Designing a Firefighter Motorcycle as an Effort to Provide an Early Response to Fire Disaster

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ABSTRACT

As an effort to mitigate the fire disaster especially in densely populated areas with very narrow accesses, the author attempted to design a firefighter motorcycle by fulfilling the minimum equipment requirements for a firefighter motorcycle. In the process of the design, the type of the pump, the pump clutch, the pump bracket, and the dimensions of outlet and inlet pipes as well as the placement/storage of the hose and the fireproof suit in the motorcycle became the factors that were put into consideration. The motorcycle was also equipped with other firefighting equipment which would not ergonomically interfere with the motorcycle's normal performance. This type of firefighter vehicle may be effective for such areas and suitable for an early response to the fire disaster due to its swift mobility to the fire location.

Keywords: *Firefighter Motorcycle, Fire Protection, Fire Disaster*

Introduction

A system that allows an early response to the fire disaster which frequently happens in densely populated areas needs to be created to minimize the loss experienced by the residents affected by the fire [1-5]. Especially in Jakarta Special Capital Region, the early response by the Fire Department Office becomes the determining factor for the success of the mitigation of such disaster. However, one determining factor, which is often neglected in the effort, is the access to the areas. In the capital city which is full of densely populated areas, the roads to such areas are often limited and too narrow for the fire trucks with certain specifications to access.

From the data taken from the official website of the DKI Jakarta Province's fire department office, from the beginning of 2017 until beginning of May 2017, there had been 169 incidents of fire disaster with substantial

ISSN 1823- 5514, eISSN 2550-164X
Received for review: 2017-05-10
Accepted for publication: 2017-06-01
Published: 2017-08-15

material loss [6]. Figure 1 shows the statistic of fire incidents and their different causes.

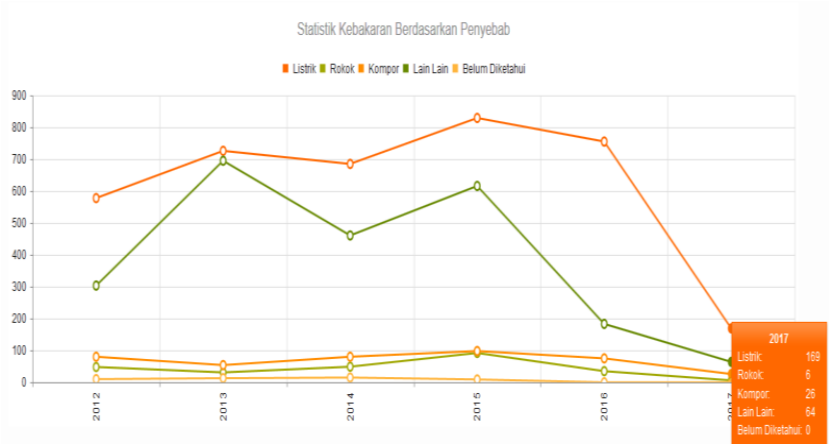


Figure 1: The graph for the fire statistics in DKI Jakarta until early May 2017 [6]

In a study case conducted in DKI Jakarta Province, the high number of population living in limited amount of lands available in the cities had limited the size of public open spaces and road access to densely populated areas. This creates difficulty for the fire trucks to access the areas affected by the fire. The scooter matic motorcycle is the perfect vehicle to be used in the basic design of firefighter motorcycle due to its flexibility in accessing narrow roads and therefore, can be used as the solution to the issue of narrow access to the densely populated urban areas when they are affected by the fire.

The design of firefighter motorcycle

Along with technological developments, social life support tools are becoming more practical and have high efficiency [7-9]. As design of *firefighting apparatus for Karba*, an Ankara-based vehicle-top equipment manufacturer [10] also the characteristic fire protection design of mountainous city and hillside building at Chongqing [11], both of them Indicates that social communities and urban environmental positions greatly influence the design of a fire fighting needs [1, 12].The main components of motorcycle firefighter adopt the main firefighter truck equipment based on NFPA 1901 standard. This can be explained as flow chart in Figure 2.

