Forensic Science International 273 (2017) 132–139

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

The development of a stabbing machine for forensic textile damage analysis

Natasha Benson[a], Robson Oliveria Dos Santos[a,b], Kate Griffiths[c], Nerida Cole[a], Philip Doble[a], Claude Roux[a], Lucas Blanes[a,*]

[a] University of Technology Sydney, Centre for Forensic Science, PO Box 123, Broadway, NSW 2007, Australia
[b] Department of Engineering, Architecture and Agricultural studies, University of Santa Cruz do Sul, Santa Cruz do Sul, RS, Brazil
[c] Specialist Operations, Australian Federal Police, GPO Box 401, Canberra, ACT 2601, Australia

ARTICLE INFO

Article history:
Received 24 October 2016
Received in revised form 6 February 2017
Accepted 14 February 2017
Available online 22 February 2017

Keywords:
Stabbing Machine
Textile damage
Arduino
Stab
Knife

ABSTRACT

This article describes the development of a horizontal stabbing machine with an interchangeable knife holder to simulate stab events. The machine consists of a motorised arm with a pneumatic system designed to deliver 60 unique stabbing positions. The mechanics were robust and the positioning system highly reproducible with standard deviations of less than 1.0 mm in the x-axis and 2.3 mm in the y-axis for a given stab position. The force of the instrument may be varied by the operator to a maximum of approximately 221 N. The suitability of the instrument for simulating stab events was evaluated by measuring the severance length and textile damage from stab delivered from four different knives and nine penetrating angles.

1. Introduction

Stab injuries and fatalities are common crimes of violence in several countries, particularly those where access to firearms is restricted including Australia, Scandinavia and the United Kingdom [1]. For example, in Australia, more homicide victims die from stab wounds than from any other single cause. The total number of homicides that were attributed to knives and sharp implements peaked in 2006–2008 to 43%, and has remained consistent on average until 2011 [2,3]. Analysis of damage to the victim's clothing such as cuts and tears caused by a weapon may provide important forensic information [4,5]. Characteristics of the knife and how it is used are major determinants of damage patterns in clothing. The blade tip type, blade tip angle, cutting edge, spine of the blade and the knife handle may determine the damage appearance. Consequently, comparisons of severance lengths and distortion in the fabric around the damage site have the potential to be linked to a knife type [1,4–6]. Other factors that contribute to textile damage include environmental conditions, the stab action, penetration angle, properties of individual textile samples and the condition of the garment [4,5,7]. In addition to these factors, differences in the force of the stabbing action may contribute to variations in textile damage. Layering textiles can increase the force required for penetration into a simulant, where an additive effect is observed greater than two differing individual textiles [8–10]. G. Nolan et al. in 2012 found that cotton on denium increased the penetration force into the simulant by 21 N, which was not necessarily equivalent to the addition of the two individual forces of individual textile type force penetration, consistent also with A. N. Annaidh et al. study also in 2012; where the addition of cotton over denim increased force of penetration by approximately 10%.

Performing manual experiments is the most common method of simulating textile damage [11] and has been applied to a range of knives and textile types [12–14]. This method has specific applications for the examination of the effects of the natural wrist rotations and hand positioning during the stab motion on textile damage; these aspects are difficult to replicate using mechanical means [11–13,15]. Simulated stabbing has also been used to measure entry speeds of penetration for a range of stabbing actions [16]. However, there are inherent errors in experiments where humans perform the stabbing action such as reproducibility of angles, forces and the differing deliveries of the stab action of individuals may lead to errors, distortions and a lack of reproducibility in textile damage and severance lengths [12,13,17]. Consequently a mechanical method of performing stabbing simulations experiments would be advantageous.

* Corresponding author.
E-mail addresses: Natasha.benson@student.uts.edu.au (N. Benson), robsonos@outlook.com (R.O. Dos Santos), kate.griffiths@afp.gov.au (K. Griffiths), ncole@swin.edu.au (N. Cole), Philip.doble@uts.edu.au (P. Doble), Claude.roux@uts.edu.au (C. Roux), lucas.blanes@uts.edu.au (L. Blanes).

http://dx.doi.org/10.1016/j.forsciint.2017.02.013

Mechanical simulations of stabbing events are not currently used in forensic laboratories but have been the subject of many recent reports. They have predominantly been used to measure the forces generated during penetration of a substrate, such as pork skin or polyurethane, and the textiles [6,7,9,10,14,18,19]. A range of mechanical systems have been described, including a Rosland drop-down tower [10], a Tinus Olsen Universal testing machine (for quasi-static tests) [14], and a Biaxial Testing Device [14,17,19]. Using a drop down system, unused identical (same brand and model) knives could show up to 100% variability in the minimum and maximum penetrating forces; This potentially reflects the lack of quality control during manufacture of the blade tip profile, which notable differences in the virgin identical knives were observed on visual inspection and the use of scanning electron micrographs [14]. Variability in penetration forces of simulant skin can also be associated to sample variation (specifically thickness) and the angle of blade relative to the direction of the skin [14]. Sturdy and fixed holders for stabbing implements reduced variation in results associated with angles [10,19]. Due to the reproducible 'stab' action of mechanical methods, severance lengths are consequently consistent for the same of textile types and blade [17]. In contrast, a spring loaded stabbing apparatus was utilised to assess the physical characteristics of textile damage for a range of knives on various fabrics, and the underlying skin in a downward stabbing action [21]. Statistical differences were found in the textile damage profile depended on the tension (loose or tight) of the textile over the skin simulant.

