Uhandisi Journal Vol. 23.1: 123-129 (1999)

PRODUCT INNOVATION THROUGH DESIGN METHODOLOGY: DEVELOPMENT OF A FUEL PUMP FOR MOTORISTS

E. Elias
Department of Mechanical Engineering
University of Dar es salaam
P. O. Box 35131 Dar es salaam, Tanzania

ABSTRACT

Design Methodology is a discipline of scientific engineering design for provision of solutions to user needs. It is composed of design models (showing the path/procedural steps of design) and design tactics (i.e. techniques, technologies and methods aiding the designer). When rigorously applied, design methodology leads to innovation of products and businesses.

The present paper describes how design methodology was applied to the development of a siphon device (Apump@) for motorists when in need to refill fuel in their vehicles away from petrol stations. The need for the device was realised through the method of Alooking around & deep thinking@ and through design steps a simple device, capable of providing a continuous flow of 7 - 10litres/min. was designed and manufactured. Preliminary promotion to possible users has collected very positive comments about the usefulness of the siphon.

It is concluded that there are many unrealised problems in our society which could be worked out for design solutions. These could be realised and designed for through Design Methodology.

INTRODUCTION

Design Methodology is a discipline of scientific engineering design which seeks to rationalise the design of products in meeting given user-needs. Design methodology in the context of systematics is composed of design strategy and design tactics. Design strategy, in terms of design activity models, suggests the general path (i.e. steps) in tackling a design problem, while design tactics are the suggested methods, techniques and principles that can facilitate the handling of different stages (activities) within the models.

Different design models have been suggested to aid the designer on his way to satisfying user demands[1, 2, 3, 4.] Models seem to converge to a common suggestion that a design process should be carried out iteratively through the following design core activities: Need analysis, formulation of a design specification, conceptual design, embodiment design, and detail design. Manufacturing and product sell as suggested by Pugh's model (figure 1), can also be considered as design activities because the designer is still involved at these stages by receiving any complaints or feedback needing his attention in design terms and in the product promotion.

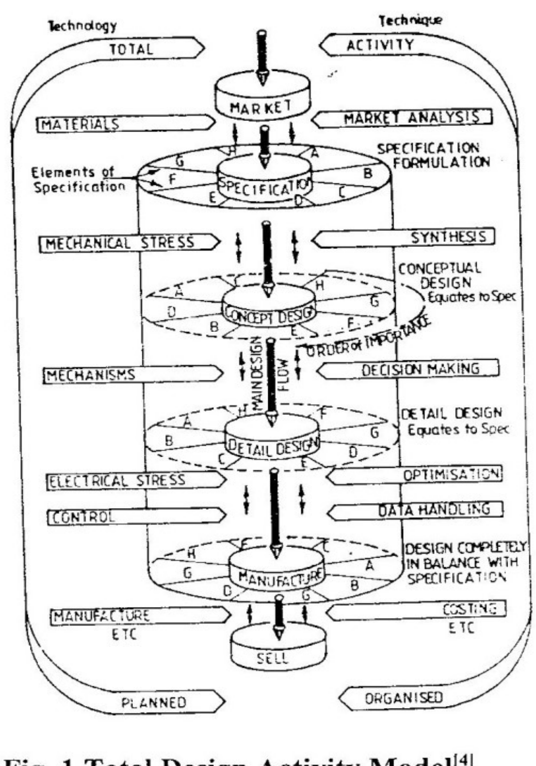

Fig. 1 Total Design Activity Model[4]

A variety of design tactics are in existence, they

Faculty of Engineering, University of Dar es salaam
P. O. Box 35131, Dar es salaam, Tanzania

spring from the imagination and creativity theories and technical knowledge from natural and human sciences. With increasing research and technological development (e.g. in computer application) many more will become available. Tactics can only be conveniently classified in accordance with the design core activities to which they are applied as design tools. The designer selects, devises and uses design tactics to satisfy the requirements of the design task in hand. Thus, we can generally have tactics for: Need or market analysis, specification writing and conceptual, embodiment and detail design.

