002). *Mechanical Design of Machine Elements and Machines: A Failure Prevention Perspective* (2nd ed), Willy.

James, J.S., Massachusetts Materials Research Inc., William, J. M, & ALTRAN Corporation. (2002). Introduction to Failure Analysis and Prevention *in ASM Metal Handbook Vol 11*. ASM International Metals Handbook, USA, 14-64.

Joshua, N.A. (2023). Requirements of Engineering Drawings. https://www.joshuanava.biz/engineering/requirements-of-engineering-drawings.html;

Kenneth, G.B. (2001). Engineers' Guide to Technical Writing. ASM International Materials Park, OH 44073, USA, 96-100, 146-149.

Khurmi, R.S., Gupta. J.K. (2005). *A textbook of machine design*. Pvt. ltd, New Delhi, 16-50, 181-196.

Luzadder, W.J. (1977). *Fundamentals of Engineering Drawing for Design, Product Development, and Numerical Control* (7th ed). Prentice-Hall.

Myer, K. (Ed.). (2002). Handbook of Materials Selection. John Wiley & Sons Inc., 4-14, 705-809.

Nwoke, O.N., Ndubuisi, P.D.I, & Mbabuike, I.U. (2021:b). Reverse Engineering and Prototyping of a Modern Laundry Machine. *Proceedings of the 3rd School of Engineering Technology Conference and Exhibition (SETCONF), Akanu Ibiam Federal Polytechnic, Unwana*, 144 – 155.

Nwoke, O.N.**,** Okoli, O.S., Okokpujie, I.P., & Okoro, U.I. (2018). Criticality of Computer Aided Design Packages in Engineering Education & Professionalism for the Developing Countries: Issues and Perspectives. *2nd Biennial School of Engineering Technology Conference and Exhibition, Akanu Ibiam Federal Polytechnic, Unwana*, 390 - 400**.**

Nwoke, O.N., Okoro, H.O., & Uche, N. (2021:a). Design of a Mechanically Driven Sprayer for Weeds and Pests Control in Farms. *Proceedings of the 3rd School of Engineering Technology Conference and Exhibition (SETCONF), Akanu Ibiam Federal Polytechnic, Unwana*, 107 – 114.

Parker, M.A. (1991). Manual of British Standards in Engineering Drawing and Design. British Standards Institution in Association with Stanley Thornes, Cheltenham England.

Rajput, R.K. (2015). A Textbook of Material Science & Engineering. Katason Books, New Delhi, 271-322, 401-406.

Rao, T.K. (2013). *Design of Machine Elements* (vol. II: 2nd ed). I K International Publishing House.

Razzaq, H.Y., Hasan, H.M., & Abbas, K.R. (2021). Machine Design Modern Techniques and Innovative Technologies. Journal of Physics: *Conference Series IOP Publishing Ltd.* doi:10.1088/1742-6596/1897/1/012072

Ronald, A.K. (2012). Interaction of Materials Selection, Design, and Manufacturing Processes. John Wiley & Sons, Inc., New York.

Shah, M.B, & Rana, B.C. (2009). *Engineering Drawing*, Pvt Ltd, 250-269.

Sharma, C.S, & Purohit, K. (2009). *Design of Machine Elements*. PHI Learning.

Sharma, P.C. (2007). A Textbook of Production Engineering (Manufacturing Processes). S. Chand & Company Ltd. ISBN: 81-219-1114-1

Terence, M.S., David, A.M., David, P.M. (2018). *AutoCAD and Its Applications* (25th Ed.). The Goodhearth-Willcox Co., Inc. ISBN: 978-1-63563-061-9.

Ullman, D.G., Dietterich, T.G., & Stauffer, L.A. A model of the mechanical design process based on empirical data. *Artificial Intelligence for Engineering Design Analysis and Manufacturing*, 2(1), 33 – 52. Available from: https://www.researchgate.net/publication/231873874_A_model_of_the_mechanical_design_process_based_on_empirical_data [accessed 28 April 2023].

Ullman, D.G., Wood, S., & Craig, D. (1990). The importance of drawing in the mechanical design process. *Computers and Graphics*, *14* (2), 263-274. DOI: 10.1016/0097-8493(90)90037-X.

Vardhan, M.V. (2021). Machine Drawing, https://vardhaman.org/wp-content/uploads/2021/03/MACHINE-DRAWING.pdf . [accessed 13 April 2023].

Zienkiewicz, O.C., Robert, L.T., & Zhu, J.Z., (2013). The Finite Element Method: Its Basis and Fundamentals. Oxford: Elsevier Butterworth-Heinemann and "The Essentials of CAD/CAM/CAE" www.machine design.com.