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Vibration characteristics of golf club heads in their handheld grinding process and potential approaches for reducing the vibration exposure

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ABSTRACT

To control vibration-induced white finger among workers performing the fine grinding of golf club heads, the aims of this study are to clarify the major vibration sources in the grinding process, to identify and understand the basic characteristics of the club head vibration, and to propose potential approaches for reducing the vibration exposure. The vibrations on two typical club heads and two belt grinding machines were measured at a workplace. A simulated test station was also constructed and used to help examine some influencing factors of the club head vibration. This study found that the club head vibration was the combination of the vibration transmitted from the grinding machines and that generated in the grinding process. As a result, any factor that affects the machine vibration, the grinding vibration, and/or the dynamic response of the club head can influence the vibration exposure of the fingers or hands holding the club head in the grinding process. The significant influencing factors identified in the study include testing subject, grinding machine, machine operation speed, drive wheel condition, club head model, mechanical constraints imposed on the club head during the grinding, and machine foot pad. These findings suggest that the vibration exposure can be controlled by reducing the grinding machine vibration, changing the workpiece dynamic properties, and mitigating the vibration transmission in its pathway. Many potential methods for the control are proposed and discussed.

Relevance to industry: Vibrations on handheld workpieces can be effectively transmitted to the hands, especially the fingers. As a result, a major component of the hand-arm vibration syndrome - vibration-induced white finger - has been observed among some workers performing the grinding and/or polishing tasks of the handheld workpieces such as golf club heads. The results of this study can be used to develop more effective methods and technologies to control the vibration exposure of these workers. This may help effectively control this occupational disease.

1. Introduction

Sanding, grinding, and polishing processes of handheld workpieces are important steps in the manufacture of some parts or components of machines, tools, sport equipment, and furniture. The fabrication of denture also requires performing dedicated sanding or grinding of fingers-held or handheld workpieces (Kaulbars, 2014). Such processes may generate significant vibrations of the workpieces, which may be effectively transmitted to the fingers or hands of the workers holding the workpieces. Prolonged, intensive exposure to such vibrations may cause hand-arm vibration syndrome (Griffin, 1990). A recent study reported that a significant prevalence (>12%) of vibration-induced white finger (VWF) (a major component of the syndrome) was found among workers performing the fine grinding and polishing of golf club

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heads (Chen et al., 2015). Effective interventions are required to stop such an occupational disease from spreading to more workers.

Important steps towards the objective intervention include clarifying the major sources of the workpiece vibrations, identifying and understanding their characteristics and influencing factors, and developing and applying appropriate methods and technologies to effectively reduce the vibration exposure. While the vibration sources and characteristics of many tools have been reported and some effective technologies have been developed to reduce the vibrations of tool handles, the vibration exposures of handheld workpieces have not been sufficiently studied. A literature search for this study found only scattered information on the vibrations of handheld workpieces (Ikeda et al., 1998; Kaulbars, 2014; Chen et al., 2015; Lin et al., 2015). While the frequency-weighted accelerations of some handheld workpieces were measured and reported in these studies, their vibration spectra were not measured or reported. Without such information, it is very difficult to clearly identify the vibration sources and influencing factors, characterize the vibrations of the handheld workpieces, and formulate or develop a set of effective methods to control the vibration exposure. As a result, it is unclear how to reduce the magnitudes of vibration from the grinding and polishing processes and how to minimize transmission of vibration to the hands of workers.

The objective of this study is to enhance the foundation for the further developments of effective methods and technologies to control the vibration exposure. Specifically, the vibration spectra of typical club heads are measured during their handheld grinding process at a workplace, together with the measurement of the vibration spectra on typical grinding machines. The machine and club head vibration spectra are used to identify and confirm the vibration sources. The club head vibration spectra are also used to calculate the frequency-weighted vibration spectra and the acceleration value defined in ISO 5349-1 (2001). The factors examined in this study include finger coupling force, grinding drive wheel condition, grinding machine foot pad, machine operation speed, vibration measurement method, etc. A simulated workstation of the grinding process is also constructed and used to help the examination. Based on the identified vibration sources, characteristics, influencing factors, and our understanding, a set of potential approaches for reducing the vibration exposure of the workers performing the grinding tasks of the club heads are proposed and discussed.

2. Methods

2.1. The nature of fine grinding and polishing processes for manufacturing golf club heads

Currently, the major manufacturing processes of a golf club head usually include casting, fine grinding, and final polishing. Fig. 1 shows an example of the fine grinding of a golf club head conducted at a typical workstation in a sport equipment manufacturer in Guangdong, China. Belt grinding machines are generally used in the grinding process. Each club head is held primarily by the fingers of both hands during the grinding or polishing process. Many of the grinding workers are paid based on the number of processed club heads and the workers are usually very productive. To make the grinding process efficient, they must quickly find the right location and orientation of the head surface to be ground and to apply appropriate push and grip forces for a certain time. The workers also often change the grinding location and orientation of the piece during the grinding process based on their observations, perceptions, and experience to achieve the desired result. Some workers also quickly swing and move the club head around to achieve the desired grinding quality. A quick measurement of the workpiece dimensions before and/or after the grinding is also occasionally performed to assure the required dimensions. These operations require dexterity of the fingers. As anti-vibration gloves certified according to ISO 10819 (2013) may largely reduce the finger dexterity and increase the grip effort (Wimer et al., 2010), the workers doing the fine grinding do not wear such gloves but they wear

Fig. 1. A worker is grinding a golf club head at a typical workstation with a belt grinding machine (with a large drive wheel) in a sport equipment manufacturer.

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