In need or market analysis, for example, we have methods such as "*looking around & deep thinking*" and SWOT analysis for realising a need; parametric analysis, and matrix analysis for synthesizing and analysing collected market information. In conceptual design we have methods such as brainstorming and analysis of natural systems for generation of concepts and the Rating-Weighting and Controlled Convergence methods for concept evaluation. These are only a few examples of design tactics (i.e methods/techniques), it may produce an "*endless*" list to try and mention all of them.

Design methodology principles, when used rigorously, can lead to innovation of products and businesses. In other words, to be more specific, the application of design methodology:

Leads to realization of existing needs in the society requiring engineering solutions.

Increases insight into problems and prompts inventive steps towards generating solutions to the problems.

Introduces new products into the market and keeps them in competition, thus keeping business going.

Aids the review or assessment of product oriented business to show a need for improvement in parts or whole.

This paper describes how design methodology was applied to develop a fuel refilling pump for motorists.

DESIGN AND DEVELOPMENT OF A FUEL PUMP

Problem/Need Identification

The need for a refill fuel pump for motorists was realised by the present author through the method of "*Looking Around & Deep Thinking*" (author=s own naming). This is a method that a designer can use to create or realise or come up with a need that exists in society and that can be designed for, so as to serve the society. It is a simple but important innovation/invention tactic whereby a designer is expected to be in constant awareness with his/her surroundings and question his/her mind in design terms about any actions, products, processes, and technologies he/she comes across.

A system of questions needing solutions normally would take place in the individual designer's mind; for example:
Why is this job done this way?

Can a new design be devised to make the situation better (easier, more productive, etc.).

Can we have a competing product to the existing one on the market?

Can a new technology be applied to replace the existing product technology?

What need in the society can be designed for and bring success in terms of a small/medium business?

Can this (existing) idea/technology be used to solve a certain problem in society?

Normally, fuel is refilled at specific petrol stations with modern centrifugal pumps that draw from underground storage tanks. However, sometimes a car can run short of fuel far away from refuelling station. In this case refuelling must be done from small containers. In our society and probably in other developing countries, it is very common to find a car driver refilling his/her tank in this situation by applying "*siphon*" method. With one end of a hose pipe dipped into the fuel container, the driver sucks the other end by mouth to pull the fuel and allow it to flow into the car tank.

Sometimes motorists do not even have the hose pipe and what they would do is just to take a container of fuel and pour it into the car tank.

Through long-time observation, the author (designer) realised that the method used was not proper for the following reasons:

Possibility of the driver to drink the fuel during sucking, which may affect his/her health.

Wastage of fuel and therefore money through spillage.

Under this situation, it was found necessary to develop a hand pump which could be used by motorists for fuel refilling purposes, thus avoiding the above drawbacks of the current practice.

Design Specifications

It is always important to start designing by putting forward a list of design specifications. Specifications guide the design in terms of design requirements, limits, targets, etc. Without a design specification, one tends to forget the consideration of some design factors, thus leading the design to failure functionally or on the market (in competition). To make sure some factors are not left out, lists of design specification elements (or check list) have been suggested to guide the designer[4].

For the present design problem the following design specifications were put forward:

The hand pump should be easily operated.

The pump must be able to draw liquid fuel from a container into the car tank at a reasonable flow rate. A flow rate of about 10 litres/minute is satisfactory for a fast operation.

A continuous flow of fuel will be preferred to an intermittent flow.

Cheap readily available material shall be used.

Preferably, the material should be resistant to environmental attack or should be treated to provide protection.

Manufacturing costs of pump must be kept low. The price of the device on the market should not exceed Tshs. 30,000/=.

The pump should be light weight; not more than 20N, to enable the user to hold it comfortably during operation.

The pump should be small in size to enable holding by one hand during operation and also to enable storage together with other tools (e.g. spanners, jacks) in the car boot.

