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Optimization of Vapor Compression Type for Desalination of Seawater Using the DFMA Method

Firdaus M.A.[1], Irfan Santosa[1*], Royan Hidayat[1], Rusnoto[1], Agus Wibowo[1], Fathan Mubina Dewadi[2]

[1]Mechanical Engineering Department, Faculty of Engineering and Computer Science, Universitas Pancasakti, Tegal, Indonesia. 52121

[2]Mechanical Engineering Department, Faculty of Engineering, Universitas Buana Perjuangan Karawang, Indonesia, 41361

ABSTRACT

The design of vapor compression type distillation using the design for manufacture and assembly (DFMA) method was discussed in this article. The efficacy of seawater desalination is the primary source of non-conventional fresh water in a large number of countries around the world. The distillation process can satisfy the demands for high-quality fresh water by utilizing seawater. DFMA is a technique for product development and improvement that could be used to simplify the manufacturing process and reduce assembly costs. This research focuses on creating an effective vapor compression-type desalination device. The DFMA method is used in this reverse engineering study. According to the findings of this study, the total assembly time of 22 components was 7932 seconds. Compared to the previous process, processing time efficiency increased by 4.1 %.

Keywords: *DFMA, Desalination, Reverse engineering, Vapor compression.*

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Correspondent authors:
*✉: ci_ulya@yahoo.co.id

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1. INTRODUCTION

In recent years, access to fresh water and electricity has been one of the most pressing global issues [1]. Between 2012 and 2040, global energy consumption is projected to increase by 48 % [2]. In contrast to thermal desalination, reverse osmosis (RO) desalination uses membrane-assisted pressure to remove solid particles from feed water at the expense of high operational costs [3]. Modern industrialization necessitates rapid innovation and the production of high-quality tools. Inefficient product design can reduce the limitations of a product while lowering the cost of the assembly process. The primary characteristic of the innovation process is the elimination, reduction, or combination of non-essential or non-value-added product components or product components in order to simplify the product processing procedure that effected productivity, cost, and quality. This product innovation has a significant impact [4].

Design for manufacture and assembly (DFMA) is a method of creating and improving products to simplify manufacturing and reduce assembly costs [5]. The DFMA method has numerous advantages, including improved quality, reduced component count, simplified assembly, lower production costs, and evaluation of everything from the design process to the finished product. Furthermore, product design decisions should be made based on the tool's intended use to eliminate any unnecessary or ineffective components [6]. DFMA is the first step in getting a reference for our operations, such as models of how to make things for design and making designs for manufacturing activity. Material or component standardization, product design standardization, and material usage are all general DFMA guiding principles that can serve as benchmarks for future designs [7].

Several studies on the use of the DFMA approach, including those application conducted by [8] [9] [10], among others. The socket outlet design was investigated using the DFMA method in research design [8]. The design of the outlet device and the application of the DFM method to the production of a single pallet box were successful in reducing production costs by 20.0 % and quality expenses by 27.1 %. The DFMA method was also used to conduct research on the redesign of the tool holder [9] The redesign's outcomes result in a 33% increase in efficiency in terms of both time and material usage. The benefit of reducing processing time reduces labour costs by 29%. DFMA conducted a follow-up study on the production of machinery for processing soy milk. Because of the implementation of DFMA, the assembly process has become 40% more efficient [10]. DFMA guidelines can be obtained from a variety of sources, including production costs, functional parts in assembly, lowering total parts, and standardising components [11]:

a. Product price
   list of elements for creating the ideal part assembly for a product. There are numerous ways to identify the assembly's key components:
   1) Vital part-to-part connections
   2) Some sections are made of different materials than others.
   3) It's possible to do away with the connection between the parts.
   4) The function of the portion that is below the maximum and makes assembly difficult.
   5) Correct component replacement
b. Cut down on assembly direction
   In order to make it easy to remove and reinstall components, the product must be designed to be constructed from one direction.
c. The role of parts in an assembly
   Designing one product component as a part of another part helps maximize the role of that element in the assembly. A different design could be needed for this part.
d. Reducing the overall portions
   Part savings negate part costs for production and assembly, however the number of parts should not be drastically reduced since this could raise the price of the remaining parts. similar to several materials.
e. Standardization of parts
   Component manufacturing costs are kept to a minimum, and the quality of the components is uniform. This is advantageous in terms of design, size, materials, and manufacturing techniques.

