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Advancements in Single-Stage Capacitive AC-Link AC-AC Power Converter Technology

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Abstract—A single-stage three-phase ac-ac converter benefiting from a high frequency alternating link voltage is proposed in this paper. In this converter, a very small film capacitor can transfer the energy from the input to the output, owing to the high frequency alternating voltage of the link. This eliminates the need for large electrolytic capacitors that are typically used in dc-link ac-ac converters. Moreover, a compact high frequency transformer at the link can replace the bulky low frequency transformers, in case isolation is required. These features increase the power density as well as reliability of the proposed converter in comparison with the conventional dc-link converters. The number of required switches in the proposed converter is 12, which is less than the number of switches needed in matrix converters, leading to lower switching and conduction losses. Despite being single-stage, the proposed ac-ac converter is capable of both stepping up and stepping down the voltage and also frequency transformation. This eliminates the need for using cascaded power converters. In this paper, the operation principles of the proposed ac-ac converter are investigated, and variable switching frequency and fixed switching frequency control methods for operating this converter are introduced. The performance of the converter is verified through simulation and experiment.
Index Terms—ac-ac converter, high frequency link, solid state transformer.

1. INTRODUCTION

Three-phase ac-ac converters are the key elements in variety of applications such as wind power generation, solid state transformers (SST), and industrial motor drives, where downtime costs are significant, and reliability is highly demanded [1, 2]. Different three-phase ac-ac converter topologies have been proposed in the literature. These converters can be categorized as single-stage and two-stage conversion systems. In a two-stage ac-ac converter, the power is transferred through a large energy storage component, which is a capacitor or an inductor, forming the dc link in these converters [3]. In low voltage systems, a two-level back-toback converter is usually employed, which includes a rectifier and a two-level voltage source inverter as the first and second stages of the converter, respectively [4]. In case the bidirectional power flow is desired, a PWM rectifier can be adopted for the first stage, which can draw sinusoidal currents from the ac source [5]. Typically, the dc-link energy storage element used in two-stage converters has a relatively large physical volume in comparison with the total volume of the converter, leading to low power densities. More importantly, electrolytic capacitors have high rate of failures, which

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lower the service lifetime of the converter [5]. Electrolytic capacitors are very sensitive to temperature and their failure rates increase significantly at higher temperatures [6]. To eliminate the large dc-link components, single-stage ac-ac power converters can be used. These converters can be direct, in which the input power is directly transferred to the output, or indirect, in which the input power is transferred to the load through a small energy storage. Matrix converters are among direct single-stage ac-ac converters. High power densities can be achieved in matrix converters, where the ac-ac conversion is accomplished without using a large energy storage component [7]. In these converters, the ac power is directly transferred to the output side, which can be a three-phase load or a motor. The major weak point in these types of converters is the limited output to input voltage ratio and the large number of semiconductor switches [6, 7]. A number of modified configurations, as presented in [8], address these issues, but inevitably the input power quality is deteriorated at the expense of output drive capability. High power density and elimination of energy storage element is achieved in matrix converters at the expense of large number of semiconductors, high switching and conduction losses, and complex control. Other than these two major families of ac-ac converters, other topologies can also be found in the literature. Recently, considerable amount of effort has been devoted to developing ac-ac converters with small number of switches, among them is the converter proposed in [9]. In this converter, six switches are employed in two switch legs as well as one leg consisting of three series dc electrolytic capacitors operating as the dc-link energy storage component. Although the number of switches is reduced in this converter, the voltage balancing strategy for the three capacitors in the dc-link can be a major problem.