The pump external features should be neatly finished and attractive to customers.

The pump will be designed for general vehicle owners including individuals, companies and garages. Generally customers of this category have a reasonable purchasing power provided the item is useful to them.

The designed product will be free of competition; there is no similar device for motorists at present in our society.

Concepts generation and Evaluation

Concepts generation

Through literature search, studying existing pump designs, "*deep thinking*" and experience; three concepts (ideas) were generated within the available length of design time to satisfy the required function. These concepts are shown in Figures 2-4 and are briefly discussed as follows:

a.<u>Concept 1</u>:Direct action single valve reciprocating pump (Figure 2)
Working Principle: The upstroke of the piston creates low pressure in the cylinder for sucking fuel in through the inlet tube. During the down stroke, liquid pressure forces the valve to open and fuel to enter in the upper part of the cylinder. In the next cycle, liquid fuel is forced out of the cylinder through the outlet tube and more is drawn into the cylinder. The cycle will be repeated until the intended fuel has been filled into the tank.

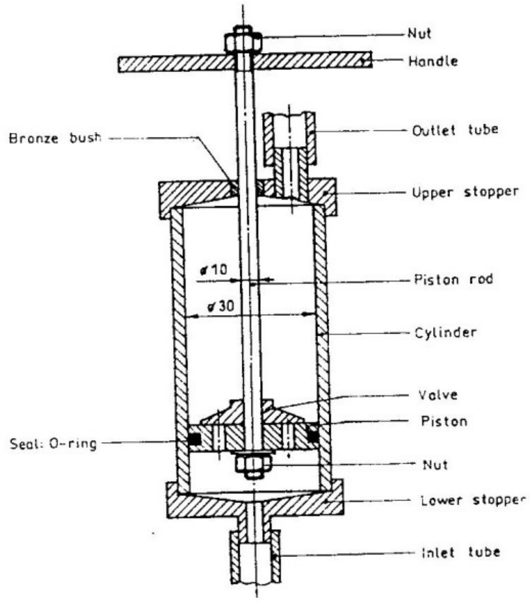

Fig. 2 Concept 1- Direct action single valve reciprocating pump

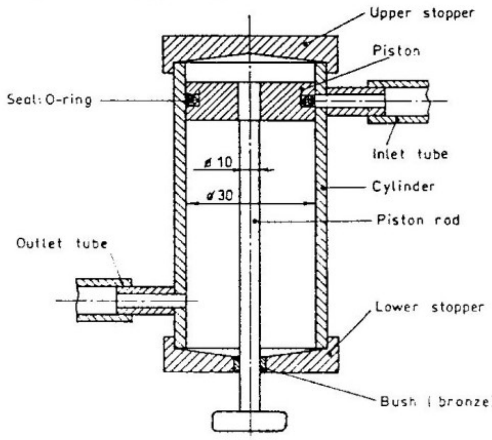

Fig. 3 Conccept 2- Single stroke gravity operated hand pump

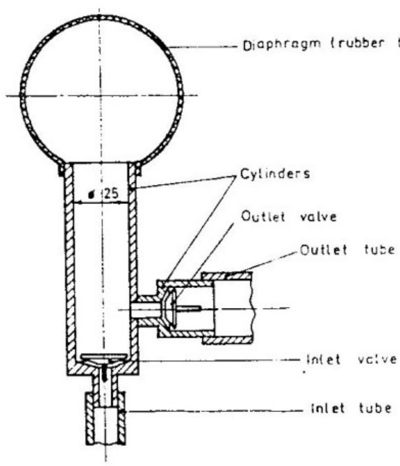

Fig. 4 Concept 3- Diaphragm suction hand pump

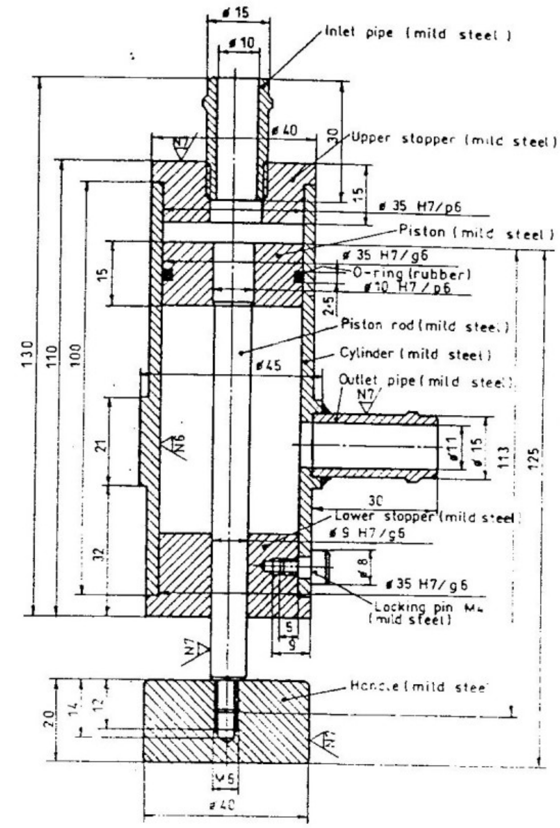

Fig. 5 Design drawing -Fuel hand pump (siphon)

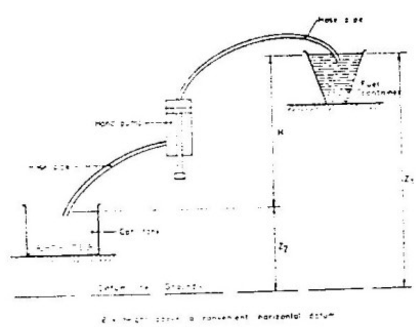

Fig. 6 Set up for measurement of fuel flow rate

b.Concept 2:Single stroke - gravity operated hand pump (Figure 3)
Working principle: The fuel container is required to be at a higher position than the car fuel tank to create a pressure head. Downstroke of the piston sucks fuel into the cylinder and as the piston is kept at the bottom of the cylinder, fuel will flow out continuously. At the end of the operation (i.e. when the intended fuel has been drawn) the piston is moved up to its original position to close the flow. For this kind of operation this design becomes a *"siphon"* rather than a pump.

