Contents list available at Directory of Open Access Journals (DOAJ)
JUTIN : Jurnal Teknik Industri Terintegrasi
Volume 6 Issue 3 2023, Page 813-818
ISSN: 2620-8962 (Online)
Journal Homepage: https://journal.universitaspahlawan.ac.id/index.php/jutin/index

Portable Fire Pump To Handle Forest Fires and Densely Populated Urban Areas

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DOI: 10.31004/jutin.v6i3.17340

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Article Info	*Abstract*

Keywords:
Portable Fire Pump;
Pressure Added;
Anthropometry Methods;

A portable fire pump is an innovative fire extinguisher with high mobility because this tool can be carried by the user. This tool can answer the problem of fires that often occur in areas that are difficult to reach by fire extinguishers in general, such as in forests or densely populated urban areas. This portable fire pump can be operated by utilizing water pressure from a pump that is placed near a water source and then the pressure is added by this tool to reach hotspots. Based on testing, this tool is capable of spraying water as far as 10 meters with a height of 15 meters. In terms of ergonomics and the risk of muscle injury from the user, this tool has been tested using anthropometry methods, Rapid Upper Limb Assessment (RULA), and Recommended Weight Limit (RWL) with results that can be used by users without risking muscle injury

1. INTRODUCTION

Forest and land fires are a recurring disaster in Indonesia, especially every dry season arrives. This potential is even greater in areas with large peatland areas, such as the islands of Sumatra and Kalimantan, which have the largest tropical peatlands in the world [1]. The forest fires that occurred in Indonesia in 1997/1998 and 2002/2005 produced smoke that was also felt by neighboring countries such as Malaysia, Singapore, Australia, and Brunei Darussalam and threatened to disrupt air transportation links between countries [2-5]. Forest fires have a significant impact on the social life of the community such as disruption of daily activities, decreasing community productivity, destroying species around the forest that can disrupt the balance of nature, and disrupting public health [5, 6]. In addition to social impacts, forest fires also result in economic losses such as the loss of potential benefits of forests, the state budget for fire management, and a decrease in state foreign exchange [7]. Compounding this problem is the progressive urban development of the suburbs, where infrastructure development and ongoing demographic changes tend to expose more people and property to these potentially catastrophic natural hazards [8]. Apart from forest fires, fires that occur in densely populated areas also often occur [9]. Similar to forest fires, fires that occur in densely populated areas are also an important problem that must be resolved because fire extinguishers are generally difficult to enter into densely populated areas so it takes a long time to extinguish the fire [10]. The problem of fighting forest fires or fires in densely populated areas is not an easy matter. Firefighters need an effective extinguisher to extinguish hotspots. However, the location of the fire in the middle of the forest made it difficult for fire trucks to reach the hotspots. Many technological innovations for fire fighting have been developed, one of which is the use of a wind tunnel that can be used portable by using two axial fans with a speed of 8 m/s [11]. In addition, the use of fire fighting robots has also been developed to be able to detect fire points and extinguish them [12]. The use of these extinguishers may be used in open land forests, but Indonesia's geographical conditions, which are hills and valleys, are difficult to access by large vehicles. In addition, densely populated urban areas are also difficult to reach by fire engines and other advanced fire fighting equipment due to narrow road access.

Received 28 July 2023; Received in revised form 28 July 2023 year; Accepted 29 July 2023
Available online 7 August 2023 /

The research conducted this time is to create an innovation related to fire extinguishers that can be used and accessed by the entire community in various places, especially in areas that are difficult to reach by fire extinguishers in general, such as in densely populated urban areas and forest fires. The tool that has been made is a booster pump that can be carried by one person with easy operation and accessibility. This tool still utilizes a pump that is placed close to the water source and then the pressure is increased by this tool to be able to reach the hotspots. This innovative product can stop the possibility of fire spreading more quickly due to the difficulty of accessing fire extinguishers from the relevant agencies to reach certain areas.

2. METHODS

A portable fire pump using a pump as the main component or what we call a fire pump uses an XG 10 ZS pump type centrifugal pump with the following specifications:

- Flow (m3/h) : 6 (rated) / 9 (max.)
- Suction port diameter (mm/inch) : 25/1
- Discharge port diameter (mm/inch) : 25/1
- Total head lift (mm) : 10 (rated) / 15 (max.)
- Suction head lift : 5 (rated) / 7 (max.)
- Pump type : Centrifugal pump/single impeller