The use of a stabbing apparatus in forensic textile damage simulation experiments will improve current practices by offering a standardised means of testing weapons of interest. Many of the mechanical stab machines described in the literature removed the handle in order to mount the blade to the instrument [6,14,17,20], which is not feasible in an operational forensic laboratory. Current mechanical stab machine designs [6,10,14,17,19,21] are unable to examine the angle of penetration and the resulting effect on textile damage.

In this article the development of a computer-controlled machine for simulating stabbing actions for forensic analysis is described. The instrument is designed to overcome limitations to current designs, with simple interchange of weapons simulating a reproducible human-based stab action. The instrument has the ability to deliver variable force of penetration and retraction, adjustable angles of penetration and change of orientation of the knife or implement.

2. Materials and method

2.1. Mechanics

The stabbing machine was constructed using a double acting pneumatic actuator (CDM2B20-200; SMC, Japan) that extends and retracts a 200 mm arm when compressed air is fed through ports via nylon tubbing (8 mm id blue; Part number SFN08/060B HosesDirect, UK). The movement of the actuator is controlled by a 5 way 2 position pneumatic solenoid valve (Testco, USA). A flow control valve was used in tandem with a generic $^{1}/_{4}$ inch pressure gauge to control and monitor the applied pressure. Fig. 1 illustrates the pneumatic system used in the stabbing machine.

The knife holder is a clamp fixed in place by an aluminium customised mount that is fixed to the arm of the pneumatic actuator. A knife is secured in the desired orientation by the clamp, which is tightened before the knife handle is locked into position from the top by a rubber sided aluminium plate and six butterfly screws. This ensures that the knife position does not change throughout the stabbing process. This design allows a range of knife handle shapes and lengths to be tested by this machine.

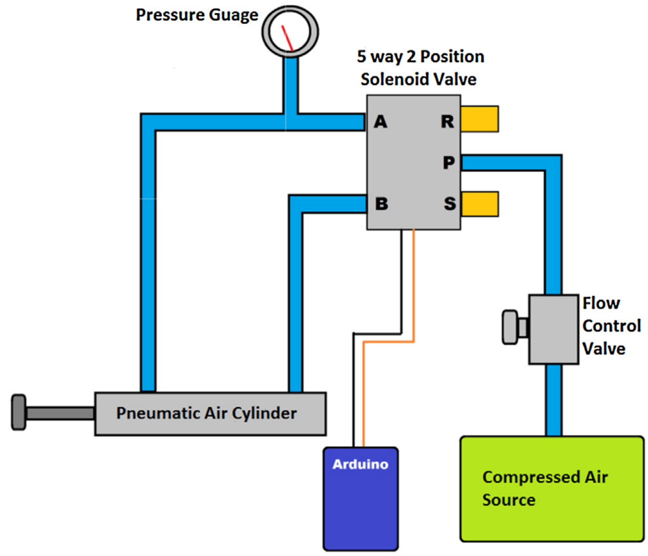

Fig. 1. Diagram of the pneumatic system. R and S are silencers that control the speed of pressure and the compressed air source.

Positioning of the blade for a 'stab' action is provided by a HY-5 axis table H-Workbench CNC rotary table (Guangzhou, China) fixed upon a XY-axis stage providing movement along the x-axis, and pivoting of both the x-axis and y-axis. The HY-5 axis table is responsible for two movements; tilting 23° upwards and downwards, and rotating left and right by a maximum of 30°. A generic XY-Axis stage moves along the X axis 7 cm from the origin to the left or right. Six touch switches were fixed onto the outer surfaces of the moving platforms to limit the mechanical movements.

2.2. Electronic and software

An Arduino Mega 2560 microcontroller, was programmed in C++ language. The coding was developed in an open source Arduino 1.6.5 Integrated Development Environment (IDE) [22]. The code integrates four individual codes that control the functions of the display screen, the stage axes, the stab function and calibrations. Graphical User Interface (GUI) software was developed in Luna Eclipse, using Java Language, which interfaces with the Arduino Mega microcontroller. Two power supplies (24 and 12 V) power the electrical system, which is comprised of seven sensors, three 23 Nema Motors, three M335 motor drivers, a solenoid valve, two push buttons, an emergency stop button and an LCD display. The program Eagle 7.2.0 was used to design two circuit boards. Fig. 2 shows a simplified diagram of the electronic system of the stabbing machine.

2.3. Stabbing machine

Due to size and weight constraints of the components of the stabbing machine, it was encased within a 1020 × 700 × 615 mm acrylic case. A folding door allows access for changing fabric samples, simulant backing and knives. The front panel houses the LCD display, pressure gauge, an emergency stop button, and two buttons that when depressed activate the stab action of the arm. The right side of the acrylic housing contains the power button, a USB connector, and a solenoid valve for air pressure input. Fig. 3 shows the instrument.

This stabbing machine has 15 stabbing positions in the x–y plane. Rotation of orientation of the knife in the knife holder of 90° intervals, using the 3 × 3 grid stab regions provides an additional