c. Concept 3: Diaphragm suction hand pump (Figure 4)
Working Principle: Pressing the bulb at the first time forces the outlet valve to open while the inlet valve closes. Air then goes out through the outlet valve and tube . Fuel is sucked into the cylinder and bulb cavity as the bulb is released. The next cycle forces fuel to go out through the outlet valve and tube and the process is repeated until when the intended fuel has been drawn.

Concept selection

Selection Criteria

Concepts need to be evaluated against set criteria towards selecting the best solution for implementation. Selection criteria are mainly formulated from the design specifications. The following criteria were used for the selection process.

a.Low production cost
b.Continuous fuel flow
c. Materials availability
d. High product durability the fuel
e. Light weight container.
f. Small size
g.Good appearance/finish
h. Simple mode of operation
i. Ease or convenience of positioning

Selection Matrix

Two matrix methods of concept evaluation are commonly used, that is the Controlled Convergence and Numerate Decision Matrix [4, 5]. The Numerate Decision Matrix was used to evaluate the concepts as shown in Table 1. The following procedure was followed in the evaluation.

a. All criteria where given weights according to their importance, where importance was determined just by *"gut-feeling"* or judgement. All weights should always add up to 1.00 or to 100% in other words.

b. Next, all concepts were given marks to reflect how they fulfilled a given criterion. Marks were assigned by judgement under the following scale.
10 = Perfect, 9 = Near to perfect, 8 = Excellent, 7= Very good, 6 = Good, 5 = Average, 4 = Fair, 3 = Poor, 2 = Very poor, 1 = Near to useless,
0 = Useless.

c. Multiplication of the weight of a criterion and the marks gave the points scored by a given concept on a given criterion.

d. Summation of points scored on each criterion gave the total marks for a given concept.

e. The concept with highest marks was selected for development.