2. LITERATURE SURVEY

In [10], a bidirectional PWM buck-boost ac-ac converter is proposed with only six switches, however, it needs three inductors as energy transferring elements. In [11], a unidirectional threephase ac-ac converter is proposed that combines three singlephase three-leg ac-ac converters. Although this converter has the advantages of multilevel input and output voltages as well as low THD of the currents, it still requires three large dc-link electrolytic capacitors. In [12], a T-type family of ac-ac converters is proposed, which is able to directly perform the acac conversion in a single-stage, and realize a modular converter for reducing the voltage stress of the switches. However, in the three-phase structure, the control algorithm is complex and the converter needs 36 switches, leading to higher losses. Resonant ac-ac converters have been proposed in [13-16] as an alternative to the conventional dc-link converters. These converters utilize a high frequency link to introduce zero voltage or zero current switching transitions. Since the link inductor and capacitor in these types of converters need to continuously resonate, high reactive rating for the link components is required, which leads to higher power losses in the ac-link. Another type of ac-link converter is proposed in [17], which utilizes 24 reverse blocking IGBTs (RB-IGBT) and benefits from zero voltage switching for the output-side switches. However, this converter cannot operate properly without a transformer. Also, the input and output currents of this converter do not have pure sinusoidal waveforms. In [18], a three-phase PWM Ćuk ac-ac converter, which requires six switches and three capacitors as energy transferring elements, is modeled and analyzed; the voltage gain is reported to be limited to 2.5. The Ćuk-based converter proposed in [18], is modified in [19] such that the three switches at each side of the converter are replaced by a diode bridge and a switch, which reduces the switch count of the converter. Although the number of switches in the Ćuk-based ac-ac converters proposed in [18] and [19] are small, they require three capacitors for transferring energy. Also, these converters are not capable of frequency transformation, which is a major drawback, and limits their applications. Universal power converters are another class of single-stage power converters that eliminate the need for large electrolytic capacitors. These converters are typically categorized as indirect single-stage converters in which a small energy storage component transfers the power from input to output. Additionally, in most universal converters, galvanic isolation can be provided through a single-phase high frequency transformer added to the link. These converters, which can have any number of sources and loads with any forms, any number of phases, any frequency or voltage amplitude, extend the principles of the operation of indirect dc-dc converters to multiphase systems. The converter proposed in [20], extends the operation of the dc-dc flyback converters to function as a threephase ac-ac conversion system. Although this converter needs only six active devices to perform the three-phase ac-ac power conversion, the ratings of the switches are high and three individual single-phase transformers are required. In [21], the principles of the operation of a dc-dc buck-boost converter was extended to a three-phase ac-ac converter. Similar to the conventional dc-dc buck-boost converter, an inductor transfers the power from input phases to output phases of this converter, and the switches have hard switching. In [22], a capacitor was added to the link of the universal buck-boost converter to allow the switches to benefit from zero voltage turn-on and soft turnoff. There are four modes in each switching cycle of this converter, during the first mode the link inductor is charged from one of the input phase pairs, and in mode 3 it is discharged to one of the output phase pairs. Modes 2 and 4 are resonating modes that facilitate the soft-switching. One drawback of this converter is the long resonating modes. Moreover, in each switching cycle, the currents of only one input phase and one output phase are regulated.

In [23], the buck-boost universal converter was further modified to allow the link inductor to be charged and discharged in both positive and negative directions. This resulted in shorter resonating modes. Moreover, in the three-phase ac-ac configuration proposed in [23], each charging and discharging mode is split into two modes to allow the currents of all three input phases and all three output phases to be regulated in each switching cycle; hence, having low current THDs. The performance of this converter was studied in detail in [6]. Despite its numerous advantages, the converter proposed in [23] requires a large number of switches, i.e. 24 switches for the three phase ac-ac configuration. To overcome this limitation, in [24-26], several modified universal configurations, which require a smaller number of switches compared to the converter proposed in [23], were proposed. Despite reducing the number of switches, the conduction losses were increased in these converters. In [27], the Dyna-C topology, which is another family of single-stage universal converters, is proposed for SST applications. This converter consists of two three-phase switch bridges connected through a high-frequency transformer; the magnetizing inductance of this transformer acts as the energy transferring component. In this paper, the control of the universal buck-boost converter proposed in [22] was modified such that there are two charging modes and two discharging modes in each cycle, while keeping the number of active devices equal to 12. However, the reported efficiencies were poor mainly because of the high conduction losses of the incorporated active devices and losses related to the diode reverse recovery [28, 29]. In [30], an auxiliary circuit is added to the Dyna-C converter to enable the soft switching transition of the switches and improve the efficiency, while keeping the desirable features of Dyna-C converter, such as step up/down of the voltage, realizing multiport structure, and high frequency isolation. The detailed design of this soft switching topology for an SST application is thoroughly discussed in [31]. Two other families of soft-switching inductive-link universal power converters inspired by non-inverting dc-dc buck-boost converters are proposed in [32, 33]. In these converters, which can operate in buck, boost, or buck-boost modes, the link peak current is reduced compared to the buck-boost type universal power converters, potentially leading to lower conduction losses. In [34, 35], another class of universal converters, which extends the principles of the operation of a dc-dc Ćuk converter to multiphase systems, was proposed and studied. This converter is dual of the converter proposed in [23]. The link capacitor is the main energy storage component, and a small inductor can be added in series with the link capacitor to allow the switches to benefit from zero current turn-off and soft turn-on. This converter requires large number of switches; a three-phase acac configuration needs 24 switches. In this paper, another class of capacitive-link universal converters, benefitting from a high frequency alternating link voltage is studied, analyzed, and evaluated.