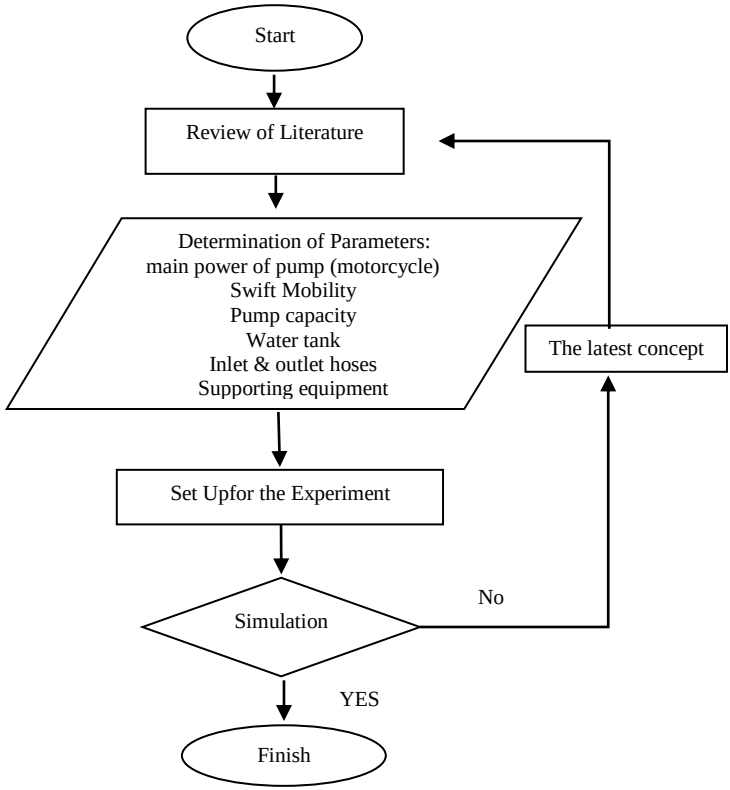


Figure 2: Flow chart of the design for the firefighter motorcycle

The calculation of the pump capacity, the power used to mobilize the pump, the inlet and outlet pipes and other supporting equipment is explained in the following sub chapter. The space available in the motorcycle was taken into account when calculation the dimension of the parts. This complies with the key requirements of the firefighting vehicles. The requirements also state the minimum equipment that the motorcycle must carry which can be seen in Table 1.

Table 1: The main equipment of the firefighter motorcycle

No	Name of equipment	Note
1	Fire extinguisher pump	mandatory
2	Water tank	mandatory (Not on motor vehicles but utilizing a water tank of residents at the point of fire)
3	Personnel protection	mandatory
4	Component protection	mandatory
5	Vehicle stability	fulfil the requirement
6	Cruise control	easy to control
7	Easy maintenance	

The specifications of the motorcycle

Based on the number of motorcycles available and the easiness of both male and female drivers, the scooter matic (automatic moped) type was selected. This type of motorcycle is more popular than the motorcycles with more manly features and the regular mopeds with manual transmission. Another advantage of this type of motorcycle is that during its immobile state, the motorcycle power is not used as the power to move the motorcycle or to move the wheels. The specification of the motorcycle can be seen in the Table 2.