From table 1, concept 2 titled *"Single stroke gravity operated pump"* has the highest score. Therefore this concept was selected for further development.

Concept Development

The selected concept was embodied and developed through theoretical analysis for strength and buckling of piston rod and stress levels in cylinder against the action of working fluid pressure. At this stage, materials for different components were selected and the design finalised into the form presented in the Design Drawing, figure 5.

From the Design Drawing, component (detail) drawings were made to enable manufacturing of the prototype.

Manufacturing and Evaluation of Prototype

The Design Drawing (Figure 5) shows that most of the material selected was mild steel (St 37) which is readily available and is machineable. But with this material, the components must be electroplated for rust-prevention before the product is lauched into the market. The components are simple in design and therefore were machined mainly by turning and drilling/boring processes. The assembling of the parts was also simple and did not require any special tools.

After assembling, the prototype was tested to observe the flow rate in relation with the pressure head. For this purpose, two hose pipes, each 1 metre long, were connected to the inlet and outlet pipes of the pump. The hose pipe connected to the inlet pipe was then dipped into a filled fuel container and the outlet hose

Table 1: Concept Evaluation by Numerate Decision Matrix

NO.	CRITERION	WEIGHT W	CONCEPT 1		CONCEPT 2		CONCEPT 3	
			MARKS M	POINTS P=WXM	MARKS M	POINTS P=WXM	MARKS M	POINTS P=WXM
1.	Low cost	0.150	5	0.75	7	1.05	6	0.90
2.	Continuous flow	0.150	6	0.90	9	1.35	5	0.75
3.	Availability of Materials	0.100	7	0.70	7	0.70	5	0.50
4.	High product durability	0.125	7	0.875	8	1.00	5	0.625
5	Light weight	0.100	6	0.60	7	0.70	8	0.80
6.	Small size	0.075	7	0.525	7	0.525	8	0.60
7.	Good appearance	0.025	6	0.15	6	0.15	7	0.18
8.	Simple mode of operation	0.075	5	0.375	8	0.60	6	0.45
9.	Ease of positioning the fuel container	0.100	8	0.80	5	0.50	8	0.80
	TOTAL	1.00		5.675		6.575		5.605

pipe directed to an empty can (Figure 6 shows the arrangement). The piston rod was pulled a complete stroke and the flow observed at the outlet. The results are summarised as follows:

a.Setting about 300 mm minimum pressure head (H) for a hose pipe of diameter 12.5mm, produced a flow rate of about 7 litres/minute.
b.Only a single pull-stroke was sufficient to cause a continuous flow of liquid fuel.
c.A single push stroke also managed to cut off the flow efficiently.
It was further noticed that the increase in the pressure head increased the flow rate. Theoretical flow estimation showed that at a head of 300mm, the flow rate was expected to be 18 litres/minute. The *"pump"* therefore did not satisfy the theoretical expectations, mainly because of the following pressure losses:

Head losses due to friction in the hose pipes
Head losses due to bends in the hose pipes
Head losses due to sudden expansion as fuel enters the pump cylinder.
`Head losses due to sudden contraction as the fuel leaves the pump through the outlet pipe
However, the flow rate demonstrated practically above, is satisfactory for the purpose of refills that motorists need to do in emergency cases as described in section 2.1. Increasing the head slightly can provide the specified 10 litres/minute flow rate requirement.