The proposed converter has the same number of switches as conventional PWM back-to-back dc-link converters, while offering high frequency alternating voltage and current in the link. This feature eliminates the need for a large unreliable electrolytic capacitor. Also, in case the galvanic isolation is desired, a compact high frequency transformer can be placed in the link. In contrast to the conventional dc-link converters, this converter has higher power density and longer life-time. In addition, since the number of switches is smaller than the matrix converters, the proposed converter can promise higher efficiency compared with the matrix converters. Moreover, the voltage gain limitation is not an issue in this converter. It is also capable of stepping up or stepping down the voltage amplitude as well as changing the frequency. This topology was first proposed in [36, 37], and its performance was evaluated through simulations. This paper provides a thorough analysis on the behavior of this converter and its control algorithm, and evaluates the performance of the proposed converter through both simulations and experiments. Table I compares the proposed ac-ac converter and a number of existing ac-ac converter topologies. Since the converters may not be optimally designed for the simulated (or experimentally tested) system, the comparison may not be fully conclusive. It can be observed that the proposed converter promises good efficiency compared to the existing topologies while offering the least complex topology with only 12 active switches and one small energy transferring element.

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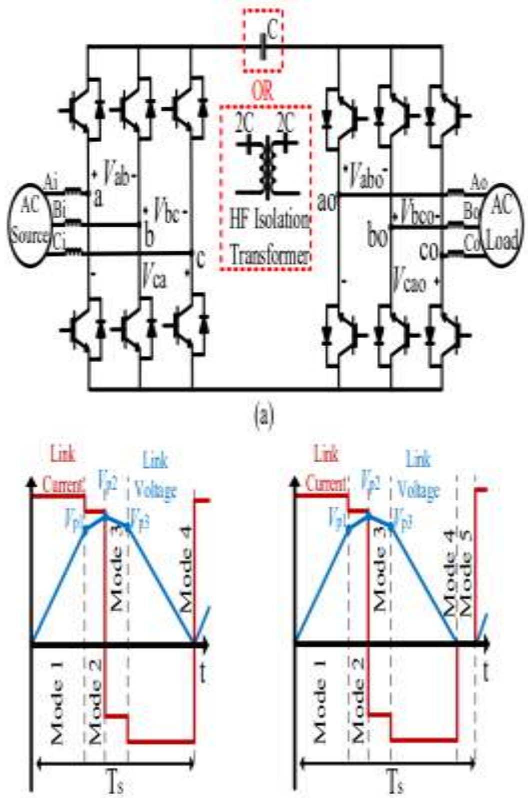

Fig. 1. (a) The proposed three-phase capacitive-ac-link ac-ac converter, (b) the link voltage and current in variable switching frequency control method, (c) the link voltage and current in fixed switching frequency control method.

The switching status of the converter depends on two factors, mode and zone. The control algorithm first checks the mode that the converter is operating in, which can be 1, 2, 3, 4, or 5. Modes 1 and 2 stand for charging modes during which the link capacitor is charged by the input phases, and modes 3 and 4 stand for discharging modes during which the link capacitor discharges into output phases. During mode 5 that exists only in the fixed switching frequency method, no power is transferred to or from the link capacitor. Once the mode is determined, the switching algorithm selects the proper switches based on the input and output zones. The zone factor does not necessarily need to be the same for the input and output sides, since the input and output voltage/current references do not necessarily have the same frequencies or phase angles. In order to determine the input and output zones, the references of the line-line voltages are needed. The references for the line-line voltages across the input and output terminals of the converter are denoted by Vab* , Vbc* , Vca * , Vabo* , Vbco* , and Vcao * , respectively. Zone determination will be discussed in detail in Section III. In the following, the behavior of the converter and the switching algorithm during each mode is explained in four subsections, A, B, C, and D.

The following explanations for switch selection are provided for the condition shown in Table II, which are corresponding to zones 2 and 8 for the input and output, respectively. It should be noted that abs(a) denotes the absolute value of (a) and the positive (+) or negative (-) signs besides the voltages and currents show their polarities. Also, it is assumed that flowing current from left to right is considered to be positive.

TABLE II. THE ASSUMED CONDITION FOR DESCRIPTION OF THE OPERATION PRINCIPLES

Side	Line-Line Voltage References	Actual Currents
Input	$abs(+V_{ab}^*) > abs(-V_{ca}^*) > abs(-V_{bc}^*)$	$abs(+i_{Ai}) > abs(-i_{Bi}) > abs(-i_{Ci})$
Output	$abs(-V_{abo}^*) > abs(+V_{bco}^*) > abs(+V_{cao}^*)$	$abs(-i_{Ao}) > abs(+i_{Bo}) > abs(+i_{Co})$

A. First charging mode (mode 1)

The first mode of operation is the first charging mode, during which the largest input current (absolute value) charges the link capacitor. Since abs(+Vab*)> abs(-Vca *)> abs(-Vbc*), According to Table II, Vab* has the largest absolute value and is positive, while Vca * and Vbc* are negative. Therefore, by the end of charging period, the

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input side unfiltered line-line voltages are formed as in Fig. 2 (a) so their averages meet the averages of the line-line voltage references shown in Fig. 2 (b). As can be observed in Fig. 2 (b), the highest, second highest, and lowest absolute line-line voltage references are Vab* , Vca * , and