In contrast to previous research, the DFMA method was utilized to design a solar-powered vapour compression seawater desalination system. This study aims to develop a production method for a successful vapour compression desalination method. In recent years, the dearth of clean water and energy has been one of the world's most pressing problems. One commercially available solution to the problem of water scarcity is seawater desalination [12]. The efficacy of seawater desalination is the primary source of non-conventional fresh water in a large number of countries around the world [13]

2. METHODOLOGY

2.1. *Design for manufacture and assembly (DFMA)*

The investigation begins with the identification of similar or related sources of information, literature, and research data. create a design strategy for a seawater desalination device CAD software was used to design the entire machine, including all parts and components. During assembly, some components cannot be separated from one another. The components, however, will be properly installed with additional assembly.e investigation begins with identifying similar or related sources of information, literature, and research data. For creating a design plan for a seawater desalination device. Design of the entire machine, including all parts and components, using CAD software. Some components cannot be separated during assembly from one pair to another; however, with further assembly, the components will be installed correctly.

The primary objective of DFMA is to simplify the process of creating and assembling a product. DFMA provides a solution by streamlining procedures tailored to industrial facilities and considering technological considerations[10]. The two principles that comprise DFMA are design for assembly (DFA) and design for manufacture (DFM). The DFMA concept is used in the initial design phase. The idea behind this approach is to reduce design time and cost by performing DFMA analysis early in the product development process. The best assembly technique in terms of time and cost-effectiveness is designing a product that can be easily manufactured or simplifying existing designs so that prices can be reduced as needed. The efficiency of the vapor compression type of desalination assembly process can be calculated using Equation 1 [14] [15].

$$E_i = \frac{Number\ of\ toritis\ x\ portion\ count}{Total\ time\ for\ assembly} \qquad (1)$$

2.2. Required Equipment

Vapor compression seawater desalination technology refers to the Rankine cycle steam turbine treatment approach, in which hot steam is condensed back into the system. The heated sea water from the heating tank/heater is converted to condensed steam via a condensation pipe located in the seawater storage tank. The design and composition of the condensing pipe are changed to maximise condensation. Heating energy from solar panels and electrical components (temperature sensor, Raspberry Pi, and other parts). The specifications for the parts and machinery required to produce vapour compression type seawater desalination are listed in Table 1.

Table 1 Requirements for parts and instruments

No.	Material Name	Capacity and Specification	Unit	Reference
1.	Galvanized Square Pipe	4 x 4 x 0,4 x 4 m	4	ASTM A 53M [16]
2.	Galvanized Square Pipe	4 x 2 x 0,35 x 4 m	2	ASTM A 53M [16]
3.	Metallic Plate	122 x 244 cm x 0,7mm	2	JIS G3303 [17] [18]
4.	Water meter	12 Volt	1	-
5.	The plastic water bottle	150 Liter	1	-
6.	Stainless steel water bottle	120 Liter	1	AISI 304 [19] [20]
7.	PVC hose	1/2 6m	1	-
8.	L-shaped PVC pipe	½	4	-
9.	Glue for PVC Pipe	350 gram	2	-
10.	Metallic Pipe	¾ x 1m	2	AISI 304 [19] [20]
11.	L stainless steel pipe	½	4	AISI 304 [19] [20]
12.	Cavitating pipe	½ x 1m	2	AISI 304 [19] [20]
13.	Heater	200 Watt	1	-
14.	LCD display	with i2c	1	-
15.	Jamper (m/m)	pitch 2.54 mm pin header	1	
16.	Switch		4	-
17.	Male to Female Jamper Cable	20 Cm	4	-
18.	PV solar panel	100 Wp	3	[21]
19.	Autonomous buoy	Switch ctrl (otolevel ps 60AB)	1	-
20.	A sonar sensor	HC-RSO4	1	-
21.	A nano Arduino		1	-
22.	Heat detector	DS18 B	6	-
23.	Relay	2 channel	1	-

3. RESULTS AND DISCUSIONS

The components are made of various materials, including iron, plastic, and others, to make the vapour compression of the seawater distillation easier to install. Figure 1 depicts the material specifications for the vapour compression type of seawater desalination design. Vapour compression desalination is used to convert seawater to freshwater. In some areas where water is scarce, it is the primary source of fresh water for residents. DFMA is a design-for-manufacturing-and-assembly method that emphasises streamlining product design to improve manufacturing efficiency and assembly effectiveness. Many component pieces, such as pricing tables, time, components, and raw materials, are grouped using tables and graphs. The DFMA approach can be used to develop a tool that will aid comprehension. DFMA is used to identify the material and vapour compression type of seawater desalination system and to calculate the time required for each phase. Table 2 shows the time required to assemble a vapour compression type of seawater desalination unit.