Production Cost

Evaluation of cost incurred in producing a particular product is an important factor required to determine the price of the product when it is launched into the market. For this particular prototype, the production costs were as follows.

a.Cost of purchasing raw materials/parts
Cost of buying steel rods for manufacturing the parts was Tshs. 3,000/=
Buying a 2m long hose pipe at Tshs. 1,500/=.
Buying one O-ring at Tshs. 500/=.
b.Manufacturing cost
This includes labour and machine charge and was determined at Tshs. 8,000/=.
c. Miscellaneous costs (including electroplating cost and overheads) are estimated at Tshs. 8,000/=.
Total production cost = Tshs. 21,000/=. With a profit of about 25% the device can be sold at a price of Tshs. 25,000/=. The price would be much lower when mass production of the components is implemented.

Preliminary Promotion

A market survey was done through visiting different places and showing the product to the target groups (customers) and demonstrating its function before them. The objective was to let the possible customers know about the *"pump"* and to collet their comments and suggestions.

Places Visited

The following groups of places were visited for this purpose.
a.Motor vehicle companies
CMC Motors Ltd
Tanganyika Motors,
Tanzania Motors Services Ltd.,
UDA and D.T. Dobie & Company (T) Ltd.
b.Garages
A division of SSG South Consult Ltd.
Beny Auto Services and Enterprises-

(Temeke)
Faculty of Engineering Garage
Miscellaneous garages in Temeke

c. Car drivers
Places for this group included Buguruni, Temeke and others in DSM.

d.Petrol stations at Buguruni and City Centre

Gathered Recommendations/Comments

There were common comments and suggestions about the prototype across the places visited. These are summarised as follows:

About the function of the device

All those who were shown the prototype working liked the idea. The general comment was that it was a good idea/concept and would solve a lot of problems in transferring fuel or lubrication oil from drums into vehicle tanks. They suggested that if the device would be advertised/promoted, it could be marketable.

About the design/prototype

Most of the potential customers commented that it was somewhat heavy and should be made lighter by using plastics (e.g. PVC) or even wood.

There was a general leakage problem below the lower stopper (refer to figure 5). So, the general suggestion was to arrest the leakage through having a threaded joint, for example.

Future Plans on the Design

Following the good observations from potential customers, it is important to plan for further development and promotion of the *Apump*. The following is the plan:

To modify the design to prevent the observed leakages and to reduce weight. Reduction of weight may be achieved by using alternative materials, e.g. plastics or aluminium. The use of such materials further would enhance the aesthetics of the product.

To re-evaluate the product cost along with the modifications to be made.

To search and realise other possible applications of the pump, both industrial and domestic.

Full promotion/advertisement and introduction to the market.

SUMMARY AND CONCLUSION

The aim of the present paper was to discuss and demonstrate the importance and application of design methodology. In particular, the aim was to demonstrate how design methodology principles or techniques can be used to enhance product innovation. The technique of "*looking around & deep thinking*" has been applied in the present case to realise the need for a fuel pump to aid motorists in refuelling; and using further steps and techniques of design, a simple pump - a "*siphon*" has been innovated. It is important to point out that the problem started with a general demand for a hand pump, but the generation of concepts and the consequent selection ended up with a simple product - a siphon.

It is important to note from here that simple solutions to our problems are always within us, i.e. within our minds and around us, i.e. in our work/domestic surroundings. But they cannot come out to the surface to alleviate our needs if we do not have a process to make this happen! Design methodology is one procedure that can enable this. The designed siphon can be a useful device in our society and the present author believes that there are many needs out there unrealised for innovation. We can possibly bring them up and work them out for engineering solutions by "*looking around & deep thinking*".

REFERENCES

1 Pahl, G. and Beitz, W.; Engineering Design - A Systematic approach, The Design Council, London, 1984.

2 Hubka, V., Principles and Engineering Design, Butterworth Scientific, London, 1982.
3 French, M.J., Conceptual Design for Engineers, The Design Council, London, Second edition, 1985.
4 Pugh, S., Total Design - Integrated methods for Successful Product Engineering, Addison - Wesley Publishing Company, Wokingham, 1991.
5 Elias, E., Application of design methodology to the development of a knee and an ankle orthotic joints; Ph.D Thesis, University of Strathclyde, U.K., 1994