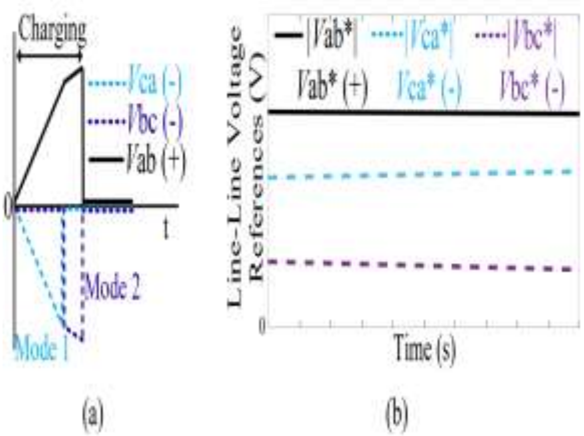

Fig. 2. (a) The unfiltered input line-line voltages during charging interval, (b) absolute input line-line voltage references during this interval.

As shown in Fig. 3 (a), none of the switches of the input side bridge is turned on during the first mode and the anti-parallel diodes conduct the three-phase input currents. Since iAi has the largest value and is positive, the anti-parallel diode of S1 starts conducting and charges the link capacitor and VLink starts increasing. The anti-parallel diodes of the output side bridge will let this current flow back toward the input phases. Since this is a three-phase three-wire system (for input and output sides), the summation of the corresponding three-phase currents has to be zero, which implies that $iAi = -(iBi + iCi)$; hence, phases Bi and Ci currents, which are both negative, have to flow through the anti-parallel diodes of switches S5 and S6. It is obvious that the direction of the input currents determines the diodes that conduct the current in mode 1. During mode 1, it can be seen that Vab=+VLink, Vca=-VLink, and Vbc is equal to zero. Once the Vbc* , respectively. Also, since this is a balanced three-phase threewire system, $Vab * = -(Vca * + Vbc *)$. During the first mode, the second highest absolute line-line voltage (phase pair “ca”) has to be regulated.

average of the unfiltered voltage across the input phase pair “ca” (shown in blue color in Fig. 2 (a)) meets the average of input line-line voltage reference Vca * , mode 1 is ended. As depicted in Fig. 2 (a), during mode 1, the second highest input line-line voltage is built up.

The voltage stress of the switches is slightly higher than that of the conventional dc-link converters. However, given recent advances in developing high-voltage semiconductor devices, this issue does not limit the application of the proposed converter. Although the peak voltage stress of the input and output sides are equal, the current stress is different. For the input side bridge, the maximum current passes through the switches during discharging modes, since during these modes the link current also passes through the input side switches. For instance, in mode 4, the current that flows through switch S3 is equal to iAi+iAo. According to Table II, iAi and iAo are the maximum input and output currents, respectively. If these two currents have their peak values, the current passing through switch S3 will be equal to $Ii,peak + Io,peak$ in which $Ii,peak$ is the peak current of the input side and $Io,peak$ is the peak current of the output side. The maximum current that passes through the anti-parallel diodes of the input side switches is equal to the peak current of the input side (Ii,ak).

TABLE III. THE SWITCHING PATTERN OF THE PROPOSED THREE-PHASE AC-AC CONVERTER

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Mode	Side (Zone →)	1	2	3	4	5	6	7	8	9	10	11	12
1	Input	-	-	-	-	-	-	-	-	-	-	-	-
	Output	S2a S4a	S3b S4b	S3b S4b	S3a S4a	S5a S5a	S5e S5e	S3o S5o	S1o S5o	S1o S6o	S1a S6a	S2a S6a	S3b S6b
2	Input	S6	S3	S2	S5	S4	S1	S3	S6	S5	S2	S1	S4
	Output	S2a S4a	S3b S4b	S3b S4b	S3a S4a	S5a S5a	S5e S5e	S3o S5o	S1o S5o	S1o S6o	S1a S6a	S2a S6a	S3b S6b
3	Input	S5 S6	S3 S6	S2 S5	S2 S5	S1 S4	S1 S4	S3 S6	S3 S6	S2 S5	S2 S5	S1 S4	S1 S4
	Output	S2a S4a	S3b S4b	S3b S4b	S3a S4a	S5a S5a	S5e S5e	S3o S5o	S1o S5o	S1o S6o	S1a S6a	S2a S6a	S3b S6b
4	Input	S5 S6	S3 S6	S2 S5	S2 S5	S1 S4	S1 S4	S3 S6	S3 S6	S2 S5	S2 S5	S1 S4	S1 S4
	Output	S2a S4a S6a	S3b S3b S4b	S3b S3b S4b	S3a S4a S5a	S5a S4a S5a	S1e S3e S5e	S3o S3o S5o	S1o S5o S6o	S1o S5o S6o	S1a S2a S6a	S1a S2a S6a	S3b S4b S6b
5	Input	S5 S6	S3 S6	S2 S5	S2 S5	S1 S4	S1 S4	S3 S6	S3 S6	S2 S5	S2 S5	S1 S4	S1 S4
	Output	S4a S6a	S3b S3b	S3b S3b	S4a S5a	S4a S5a	S1e S3e	S3o S3o	S5o S6o	S5o S6o	S1a S2a	S1a S2a	S4b S6b

