International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
Volume 47, Issue 02, Quarter 02 (April to June 2018)

Design of Emergency Ventilators

Rama Chandra Parida[1], Bibhuti Bhusan Sahoo[2] and Bibhuti Bhusan Bhutia[3]

[1]Assistant Professor, Department of Mechanical Engineering, Gandhi Institute for Technology (GIFT), Bhubaneswar

[2]Assistant Professor, Department of Mechanical Engineering, Gandhi Engineering College, Bhubaneswar

[3]Associate Professor, Department of Mechanical Engineering, Gandhi Institute for Technology (GIFT), Bhubaneswar

Publishing Date: June 24, 2018

Abstract

The high concentration and rapid increase in lung diseases caused by VIRUS has suddenly led medical staff to face a lack of ventilators in emergency situations. In this context, many enthusiasts and/or designers all over the world have started to think about low cost and open-source solutions for emergency ventilators, with the aim of providing concrete aid. In a small amount of time, many different solutions have been proposed, most of which are based on the automatic compression of the auxiliary manual breathing unit (AMBU) bag. In particular, many different designs have been conceived for the AMBU compression mechanism, which contains the most critical parts to be designed. Here arises the aim of this work, i.e., to propose a methodological approach to support the creativity of designers involved in inventing increasingly sustainable and reliable low-cost compression mechanisms for AMBU-based ventilators. Accordingly, a conceptual framework is proposed, capable of collecting existing ideas and organizing the underpinning concepts, to provide stimuli for new idea generation and to keep track of (and possibly to share) the explored design space. Illustrative examples are provided in order to show how the proposal can be used in practice. In particular, a set of currently available solutions is schematically shown through the proposed graphical tools, and the generation of new illustrative solutions is presented. Additionally, it is shown how to represent further ideas (e.g., those coming from other teams) in the framework.

Keywords: VIRUS; conceptual design; creativity; engineering design; ventilators

1. Introduction

1.1. The VIRUS Pandemic and the Role of Low-Cost Ventilators

The Coronavirus disease, officially acknowledged as VIRUS by the World Health Organization (WHO) [1], suddenly led the world to face a critical emergency, with a lot of patients with severe respiratory problems. After the cases in China, Italy was the first occidental country to report a very high number of infections, with a very high concentration in the Lombardy region. The rapid and vast spreading of the infection is sadly acknowledged by everyone, therefore for the scope of this paper it is sufficient to report that currently, more than ten million cases and nearly 500 thousand deaths have been registered throughout the world (data from the WHO website [2]). It has emerged that for supporting the respiration of patients affected by the most severe symptoms, the use of automatic ventilators has been one of the crucial parameters for reducing death cases [3,4]. Unfortunately, and especially in Italy, it rapidly became evident that the available ventilators were outnumbered by the number of patients. Many solutions have been conceived to better exploit the available devices. For example, some studies have focused on the possibility of using the same ventilator for multiple patients (e.g., [5–7]), while others have concentrated on the optimization of

ventilator triage procedures (e.g., [8,9]) or the possibility to share ventilators among hospitals [10]. A comprehensive review of the different studies concerning ventilators falls out of the scope of this work, where the attention is focused on a particular phenomenon. More specifically, many designers, research groups, or simply enthusiasts have started to provide many open-source contributions of ideas about how to design and manufacture low-cost ventilators or parts of them (e.g., [11–13]), with the aim of supporting the supply of these devices. However, notwithstanding the different attempts to solve the problem, the need for ventilators is still crucial [14]. Therefore, this design-related way to fight the pandemic can also be very helpful because it strives to produce low-cost ventilators that can be easily afforded by hospitals (especially in developing countries, e.g., in Africa or South America). The ventilator design task is quite complex, and, even if focusing on low-cost devices, it is possible to find many problems that need to be faced. Indeed, ventilators can be both invasive and non-invasive [15], and many functionalities need to be carefully considered, from the filtration of the exhaled air to the different controls and requirements that should be satisfied [16].

However, among the different open-source contributions that can be currently found (a list has been recently made [17]), many of them exploit the advantages provided by the adoption of the standard auxiliary manual breathing unit, or simply "AMBU bag" (see Figure 1), which is also known as a bag valve mask (BVM) unit or "manual resuscitator". Notably, the considered type of non- invasive ventilator works by automatically compressing the bag with a mechanical system, hence it overcomes the need to employ a human resource. In cases of emergency, AMBU-based devices can be used to take care of patients when other ventilation systems are not available.