Table 2: The Specification of the Scooter matic-Type Motorcycle

	Description	Remark
A.	**ENGINE**	
	Type of Engine	4 Steps, SOHC 2-Valve air cooler AIS (Air Induction System) EURO 2 Ready
	Diameter x Step	50.0 x 57.9 mm
	Cylinder Volume	113.7 CC
	Compression Comparison	8.8 : 1
	Combustion system	DC-CDI
	Transmission	V-Belt Automatic
	Gear Ratio	2.399 – 0.829
B.	**CHASIS**	
	Net weight	87 Kg
	Type of structure	Steel Tube
	Tank capacity	3.7 Liter
	Wheel radial	1,240 mm
	Distance to the ground	130 mm

C.	**PERFORMANCE**	
	Dimension (L x W x D)	1,820 x 675 x 1,050 mm
	Starter System	Kick & Electric
	Maximum Power	6.54 Km (8.9 ps) / 8,000 rpm
	Norm Torque	3.6 HP / 1,500 rpm
	Maximum Torque	7.84 HP / 7,000 rpm

Determination of the type of pump

In determining the type of pump used in the firefighter motorcycle, calculation was made based on the amount of power generated by the motorcycle when the engine was on without any load or when the engine was on, but the motorcycle was immobile. Based on the specifications of the motorcycle used in the prototype, the power generated by the motorcycle in its immobile state was 3.6 horse power / 1500 rpm in a normal rotation condition. In the normal rotation condition, the pump selected which was a centrifugal pump could still perform well.

The design of the firefighter motorcycles uses water (fluid) as the media for extinguishing the fire. Therefore, the calculation of the capacity of the centrifugal pump can use the following formula:

$$P = \frac{Q.H.\rho}{270\ \eta} \quad (1)$$

Where:

P = Power in horse power (HP) with 3.6 HP
Q = Debit or the capacity of the pump
H = Head of the total of the pump catalog
ρ = The specific gravity of fluid in kg/m^3
η = Efficiency in percentage (%)
270 = Conversion factor for the unit of power

Based on the power generated by the motorcycle, the selection of suitable centrifugal pumps is a 3.6 HP equal to 2.6 KW. The next one will be paired to the engine motor rotation used . This is based on the Equation 2.

$$1\ horse\ power = 0{,}7457\ Kilowatt$$
$$3{,}6\ HP = 2{,}6\ KW \quad (2)$$

The power that can be used is 2.6 KW, while in the market for the type of centrifugal pump with power close to that value is of 2.2 KW. So that the centrifugal pump to be mounted on the motor vehicle engine is 2.2 KW with specifications in accordance with the existing in the market in the Table 3.

Table 3: Specifications of selected centrifugal pump

No	Description	Remark/Spesification
1	Power	2,2 KW / 2,9 HP
2	Rotation	1450 rpm
3	pressure	3,2 bar (max)
4	Q max	500 l/menit
5	H max	18,5 m
6	Shead	9 m

Based on the calculation above, the selection of the pump is based on the debit or Q = 450 Liter /Minute (Max) with standard water temperature = 30^{o}C. Pressure 3.2 bar (Max), and the calculation of the maximum height is 9 m.

This type of pump is suitable to be used as a fluid pump. During fire, water (fluid) can only be used to extinguish Class A fire [8]. This type of pump, however, is not suitable to be used for other classes of fire as can be seen in the following table.

Table 4: Classes of Fire [8]

Class of fire	Descrption	Extinguising media
Class-A	Fire involving ordinary combustible materials like wood, paper, textiles, rubber, etc	Water
Class-B	Fire involving flammable liquids or liquefiable solids, such as oils, solvent, petroleum products, paint, varnishes etc.	Foam, Dry chemical powder, Carbon Dioxide
Class-C	Fires involving gaseous substances such as LPG Hydrogen etc	Dry Chemical Powder Carbon Dioxide
Class-D	Fire involving combustible metal such as Magnesium, Sodium Zinc, Titanium. etc	Special Dry Powders such as Temary Eutectic Chloride

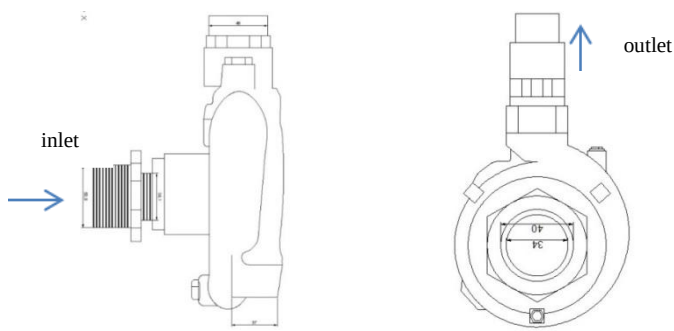
As can be seen in the Table, each class of fire has its own characteristics and specific management. Aside from Class A, other classes of fire rarely happen in densely populated housing areas.