3. EXPERIMENTAL RESULTS

A 1-kW prototype, as shown in Fig. 21, has been fabricated, and the three-phase ac-ac converter is experimentally evaluated. The prototype consists of three boards: two switch boards for input-side and output side, and a control board. The specifications of the experimental setup for both control methods are listed in Table IV. The control algorithm is implemented on a TMS320F28335 Delfino microcontroller. the output phase voltages, when the desired output frequency is 120 Hz. The link voltage and current are shown in Fig. 23. As can be seen, during mode 1 that the link current is equal to the highest (absolute value) input phase current and is positive, the link voltage increases. During mode 2 that the link current is equal to the second highest (absolute value) input phase current and still positive, the link voltage increases; however, the rate of increase is lower than that of the first mode. During discharging modes, the energy stored in the capacitive-link discharges into the output. Therefore, the link current is negative, leading to decrement of the link voltage. During mode 3, the second highest (absolute value) output current discharges the link capacitor, while the highest output current discharges the link capacitor in mode 4. It can be seen that once the link voltage is fully discharged, the next cycle starts. Furthermore, Figs. 24 (a) and (b) represent the input and output unfiltered line-line voltages, respectively. It can be observed that the longest charging and discharging modes are corresponded to modes 1 and 4, respectively. During charging modes, the output unfiltered line-line voltages are equal to zero and similarly during the discharging modes the input unfiltered line-line voltages are zero. Fig. 25 illustrates the capability of the proposed converter to change the frequency of the output phase voltages during the operation of the converter. It can be observed that the output frequency smoothly changes from 120 Hz to 60 Hz during the full load operation of the converter.

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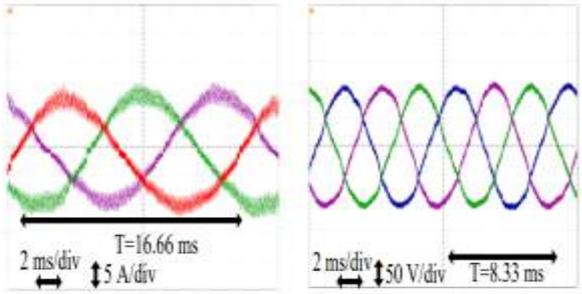

Fig. 3. The experimental results of the three-phase ac-ac converter with variable switching frequency control method, (a) input phase currents and (b) output phase voltages across the resistive load. The output frequency is 120 Hz, while the input frequency is 60 Hz.

4. CONCLUSION

In this paper, a novel three-phase ac-ac converter topology, which benefits from the high frequency alternating voltage across a capacitive link, is introduced and studied. The high frequency voltage variation of the link allows using very small film capacitors at the link for transferring the power from the input to the output. Moreover, use of compact high frequency transformers, in case galvanic isolation is required, is applicable; this feature significantly reduces the size, weight, and volume of the converter. Unlike conventional dc-link converters, this converter does not suffer from the unreliable characteristics of the large electrolytic capacitors, owing to the very small film capacitors used for transferring the power, even at high power applications. This converter is capable of both stepping up and stepping down the voltage amplitude as well as changing the output side frequency. Although this converter performs the ac-ac conversion in a single stage, only 12 switches are required, which is a major advantage over the matrix converters. The advantages and promising features of the proposed converter are validated in this paper through simulations and a 1-kW experimental setup.

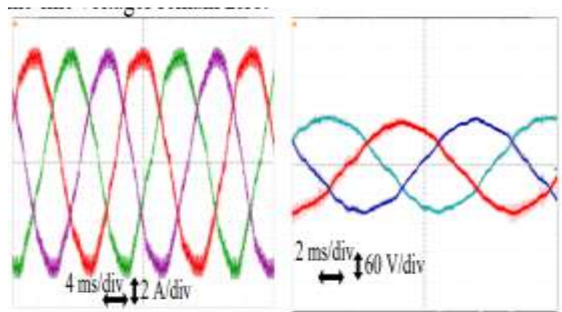

Fig. 4. The experimental results of the three-phase ac-ac converter with fixed switching frequency control method, (a) input phase currents and (b) output phase voltages across the resistive load.