To be able to drive the pump, the selection of a combustion engine is the best choice because it is according to use where this tool is used to handle fires in forest areas and densely populated urban settlements that are difficult to access by fire engines or fire extinguishers in general. The engine used is 63 cc with a power of 25 HP. The working principle of this portable pump is to utilize water pressure. The feeder pump, which is close to the water source, serves to push water into this portable pump, then this portable pump functions as a booster so that it can spray water with higher pressure. No less important is the frame design which is specially designed to be carried by humans. Figure 1 shows the design of a portable fire extinguisher selected from several design concepts that have been made. Structural analysis of the frame is carried out using the finite element method to ensure that the frame design can support the pump load. In addition to the frame, other components are designed to adapt to this portable device such as a shaft as a rotary drive from the engine to the pump impeller, a shaft adapter to connect between the pump and the engine and hold the bearing and shaft, a jet nozzle to transmit water flow and pressure, and coupling to connecting pump and hose. The components that have been prepared are then assembled into portable fire extinguishers for further testing to obtain data related to the distance of the water spray from both the vertical and horizontal sides. Figure 2 shows the piping and instrumentation diagram of the use of the tool for testing and operation where the feeder pump will push water towards the tool to be sprayed with the help of a portable booster pump and Figure 3 shows an illustration of the operation of the tool. Pump testing is carried out using a 30-meter-long hose and a 63 cc 25HP engine power.

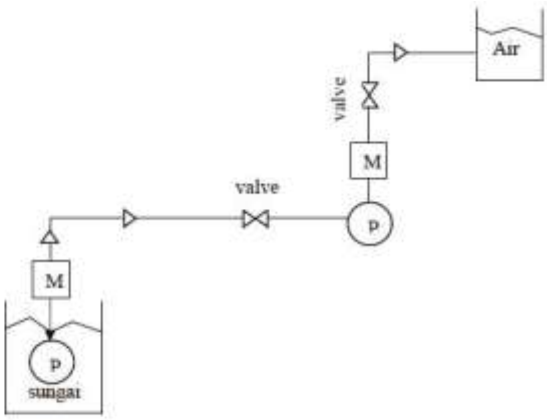

Figure 1, 2 PNID portable fire pump

Figure 3. Illustration of the operation of a portable fire pump

Antropometry Data

The frame design that is made must meet a high level of ergonomics so that users are comfortable using this tool it can be used for a long time. The method used in testing the framework to determine the ergonomic level of this tool is anthropometry [13].

Human height varies greatly between individuals and between populations for a variety of complex biological, genetic, and environmental factors [14]. Tests carried out to obtain anthropometric data were carried out by measuring human height, elbow height when standing, and outstretched fist height. The test was carried out on 5 Indonesians with varied heights as shown in the table below.

Table 1 Antropometry data for ergonomic test

Antropometry Data	Body Height (cm)	Fist Height when Standing (cm)	Elbow height when Standing (cm)
Subject 1	165	113	116
Subject 2	168	116	117
Subject 3	170	117	118
Subject 4	172	118	120
Subject 5	175	120	122

Rapid Upper Limb Assessment (RULA)

Evaluate the exposure of individual workers to ergonomic risk factors using the Rapid Upper Limb Assessment (RULA) method [15]. All steps are carried out, both Arm and Wrist Analysis or Neck, Trunk, and Leg Analysis to get the level of musculoskeletal disorder (MSD). The data from the test results with this method will be evaluated according to the level of risk as shown in the table below.

Table 2 Level of MSD risk with RULA method [15]

Score	Level of MSD Risk
1 - 2	Negligible risk, no action required
3 - 4	Low risk, change may be needed
5 - 6	Medium risk, further investigation, change soon
6+	Very high risk, implement change now

Recommended Weight Limit

In addition to the RULA method, the Recommended Weight Limit (RWL) test method is carried out to determine the safety level of the tool when used for a certain time without increasing the risk of low back pain [16]. RWL is calculated based on six variables, including horizontal location, vertical location, destination, angle of asymmetric, frequency of lifting, and coupling classification. The equation to determine the recommended load to be lifted by the user under certain conditions according to NIOSH is as follows

$RWL = LC \ x \ HM \ x \ VM \ x \ DM \ x \ AM \ x \ FM \ x \ CM$ [17]

The results of the RWL calculation will be used in calculating the lifting index (LI), where LI = Weight of the load/RWL.