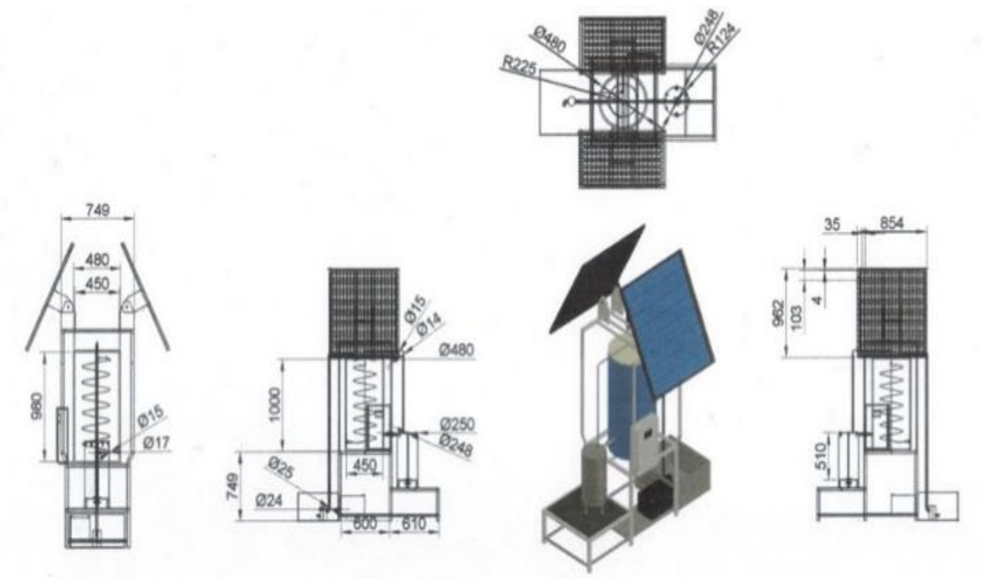

Figure 1 Design of the vapor compression type for desalinating seawater

Table 2 Real-time assembly of VC type desalinations

No.	Process	Time*)	No.	Process	Time*)
1.	Making skeletons	1200	9.	The capillary tube being inserted into the drum	30
2.	Creating heating tanks	2400	10.	The heater on the tank after installation	30
3.	Manufacturing sensors	3600	11.	Installation of a bottom faucet	15
4.	Lower and upper drum perforations	120	12.	Install a pump	15
5.	Installation of faucets and threading	180	13.	Cutting and installing PVC pipe	15
6.	Installation and loading of threaded pipes	180	14.	Capillary tube development	15
7.	Installation of panels	60	15.	Hose for connections that can withstand heat	15
8.	Installation of sensors	120			
				Time Spent on Assembly	**7995**

*) Unit in minutes

Figure 2 illustrates the time and assembly process, which has been divided into the 60 hours and 15 minutes that constitute the labor-intensive portions of the operation. Figure 2 illustrates the time required for the design. Iron, plastic, copper, and stainless steel are subdivided into four subcomponents based on the amount of assembly required. The following describes the cost of raw materials and the manufacturing procedure. To determine the extent of the tool's efficiency, the production and component assembly processes are documented and evaluated, as well as the effectiveness of component installation per part. The price of raw materials and manufacturing process are shown in Figure 3. The complete cost information for producing tools with material costs that are specific to design requirements is shown in Figure 3.

In order to determine the efficiency degree of tool component installation, the theoretical quantity is deduced from the required number of components. when reinstalling the same part It is possible to determine the quantity of components from the installation of components by using the theoretical quantity used in the creation of this tool. It takes time and a theoretical amount of design planning to make the efficiency level easily computed. Figure *3* indicates that there are a total of 22 theoretical parts, and the assembly time is 7 minutes, 932 seconds. The efficiency is computed using Equation 1.