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Design and Fabrication of a Leaf-Type Drill Jig for Penholder Component

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ABSTRACT- This work focuses on the design and fabrication of an innovative leaf-type drill jig for the penholder component. The primary objective is to enhance operational efficiency by facilitating quick loading and unloading of the component, thereby reducing operating time, increasing production rates, and minimizing operator fatigue. The design incorporates round locators at the center for rapid loading and a leaf plate mechanism for efficient unloading. The integration of this innovative leaf-type drill jig not only improves production efficiency but also contributes to maintaining high accuracy in the manufacturing process. By reducing the time and effort required for each operation, this drill jig enhances overall productivity while minimizing operator fatigue. The study highlights the significance of advanced manufacturing techniques, specifically CNC machining, in achieving the desired precision and efficiency in the fabrication of such specialized tooling systems

Keywords: Leaf Jig, Penholder, drill jig, mass production

1. Introduction

In various manufacturing industries, the pivotal role played by Jigs and Fixtures in assembly, mass production, and inspection processes cannot be overstated. Jigs, designed for precise positioning and guiding of cutting tools, ensure the quality of components and contribute to increased production rates. Fixtures, on the other hand, are employed for machining, assembly, and inspection purposes, providing proper component positioning and clamping, thereby achieving repeatability and accuracy.

This paper reviews the works of several authors who have contributed to the field of Jigs and Fixtures. PriyaShinde et al. [1] innovatively designed a pneumatic drill jig for a cover plate, incorporating a pneumatic clamping system for workpiece clamping. Anand N et al. [2] focused on a turning and drilling fixture for a housing component, conducting stress analysis during drilling operations using Ansys software. Raghavendra H et al. [3] developed an indexing drill jig for various workpiece materials and analyzed machining time. H Radhwan et al. [4] proposed a semi-automatic jig and fixture design for easy handling, incorporating FEA analysis for stress evaluation. Rushikesh D. Bhosale et al. [5] designed a welding fixture for a base frame, reducing daily working time by 90 minutes. AnujShrivastava et al. [6] analyzed and designed an adjustable welding fixture for suspension arms welding in passenger vehicles. AvadhutKulkarni et al. [7] focused on designing a drill jig for drilling small diameter holes at a specific angle for a rod guide component. Abdulhamid .A et al. [8] conducted a study on various jigs used for drilling operations and designed a drill jig for different workpiece shapes. In this present work, the focus is on the design and fabrication of a leaf-type drill jig for the pen holder component. The objective is to facilitate easy loading and unloading of the component, enhancing production rates and ensuring the quality of the components. This leaf-type drill jig takes into account considerations for easy loading and unloading, with the aim of increasing production rates and achieving high-quality components for pen holder assembly. The design and fabrication process involves careful consideration of these factors, and the lessons learned from the reviewed works contribute to the optimization of this specialized tool for efficient and precise drilling operations in pen holder manufacturing

2. Design of Drill Jig

Penholder component drawing: The component or workpiece material is taken as EN8. The component consists of dia 8mm x 6 holes. A drill jig has to be designed to drill these holes accurately with minimum time. The dia 12 mm hole at the centre of the component is already made and that can be used for location of the component in the drill jig. The dimensions of the penholder component are shown in the Fig1.

