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Multiple vibrating plates of sound suppression mask for minimizing tics impulse acoustics of Tourette's patients

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ABSTRACT

Tourette syndrome is an inherited neurophysiologic disorder with onset in childhood, characterized by multiple physical (motor) tics and at least one vocal (phonic) tic. Between 0.4% and 3.8% of children ages 5–18 may have Tourette's; the prevalence of other tic disorders in school-age children is higher, with the more common tics of eye blinking, coughing, throat clearing, sniffing, and facial movements. This paper is mainly focused on a novel multilayer vibrating plate design in conjunction with the 3D scanned data/3D printed fabrication process for the customized face features. The field test results revealed an effective sound suppression capability in terms of the amplitude of sound pressure can be fulfilled in the range of 69–99% for the frequency range 100–1800 Hz. The sound suppression performance of customized mask is shown to be superior to that of any commercially available mask in the market. Therefore, the design goal is successfully accomplished to design and develop an alternative low-cost, damped vibrating plate structure for the patients of Tourette's syndrome.

1. Introduction

Tourette disorder is a chronic neurologic disorder characterized by motor and vocal tics. Prevalence estimates in school-aged children range from 1 to 10 per 1000, with a rate of 6 per 1000 replicated in several countries. Tics are usually brief, rapid movements (e.g., blinking, facial grimacing) or vocalizations (e.g., throat clearing, grunting) but can include more complex movements and vocalizations [1]. The prevalence rate of Tourette's syndrome was around 0.56%. The ratio of male to female was 9–2. The comorbid rate of attention deficit hyperactivity disorder was 36%, self-injurious behaviors 27%, and obsessive-compulsive behaviors 18%. When tics are so severe that medication is necessary, haloperidol is no longer the first or only choice. We tried clonidine, atypical neuroleptics such as risperidone or olanzapine, or pergolide [2].

On the properties of sound absorbing materials, the nonwoven sound absorbent systems such as micro-fiber, nonwoven fabrics and textile materials [3–7] were intensively investigated in the past and the fiber sizes/types/fiber cross section/thickness/density and porosity can drastically change the absorption behavior. Other novel sound absorption materials also demonstrated the potentials in terms of acoustical characteristics such as Shoddy-based absorbers [8], natural bio-based fiber-reinforced polymer composites [9], recycled textile absorption-barrier-absorption (ABA-cotton) panel and recycled textile DL (DL-cotton) panel [10], fibers from the oil palm empty fruit bunch (OPEFB) [11], waste materials (rubber particles, polypropylene, crumbled plastic, wood flour, jute and cord fabrics) with different backing plates (plasterboard, oriented strand board – OSB, polystyrene) [12]. The most recent investigation of the membrane type acoustic metamaterials has been proposed and the measurements demonstrated the possibility in practice of aerospace vehicles [13].

Concerning the effective measures of sound suppression, the low frequencies (<1000 Hz) are the most difficult to achieve due to the resonance effects associated with the creation of stationary waves within the acoustic chambers.[14] The standard measurement of the sound absorption property is the impedance tube method or impedance tube interferometer [15,16]. On the other hand, acoustic absorption can be a complicated phenomenon and heavily involved not only the material properties, but also the structural variations. For example, 3D crimped hollow polyester was reported to considerably affect the average absorption coefficients, particularly at low-mid frequency range [17]. Therefore,

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the finite-element (FE) method can be an effective tool in the design process of acoustical properties [18]. In particular, the FE model is used to determine an optimal position of the external microphone and to obtain estimates of exposure levels using the left and right ear exterior microphones [19].

2. Design concept

Coprolalia (the spontaneous utterance of socially objectionable or taboo words or phrases) is the most publicized symptom of Tourette's, but only 19.3% of male and 14.6% of female Tourette's patients exhibit it. People with Tourette Syndrome often feel immense anxiety about expressing their tics, particularly when they have vocal tics or coprolalia. This anxiety may make symptoms worse for some people, and frequently leads to social isolation. If we can design a mask to reduce the intensity of vocal tic or coprolalia, the patients with Tourette syndrome will have a better life quality. In this study, we specially design several customized masks with multilayer vibrating plate design and face features of silicone rubber for different acoustic absorption parameters, such as configurations of elliptical and rectangular shapes and associated resonance parameters. Acoustic barriers made of multilayer vibrating plate can have superior sound suppression capability. According to the best knowledge of the authors, the reported masks for acoustic absorbing materials have not been discussed by other researchers.