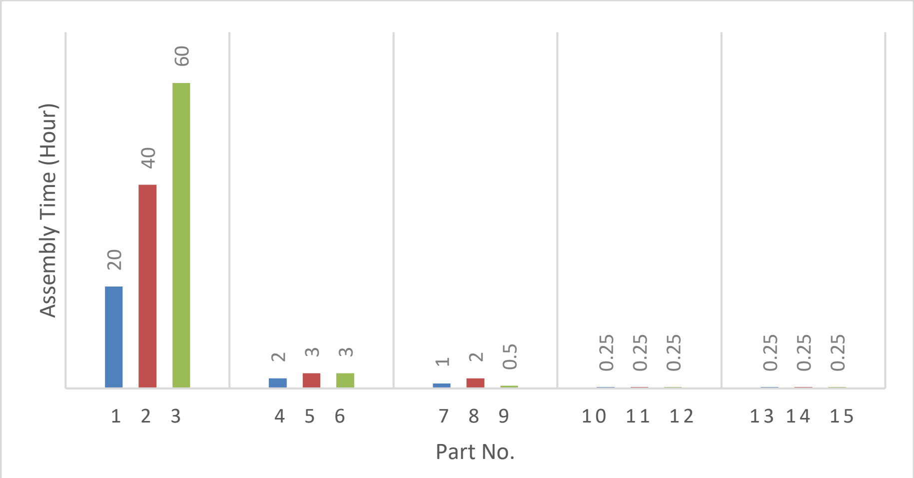

Figure 2 The time needed for each process's assembly

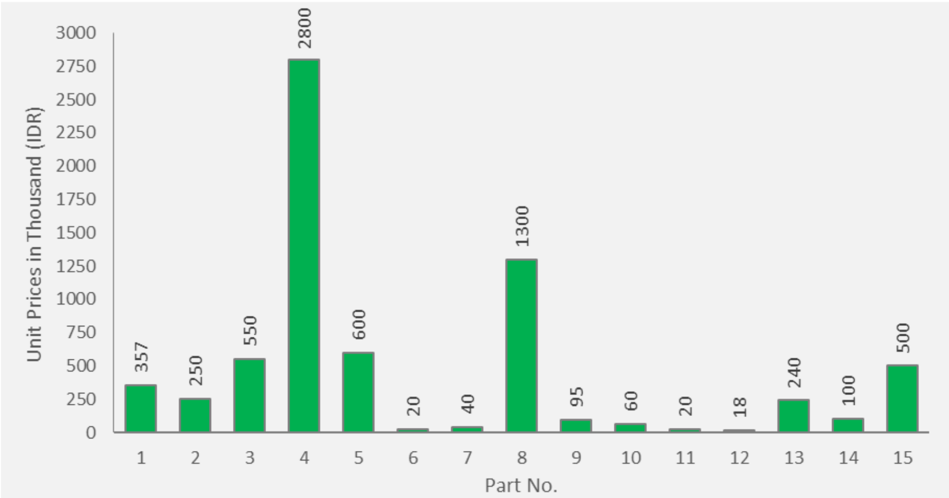

Figure 3 Manufacturing processing and material costs

$$.E_i = \frac{Number\ of\ toritis\ x\ portion\ count}{Total\ time\ for\ assembly}$$

$$E_i = \frac{15\ x\ 22}{7.995} = 0{,}041$$

According to the calculations and analysis, the assembly efficiency is 0.041 or 4.1 %.

a. Review of Design

Designs that have been created and evaluated for performance after a drawn-out manufacturing process, the use of crucial components, and reviews from testing tools: (table 4)

b. Results

The result of the calculations is the data presented in Table 3. Table 3 provided of the DFMA specifies that there are 22 theoretical parts in total. Investing 3,600 seconds in the production of a sensor is a wasteful endeavour. The efficiency of the assembly procedure is 0.041, or 4.1 percent of the 22 pieces assembled.