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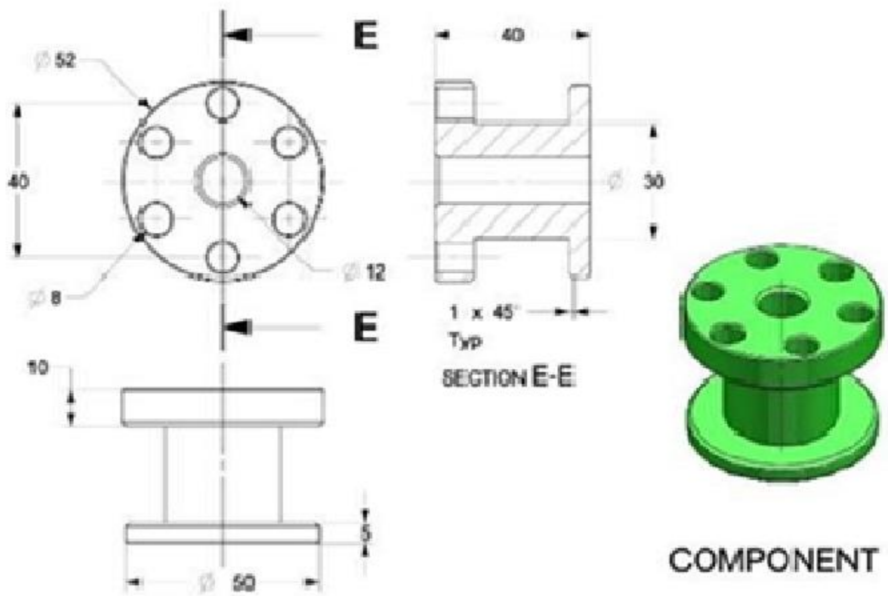
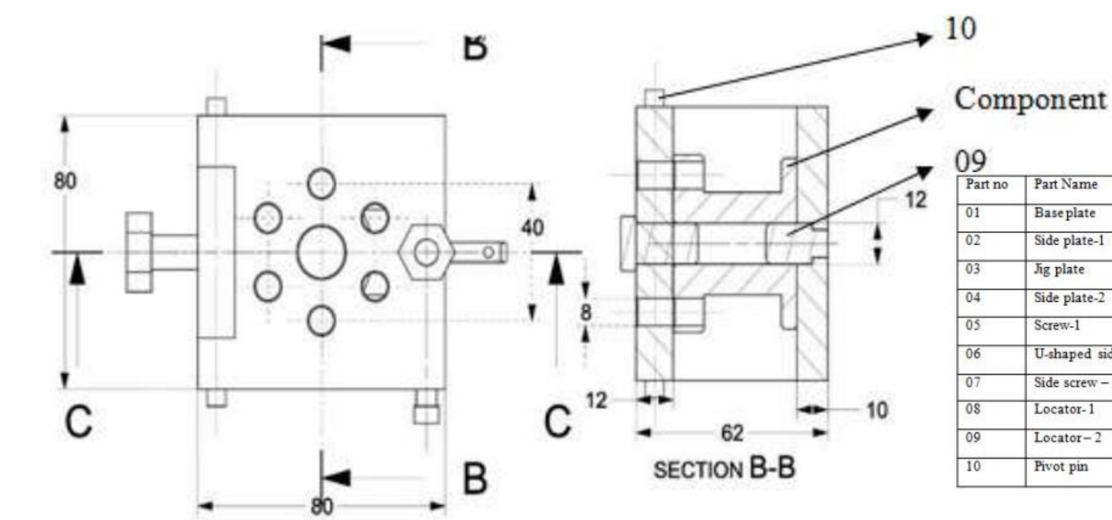


Fig.1 Penholder component drawing



Part no	Part Name
01	Base plate
02	Side plate-1
03	Jig plate
04	Side plate-2
05	Screw-1
06	U-shaped side locator
07	Side screw – 2
08	Locator- 1
09	Locator – 2
10	Pivot pin

fig 2 Leaf drill jig assembly design:

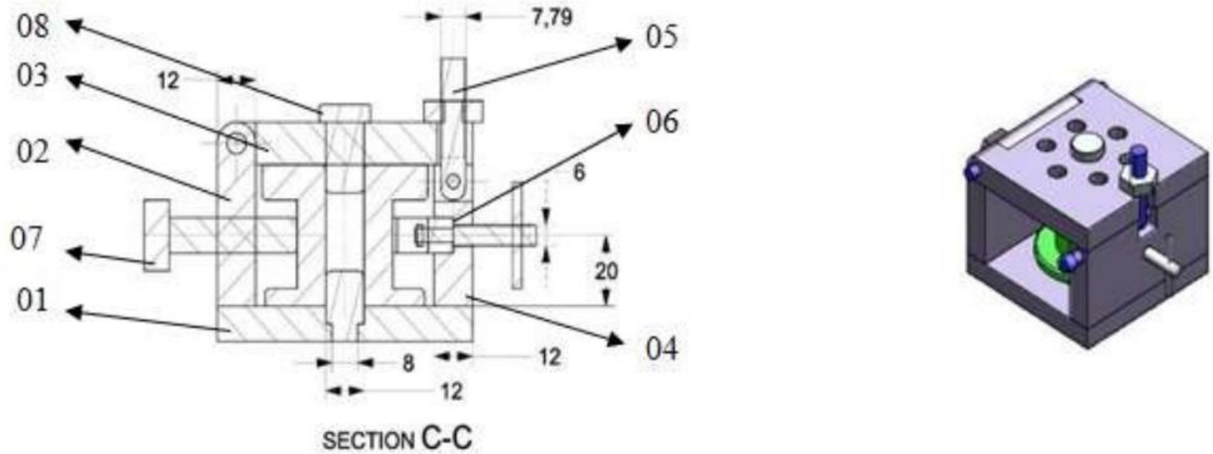


Fig.3 Assembly design of Drill Jig

A Leaf Jig is designed for penholder component to drill six holes as per component drawing. The leaf jig design assembly is shown in Fig 2. door using pivot pin. This facilitates for easy loading and unloading of component. The component can be locked with a bolt at the end of Jig plate. It also consists of locator at bottom that locates the olds the workpiece from one side and from another side a screw is placed that can be tightened and loosened. Another locator at the Jig plate locates the component from top side. Hence the design of drill jig is made by ensuring all the degrees of

