UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

EFFECTS OF TORQUE DIRECTION, SHAPE, SIZE, SENSATION AND TECHNIQUE ON PINCH FORCE

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DECLARATION

I declare that this thesis entitled "Effects of Torque Direction, Shape, Size, Sensation and Technique on Pinch Force" is the result of my own research except as cited in the references. The thesis has not been accepted for any other degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ....

Date : ....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATION

To my beloved mother and father

ABSTRACT

In manual work, high pinch force exertions can be associated with the development of hand-related musculoskeletal disorders. Conversely, low pinch force exertions can cause slippages, which can lead to hand-related injuries. In association to this, researchers found that handgrip force is significantly affected by torque direction, size and sensation. However, there appear to be few related studies on the effects of different pinch parameters on pinch force. The novelty of this research lies in its aim which is to disclose the effects of pinch parameters such as the torque direction of pinches, shape and size of objects, sensation of fingers and technique of pinches on pinch force. The research uses a full factorial design of experiment with 5 variables. Three common types of screw knobs of 3 different shapes (spherical, cylindrical, 5-lobes) and sizes (large, medium, small) are identified and fabricated for the experiment, which involves approximately 30 participants. Participants are required to pinch the knobs with 3 commonly-used pinch techniques (lateral, 3-jaw chuck, pulp-2) while wearing pressure sensors that record the forces between the fingertips and knobs. The forces are recorded in Minitab 16. The analysis of variance is used to determine the effects of the main and combinatorial factors on pinch force while the response surface regression and response optimisation are used to determine the optimised pinch force response. It is found that pinch force is significantly affected by all the main parameters. For the two-way interactions, only interactions of sensation with pinch technique, sensation with size, pinch technique with torque direction, pinch technique with size, torque direction with size and shape with size are significant. A response surface regression model representing these effects is also generated. This is useful for the pinch force prediction using any of the parameter combinations. By defining the predicted maximum, minimum and average pinch force responses through the response optimisation, a total of 3 major factorial combinations were identified. The findings potentially aid the development of both safety and design guidelines for ergonomic precision designs. Although much research is required, it is hoped that this study can serve as a precursory guideline for researchers to further expound ideas related to pinch force capacity.

ABSTRAK

Dalam kerja manual, daya cubitan tinggi dikaitkan dengan punca penyakit muskuloskeletal tangan. Sebaliknya, daya cubitan rendah menyebabkan kegelinciran yang membawa kepada kecederaan tangan. Sehubungan itu, para penyelidik mendapati bahawa daya cengkaman tangan dipengaruhi oleh arah tork, bentuk, saiz, sensasi sentuhan dan teknik cubitan. Walau bagaimanapun, terdapat hanya beberapa kajian yang berkaitan dengan kesan-kesan arah tork, bentuk objek, saiz objek, sensasi sentuhan dan teknik cubitan kepada daya cubitan. Oleh itu, kajian ini bertujuan menentukan kesan-kesan arah tork, bentuk, saiz, sensasi dan teknik kepada daya cubitan. Kaedah penyelidikan ini melibatkan pengunaan reka bentuk faktorial eksperimen yang lengkap, yang mana 3 tombol skru dalam 3 bentuk (sfera, silinder, 5-cuping) dan 3 saiz (besar, sederhana, kecil) dikenalpasti dan direka bagi eksperimen ini. Sekitar 30 subjek ujian dikehendaki mencubit tombol-tombol yang direka dengan 3 teknik cubitan (lateral, chuck 3-rahang, pulpa-2) sambil memakai sensor-sensor tekanan yang merekodkan daya di antara hujung jari dan tombol. Daya direkodkan dalam Minitab 16. Analisis varians digunakan untuk menentukan kesan-kesan dari faktor-faktor utama dan kombinasi kepada daya cubitan, manakala regresi respons permukaan dan pengoptimuman respons digunakan untuk menentukan respons daya cubitan optimum. Keputusan kajian menunjukkan bahawa daya cubitan dipengaruhi oleh semua faktor-faktor utama dan kombinasi. Bagi interaksi dua arah, hanya interaksi sensasi dengan teknik cubitan, sensasi dengan saiz, teknik cubitan dengan arah tork, teknik cubitan dengan saiz, arah tork dengan saiz dan bentuk dengan saiz dikenalpasti sebagai interaksi-interaksi yang ketara. Model regresi respons permukaan yang mewakili kesan-kesan ini juga dihasilkan. Dengan pentakrifan jangkaan respons daya cubitan maksimum, minimum dan purata melalui pengoptimuman respons, sebanyak 3 kombinasi faktorial yang ketara dikenalpastikan. Penemuan ini berpotensi membantu penghasilan garis panduan keselamatan dan reka bentuk peralatan ergonomik persis. Walaupun banyak kajian perlu diterajui, adalah diharapkan bahawa kajian ini dapat menjadi garis panduan pendahuluan bagi para penyelidik supaya menyumbangkan lagi ide-ide berkaitan dengan kapasiti daya cubitan.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PUBLICATIONS