Installation of the centrifugal pump in the scooter matic

This section elaborates how the motorcycle generates power to move the centrifugal pump. After the calculation of the capacity and the power needed for the pump was made above, the specification and dimension of the centrifugal pump can be determined (as seen Table 5). This dimension becomes the determining factor for the design of the connection between the pump and the motorcycle. In this design, the centrifugal pump is illustrated in Figure 3 (a) and 3 (b).

Table 5: Specification of centrifugal pump

Description	**Specification**
Pump picture with electric motor	
Dimension of pump casting (WxDxH)	222x158x284mm
Weight with motor electric	33,5 kg
Weight without motor electric	5,5 kg
Inlet/outlet	2 inch/2 inch



(a) (b)

Figure 3: (a) Centrifugal pump without electric motor from the right side (b) Centrifugal pump from the front side

From the illustration above, it can be seen that the inlet and outlet pipes have a certain dimension. This will ease the connection between the inlet and the outlet pipes of the pump as explained further below. Figure 4 shows the back side of the pump which connects the pump to the body of the

motorcycle. The center of pump is the part that spins the impeller of the pump and the four holes in the outer side are the places to screw tight the pump to the body of the scooter matic motorcycle.

The next step is the installment of the bracket to the body of the motorcycle. The bracket is placed right the moving part of the motorcycle to transfer the power by adding the clutch. The bracket is equipped with 4 screw holes to tighten the bracket to the motorcycle and right in the middle is the clutch hole which transfers the motorcycle power to the pump. The position of the bracket can be seen in Figure 5.

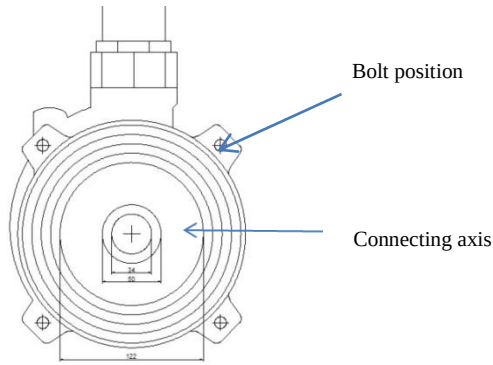


Figure 4: The back of the centrifugal pump

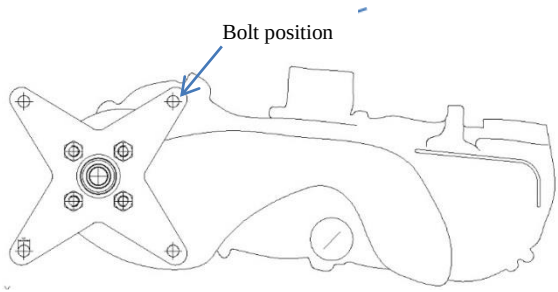


Figure 5: Bracket in the body of the motorcycle

Determination of the supporting equipment

As protection for the firefighters during fire, the following equipment must be made available as seen in Table 6. The weights and the dimensions of these supporting equipment need to take account the load capacity of the type of the motorcycle selected. The supporting equipment are stored in the box

behind the steer which would not interfere the functions of the motorcycle and which makes it easy for the motorcycle to head to the location of fire.