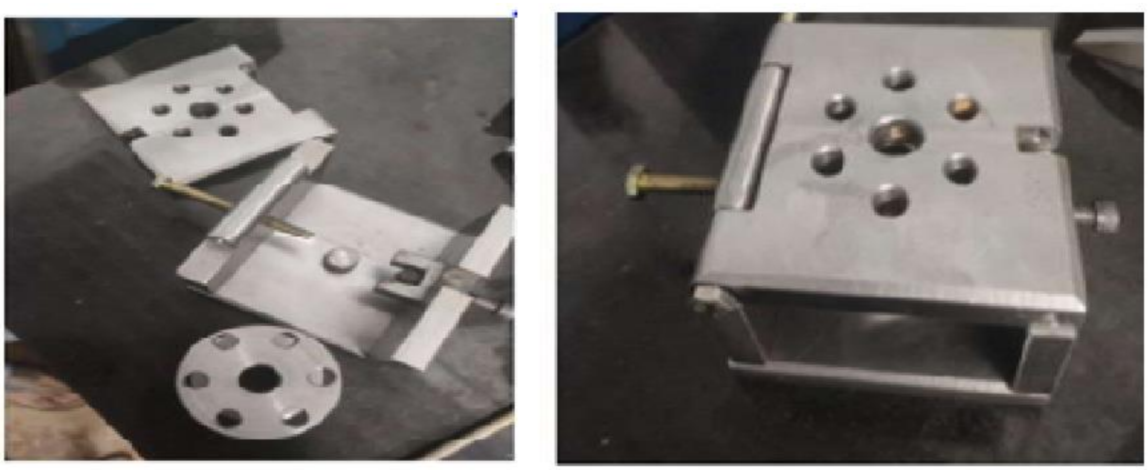


Fig. 4 Fabricated parts of Drill jig

s. Loading Fig. 4 Sequence of operations performed during drilling of holes. 4. Conclusions The objective of this paper is to design and fabrication of leaf drill jig for pen holder. The design of the drill jig is pre software. The design is made such a way that easy loading and unloading of the component/workpiece is done through leaf type drill Jig. The drillInternational Journal of Research Publication and Reviews, Vol 3, no 7, pp 44-47, July 2022of the component is arrested during operation and also easy loading & unloading of the component. A Leaf drill Jig is fabricated as per the design. The EN 19 material is used for making the total body of the Jig. The fabricated par Fig. 3 Fabricated parts of Drill jig The aim of present work is to drill the holes on workpiece/component with less time by using leaf drill jig. In this, the dri jig plate to the correct position. Drill bushes also can be designed in the place of holes. So that any replacement of holes The sequence of operations carried out for drilling of holes using drill jig are shown in the Fig.4. contains a jig plate at the top side that can be opened and closed like a door using pivot pin. One locator is fitted to jig of the Drill jig. Hence lift the jig plate and place the work piece inside the leaf jig. Place the work piece perfectly on end locator at the bottom side (base plate) of the Jig. The leaf jig consists of one u-shaped locator that holds the workpiece from one side. The other end consists of a screw that can be used to tightened or loosened, so that workpiece can't be moved while drilling operation. Now jig plate is locked by Next ensure that all the degree of freedom is arrested for workpiece. Now perform drilling operations on workpiece through passing drill bit through the jig plate holes, drilling of holes is done on workpiece perfectly. Now unlock the jig plate by loosening the bolt and lift the jig plate. Now loosen the side screw and u-shaped locator. Now take the tside easily by lifting it up. Clean the chips that are produced while doing drilling operations on workpiece. Now place anot Drilling UnloadingFig. 4 Sequence of operations performed during drilling of holes. The objective of this paper is to design and fabrication of leaf drill jig for pen holder. The design of the drill jig is prepared using AutoCAD &Catia is made such a way that easy loading and unloading of the component/workpiece is done through leaf type drill Jig. The drill2022 46 ated parts are shown in Fig. 3 T

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Loading Drilling Unloading

Fig. 5 Sequence of operations performed during drilling of holes.

3. Conclusions

This paper presents the design and fabrication of a leaf drill jig for pen holder components, focusing on optimizing the drilling process for increased efficiency and improved production rates. The designed jig facilitates easy loading and unloading of the workpiece, reducing drilling time significantly when compared to conventional methods without a jig. The fabrication process employs CNC machining to ensure precision, especially in critical areas such as the jig plate and locating pin holes. Jigs and fixtures are integral tools in manufacturing processes, enhancing precision, efficiency, and overall production rates. This paper addresses the specific design and fabrication of a leaf drill jig for pen holders. The key objective is to streamline the drilling process by incorporating features that allow quick and efficient loading and unloading of workpieces.

The presented leaf drill jig design for pen holder components showcases a significant improvement in drilling efficiency and production rates. The use of CNC machining ensures precision in critical areas, leading to the fabrication of a high-quality and reliable tool for the manufacturing process

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