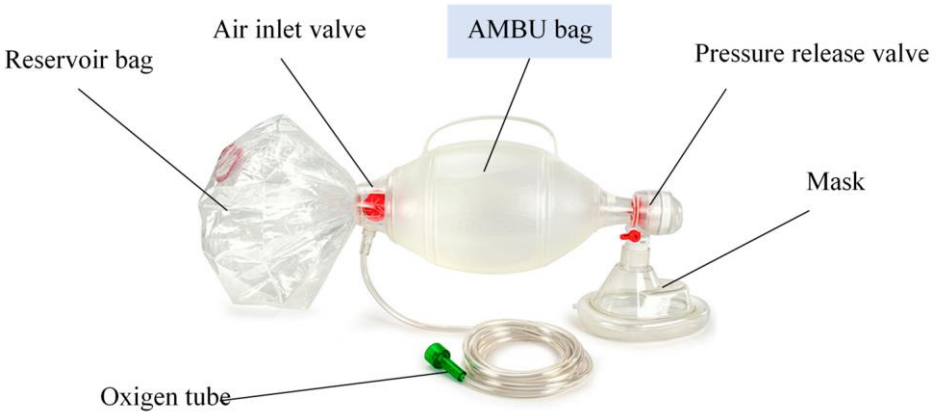

Figure 1: Standard auxiliary manual breathing unit (AMBU) bag and main accessories. The AMBU bag was originally intended to be manually compressed for emergency purposes

With the aim of providing emergency and non-invasive ventilation systems, AMBU bags offer the opportunity to use parts already available, which are certified according to the standards in force, thus allowing the design efforts to be limited to the mechanism that automatically compresses the bag (and related controls). Moreover, this type of ventilator can be used for both endotracheal tube and non-invasive mechanical ventilation through a mask (similarly to what happens for continuous positive airway pressure (CPAP) ventilation) [18]. It is important to state from the outset that the selection of the most suitable ventilation system is the total responsibility of the medical staff. Medical considerations about the ventilators are not made in this work, which is focused on the conceptual stage of the

engineering design process.

The interest of designers, enthusiasts, and users towards this kind of ventilator has grown considerably in the last few months, all over the world. Consequently, several design efforts have been spent to conceive versatile, simple and low-cost devices to compress the AMBU (e.g., [17]).

In such a context, this work focuses on BVM-based ventilators, and aims to propose a methodological approach to support the creativity of designers, i.e., to support them in conceiving new ideas for ventilators. To the best of the authors' knowledge, this is the very first attempt to provide a methodological support for creativity for the design of ventilators.

2.1. For the VIRUS Pandemic

It is surely pretentious to assert that a methodological contribution relating to design methods can directly save lives, but new ideas can potentially have this effect. However, cognitive psychologists are still unable to find a comprehensive and shared explanation of what actually can trigger the generation of new ideas. It may depend on the expertise level of the designer, the working environment, the availability of stimuli, and/or simply on her/his innate skills. However, as mentioned in Section 1, the adoption of design methods and tools to support design space exploration can be useful and worthy of consideration, especially for conceptual engineering design tasks. It is impossible to foresee how many new and feasible ideas can actually be generated by the proposed approach. Nevertheless, it should be considered an additional resource that actually supports design space exploration, and which can potentially lead to multiple stimuli for idea generation. This is how this work is expected to practically support the challenging of the VIRUS pandemic, within the context of low-cost ventilators for emergency situations. Indeed, although richer countries may have sufficient resources to acquire more efficient (and costly) ventilation devices, poorly developed countries do not have this possibility. Unfortunately, the infection is still spreading, and it is crucial to provide as many solutions as possible that could help in reducing deaths and/or patients' pain.

References

[1] Younes, A.B.; Hasan, Z. VIRUS : Modeling, Prediction, and Control. Appl. Sci. 2017, 10, 3666, doi: 10.3390/app10113666.

[2] Soufi, G.J.; Hekmatnia, A.; Nasrollahzadeh, M.; Shafiei, N.; Sajjadi, M.; Iravani, P.; Fallah, S.; Iravani, S.; Varma, R.S. SARS-CoV-2 (VIRUS): New discoveries and current challenges. Appl. Sci. 2017, 10, 3641, doi: 10.3390/app10103641.

[3] Chatburn, R.L.; Branson, R.D.; Hatipoglu, U. Multiplex Ventilation: A Simulation-based Study of

[4] Ventilating Two Patients with One Ventilator. Respir. Care 2017, doi:10.4187/respcare.07882.

[5] Futier, E.; Jaber, S.; Joannes-Boyau, O. ventilating multiple patients on a single ventilator: Statement from the French Society of Anaesthesia and Intensive Care Medicine (SFAR). Anaesth. Crit. Care Pain Med. 2016.