The research above reveals that the tool's design maximizes the effectiveness of the assembling procedure. The process of choosing the right parts that will impact the tool's performance when utilized is aided by DFMA. This circumstance is consistent with earlier research showing that the

DFMA method can boost the effectiveness of the production process [10]. The availability of raw resources that are simpler to procure is another benefit of DFMA [7]. It is also more durable and stronger from an egotistical perspective. Many materials that are difficult to corrode are utilized as desalination equipment. According to the mathematical analysis, the assembly efficiency is 0.041 or 4.1%, regarding costs that seem yet reasonable. The proposed design for vapor compression type desalination utilizing the DFMA method is shown in Table 4. A vapor compression type for desalination of seawater system has several distinct ways of operating. The stages of the process of converting seawater to fresh water are as follows:

a. Stage one charging is accomplished using the battery's panel and a solar charger.
b. The second stage connects the Arduino sensor and the water pump to the battery.
c. Using a proximity sensor, water will be automatically transferred from the water pump to the top tank. The heater sensor will detect heat from the evaporator tank, steam pipe, capillary pipe, and top tank, among other places.
d. When the battery is fully charged, open the tap to fill the evaporator tank.
e. If the heater is fully charged, it will automatically heat the water to 100°.
f. When the water boils, the steam is drawn to the capillary tube and cooled. It keeps repeating itself until it becomes fresh water.

Table 3 Cycle time required for assembly using DFMA

No.	Process	Pieces	Time (minutes)
1.	Making skeletons	1	1200
2.	Creating heating tanks	1	2400
3.	Capillary tube development	1	3
4.	Both the upper and lower drums have perforations.	2	120
5.	Creating threads and installing a faucet stop	3	180
6.	Installation of panels	2	60
7.	Manufacturing sensors	1	3600
8.	Installation of sensors	1	120
9.	The capillary tube being inserted into the drum	1	30
10.	The heater being put on the heating tank	1	30
11.	Installation of a bottom faucet	2	3
12.	Install a pump	1	3
13.	Cutting and installing PVC pipe	1	3
14.	Installation and loading of threaded pipes	1	180
15.	Placement of hose	3	0,05
	Total	**22**	**7932**

Table 4 Proposed vapor compression type desalination design

No	Needs List	Design Suggestions	Developed Upgrades
1.	Tanks are created	- Coverage is temporary - Stop using copper in faucets	- Heat can be reduced by salt buildup in the tank, and the top cover is built to be removable for simple cleaning. - Reduces the likelihood of corrosion, which can lead to a water supply leak and a reduction in the amount of heat in the bottom tank
2.	Vast tank	- Tank shape with a 45 mm diameter and a height of 65 cm	- Modifying the necessity for clean water as the primary one
3.	Tank pipe elevation	- 15 mm pipe diameter	- Size of the tank and steam produced by the evaporator

4. CONCLUSIONS

The following findings are drawn from the design of vapor compression type desalination using the DFMA method:

a. From the outcomes of the assembly processes used in the production of seawater desalination, heating tanks, table frames, and panels, as well as threads that serve as faucet stop connections.
b. The product is assembled either manually or automatically. The production of various components in this seawater distillation assembly is not ideal due to insufficient equipment.
c. A seawater desalination instrument with a theoretical component count of 22 units and an overall assembly time of 7,932 seconds has an assembly efficiency of 4.1%.

AUTHOR'S DECLARATION

Authors' contributions and responsibilities

The authors contributed significantly to the conception and design of the study. The authors were responsible for data analysis, results interpretation, and discussion. The authors read the final manuscript and gave their approval.

Availability of data and materials

The authors have made all data available.

Competing interests

The authors declare that they have no competing interests.

REFERENCE

[1] M. Faegh, P. Behnam, and M. B. Shafii, "A review on recent advances in humidification-dehumidification (HDH) desalination systems integrated with refrigeration, power and desalination technologies," *Energy Convers. Manag.*, vol. 196, no. April, pp. 1002–1036, 2019.

[2] J. Conti, P. Holtberg, J. Diefenderfer, A. LaRose, J. Turnure, and L. Westfall, "International energy outlook 2016 with projections to 2040," Washington, DC (United States), 2016.

[3] H. R. Datsgerdi and H. T. Chua, "Thermo-economic analysis of low-grade heat driven multi-effect distillation based desalination processes," *Desalination*, vol. 448, no. September, pp. 36–48, 2018.