Table 6: Other supporting equipment

No	Supporting equipment	Storage in the motorcycle
1	A fireproof suit	Stored in the motor box
2	A fireproof helmet	Stored in the motor box
3	Fireproof gloves	Stored in the motor box
4	Fireproof shoes	Stored in the motor box
5	A fireproof blanket	Stored in the motor box
6	An axe	Stored in the motor box
7	A breathing apparatus	Personal equipment
8	A siren	Installed in the motorcycle

The storage of the firefighting equipment in the motorcycle

After the centrifugal pump, the outlet and inlet pipes, and the supporting equipment were selected and complied with the requirement; considerations were made for the storage of the whole equipment in the motorcycle. Easiness of handling without reducing the functions of the firefighter motorcycle, which is to extinguish fire by using water, had become the main consideration for the storage of the equipment as can be seen in Figure 6.

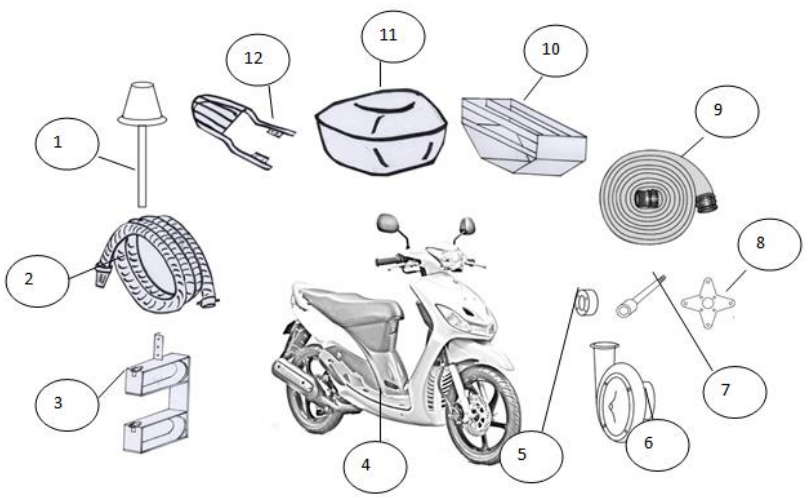


Figure 6: The parts required for the firefighter motorcycle

Each numbered part is explained in the Table 7.

Table 7: Parts in the firefighter motorcycle

No	Description	Specification/ placement
1	Siren Lamp	backside, adjacent to the box
2	Suction hose	diameter 2 inch, length 8 m
3	Suction hose bracket	handmade, custom
4	Scooter matic motorcycle	brand x
5	Pump axis bearing	-
6	Centrifugal pump	2,2 KW
7	Pump axis	custom
8	Pump bracket	custom
9	Rubber hose (outlet)	2 inch length 20m
10	Rubber hose bracket	handmade, custom
11	Box	Capacity 20 liters
12	Box bracket	handmade, custom

Then, the prototype of the motorcycle is shown in Figure 7.

Figure 7: The prototype of firefighter motorcycle

Result and Discussion

After assembling on the scooter matic, the centrifugal pump installation has little effect on engine performance, maneuverability and handling of motorcycle, while pump ability is affected by unstable engine performance. The ability of the pump thrust is shown in Table 8 and Figure 8 and Figure 9.

Table 8: Preliminary testing of firefighter motorcycle

No	Motorcycle rotation (rpm)	Pressure(bar)	Thrust average (m)
1	750	1,05	1
2	1000	1,18	1
3	1250	1,31	3
4	1500	1,39	4
5	2000	1,69	6

Figure 8: Firefighter motorcycle handling test

Figure 9: Preliminary test of motorcycle firefighter

Conclusion

From the explanation above, it can be concluded that the newly designed firefighter motorcycle can be used as an alternative to an early response of fire for densely populated urban areas. The specifications for the motorcycle are that it has to have a centrifugal pump and to fulfill the required dimension. Also, the type of inlet and outlet pipes has to adjust to the power used by the motorcycle.

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