Fig. 1 schematically shows structures of the customized mask design, which includes a series combination of 5 layers of copper foil and/or stainless steel sheet metals, intertwined with nonwoven cloth layers. There are three design variants to be investigated in this study, i.e., design A, B and C respectively. Design A prototype of sound suppression mask consists of a basic module of five layers of copper foil (PK-DSS-LLP, LCY Technology Crop., Taiwan, rectangular dimension of 54 mm × 36 mm × 0.2 mm) and five layers of stainless steel plate (304 stainless steel, Yuan Long Stainless Steel Corp., Taiwan, elliptical dimension of long/short axis and thickness of 54 mm × 36 mm × 0.2 mm) as well as nonwoven cloth (Polyester Felt, Jhih Cheng Non-woven Co., Ltd., Taiwan, rectangular dimension of 20 mm × 20 mm × 0.1 mm) (Fig. 1(a)). Other design variants also include design B, which is structurally composed of basic module of above-mentioned five layers of copper foil/stainless steel plate/nonwoven cloth. The major difference lies in the geometrical shape covering the nose part (Fig. 1(b)). Similarly, design C consists of the configuration of multilayer vibrating plate design, with a face-fitting silicone rubber seal (Fig. 1(c)). The overall design of the sound suppression mask is schematically depicted in Fig. 1(a)–(c) for the top and bottom views respectively. In order to provide a good sound suppression mask and ensure the vibrations for a wide range of frequencies, the multiple layers were specifically designed and face-customized mask of 3D printed (Smart Bot SQ, Ming Yang Technology Crop., Taiwan) using the thermoplastic elastomer (PLA, Ming Yang Technology Crop., Taiwan) was individually printed as the cover mask. The sound suppression concept works in a way that when the vibrators in different compositions and dimensions (copper foil, stainless steel, nonwoven cloth) are acoustically actuated, the vibrators will resonate and dampen the tics impulse of Tourette's patients, thus assisting in effective sound suppression.

Fundamentally, the thickness of masking materials and sound transmission is directly proportional, but it is also closely related to the frequency (spectrum dependent). However, increasing the thickness is of little effect if the frequency of incidence sound wave (length) exceeds the sound absorber thickness. Furthermore, the sheer physical dimension is prohibitive to be used for any wearable

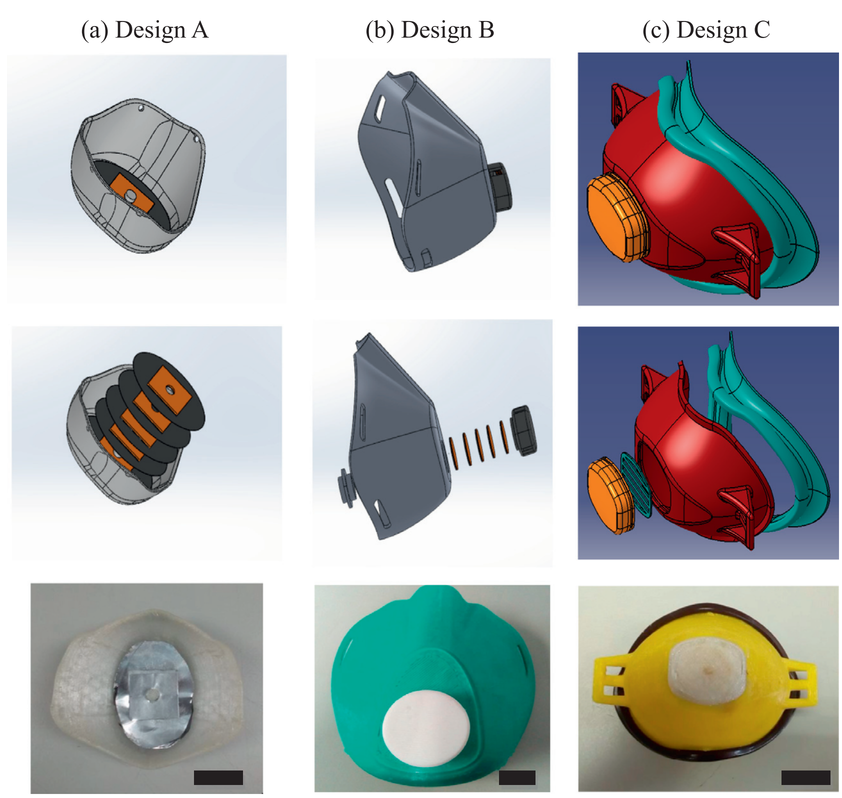

Fig. 1. The customized mask design including multilayer vibrating plate design (a series combination of 5 layers of copper foil and/or stainless steel sheet metals/nonwoven cloth as the acoustically damping vibrators) (a) The customized mask of design A, (b) The customized mask of design B and (c)The customized mask of design C. All scale bars are 2 cm.