Stress and displacement simulations are performed on the tool frame using the finite element method. Figure 4 shows the results of the simulation that has been carried out. Figure A shows the maximum stress received by the frame of 0.013 N/mm2 and Figure B shows no deflection that occurs when the frame is given a load of 15 kg. The simulation of strength and deflection in the frame of this tool must be supported by the use of an ergonomic tool so that it can be used comfortably and provides high mobility for its users. Apart from the strength of the frame, calculations are carried out to determine the head loss and the pressure coming out of

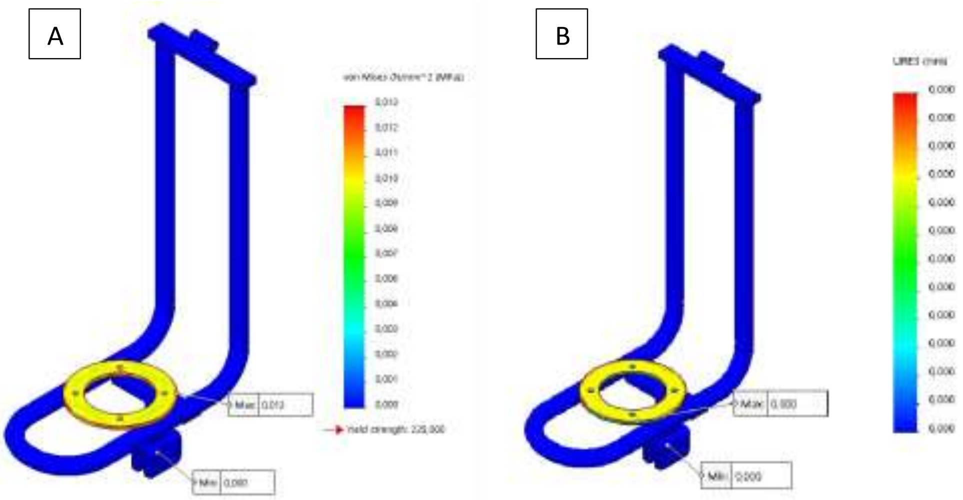

Figure 4 Stress analysis by finite element method

the nozzle to get a high jet of water over a long distance. With water property data, engine speed of 6800 rpm, discharge of 85 L/minute, and an interval of 30 meters, the total head loss value is 1.38 meters and the nozzle exit pressure is 2.6 bar. Based on the test results, this booster pump is capable of spraying water as far as 10 meters with a height of 15 meters as shown in Figure 5. The distance of the spray of water produced by this portable fire extinguisher is sufficient to reach hotspots that can be used especially in densely populated urban areas and also wilderness where at that location it is very difficult to be accessed by the fire department.

Figure 5. Water spray test

As an alternative fire extinguisher that can be used in areas that are difficult to reach by a fire engine, this tool must of course consider the ergonomic aspects and the risk of muscle injury when the user uses the tool to extinguish a fire. Based on the results of anthropometry tests that have been carried out as in the table below with a 5% percentile, the ideal user's body height to use this tool is 162 cm. While the fist height and elbow height when standing at 112 and 115 cm respectively are the ideal height for use by the user. This is important information regarding the design of the tool frame because the average height of adult men, especially in Indonesia, is 166 cm [18].

Table 3 Antropometry test result

No	Data Type	Number of Test	Average	Deviation	Upper Control Limit	Bottom Control Limit
1	Body height	3	168.3	3.51	175	161
2	Fist height when standing	3	115.3	2.04	119	111
3	Elbow height when standing	3	117.7	2.08	122	114

The table below shows the results of the Rapid Upper Limb Assessment (RULA) test data input. Based on these data, the overall score of using this tool is +4 where the risk level of musculoskeletal disorder is low but requires a design change so that the user does not experience injury.

Table 4 Test scor with RULA method

Step	Position	Score
1	Upper arm	2
2	Lower arm	1
3	Wrist	2
4	Wrist twist	1
5	Posture A Score	4
6	Add muscle use	1
7	Add force/load	3
8	Wrist and Arm score	8

Step	Position	Score
9	Locate neck	3
10	Locate trunk	2
11	Legs	1
12	Posture B Score	3
13	Add muscle use	0
14	Add force/load	0
15	Neck, Trunk, Leg Score	3

The tool load of 13 kg is likely to make the user experience low back pain if using this tool for a long time so it requires the selection of lighter materials to reduce the burden of this tool. To find out how likely low back pain will occur to users, in this study, a recommended weight limit was tested with test results as shown in Table 5.

Table 5 Recommended weight limit test data

Condition	Object Weight (kg)	H (cm)	V (cm)	D (cm)	A (°)	FM	CM	RWL (kg)	LI
Origin	13	30	0	93	0	0.84	1	28.77	0.45
Destinantion	13	30	0	93	0	0.84	1	28.39	0.46

Based on the results of the RWL test, the lifting index value is smaller than 1 which means that there is no risk of low back pain and the activities carried out will not cause injury

3. CONCLUSION

A portable fire pump that has been created as an innovation for fire extinguishers in certain areas has been successfully made. This portable fire pump can reach hotspots as far as 10 meters with a height of 15 meters. In terms of ergonomics, this portable fire pump will be easy to operate by users with a height of 162 cm but can still be used by users with a height of more than 162 cm or even below that height without causing muscle injury when used

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