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CHAPTER 1

INTRODUCTION

1.1 Background

In spite of the technological advancements in numerous manufacturing firms, hands and fingers are still primary tools for high precision manufacturing work and are often used to pinch, grip and manipulate objects such as fasteners, clips and electronic components. The use of hands and fingers are common in many manual activities such as twisting the handle of a screwdriver, turning a machine knob and pinching small threaded or unthreaded components (Seo and Armstrong, 2008; Seo et al., 2008b; Shivers et al., 2002). However, awkwardly positioned, high-force pinch grip exertions can lead to injuries and musculoskeletal disorders (Ellis et al., 2004). High-force pinch force exertions can cause fatigue, discomfort and injury to the hand in industrial populations (Shivers et al., 2002).

A pinch grip is defined as an act of gripping or squeezing an object between the thumb and the finger (Trew and Everett, 2005). For example, a pinch grip is used to hold a key in a position just before it is used to operate a lock. A pinch grip is considerably different from a hand grip which is used to grip an object between the palm of the hand with a force from the thumb opposing the combined forces from the other fingers (Kumar, 2008). For example, a hand grip is used to hold a hammer in a position just before it is used to deliver an impact to an object.

High-force pinch tasks are common risk factors associated with the development of hand cumulative trauma disorders in many occupational activities (Eksioglu et al., 1996; Shivers et al., 2002). Most epidemiological studies have pointed out that the use of pinch grips at high loads are positively related to cumulative trauma disorders such as carpal tunnel syndrome (Keir and Wells, 1999).

Some cumulative trauma disorders also present symptoms which include a diminished sense of touch which disallows workers from performing tasks such as pinching (Sesek et al., 2007). This sensory disability hinders individuals from manipulating hand-related tasks since they often crush fragile objects easily or drop them (Nowak et al., 2003). Applications of various pinch techniques can also affect the risk of upper extremity cumulative trauma disorders such as chronic pain in the wrist and fingers (Ellis et al., 2004).

To further complicate matters, the use of unsuitable torque directions while inducing a grip can cause slippages to occur, leading to hand injuries (Seo et al., 2007). Besides that, the shapes and sizes of various tools and objects can also play a role in the productivity of industrial workers and the development of musculoskeletal disorders such as carpal tunnel syndrome, tendinitis and ganglionitics (Aldien et al., 2005; Kong et al., 2004).

In summary, it appears that the prevalence of upper extremity injuries, musculoskeletal health issues and cumulative trauma disorders due to pinch forces beg the need for researchers to study the possible factors that are related to these issues. Researchers have developed models to explain the relationship between grip forces and torque directions by using cylindrical handles (Pheasant and O'Neill, 1975; Seo et al., 2007; Seo et al., 2008b). There have also been models created to describe the relationship