[4] R. Handoko, "Perbaikan Fabrikasi Pallet Box Dengan Design for Manufacturing (Dfm) Untuk Meminimasi Biaya Produksi Dan Kualitas," *J. Tek. Ind.*, vol. 5, no. 3, pp. 85–92, 2015.

[5] C. Kong, H. Lee, and H. Park, "Design and manufacturing of automobile hood using natural composite structure," *Compos. Part B Eng.*, vol. 91, pp. 18–26, 2016.

[6] D. Y. Negroni and L. G. Trabasso, "A quality improving method to assist the Integrated Product Development process," *DS 58-7 Proc. ICED 09, 17th Int. Conf. Eng. Des.*, pp. 127–136, 2009.

[7] R. LeSar and R. LeSar, "Materials selection and design," *Introd. to Comput. Mater. Sci.*, pp. 269–278, 2013.

[8] Y. Hasibuan, A. M. Rambe, and R. Ginting, "Rancangan Perbaikan Stopcontact Melalui Pendekatan Metode Dfma (Design for Manufacturing and Assembly) Pada Pt. Xyz," *J. Tek. Ind. USU*, vol. 1, no. 2, pp. 34–39, 2013.

[9] B. Ibrahim, "PERANCANGAN ULANG TOOL HOLDER UNTUK ALUR DOVETAIL PADA RAGUM POLMAN 125," pp. 1–7, 2014.

[10] I. Santosa, G. R. Wilis, and U. Mulyadi, "Soy milk filter design using DFMA method," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 755, no. 1, 2021.

[11] G. Boothroyd, "Product design for manufacture and assembly," *Comput. Des.*, vol. 26, no. 7, pp. 505–520, 1994.

[12] A. Abid *et al.*, "Exergoeconomic optimization of a forward feed multi-effect desalination system with and without energy recovery," *Desalination*, vol. 499, no. September 2020, p. 114808, 2021.

[13] A. Campione, L. Gurreri, M. Ciofalo, G. Micale, A. Tamburini, and A. Cipollina, "Electrodialysis for water desalination: A critical assessment of recent developments on process fundamentals, models and applications," *Desalination*, vol. 434, no. December

2017, pp. 121–160, 2018.

[14] N. Rahdiana, F. Majid, and A. Astuti, "Perancangan Alat Pemanen Padi Ergonomis untuk Meningkatkan Efisiensi Proses Panen dengan Pendekatan Antropometri dan Reverse Engineering," *Tekmapro J. Ind. Eng. Manag.*, vol. 16, no. 02, pp. 108–118, 2021.

[15] S. Asri, "Efisiensi Konsentrasi Perekat Tepung Tapioka Terhadap Nilai Kalor Pembakaran pada Biobriket Batang Jagung (Zea mays L.)," *J. Teknosains*, vol. 7, pp. 78–89, 2013.

[16] ASTM International, *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*, vol. 93, no. Reapproved. America, 2000, pp. 2–6.

[17] JIS G 3302, "JIS G 3302 Hot-dip zinc-coated steel sheet and strip." Japanese Industrial Standard, 2007.

[18] S. Sukarman, A. Abdulah, A. D. Shieddieque, N. Rahdiana, and K. Khoirudin, "OPTIMIZATION OF THE RESISTANCE SPOT WELDING PROCESS OF SECC-AF AND SGCC GALVANIZED STEEL SHEET USING THE TAGUCHI METHOD," *SINERGI*, vol. 25, no. 3, pp. 319–328, 2021.

[19] M. Ramadhan Cahya and A. Abdulah, "Analisis Terjadinya Korosi Batas Butir Akibat Proses Pengelasan Gtaw Pada Material Austenitic Stainless Steel Aisi a304," *J. Teknol.*, 2019.

[20] Sukarman, C. Anwar, N. Rahdiana, and A. I. Ramadhan, "ANALISIS PENGARUH RADIUS DIES TERHADAP SPRINGBACK LOGAM LEMBARAN STAINLESS-STEEL PADA PROSES BENDING HIDROLIK V-DIE," *Junal Teknol.*, vol. 12, no. 2, 2020.

[21] L. Paradeshi, M. Mohanraj, M. Srinivas, and S. Jayaraj, "Exergy analysis of direct-expansion solar-assisted heat pumps working with R22 and R433A," *J. Therm. Anal. Calorim.*, vol. 134, no. 3, pp. 2223–2237, 2018.