Conference Proceedings

SUT INTERNATIONAL VIRTUAL CONFERENCE
ON SCIENCE AND TECHNOLOGY

6th August 2021

At Suranaree University of Technology

Committee

INTERNATIONAL ADVISORY BOARD

Prof. Dr. James Kutudat-Cairns
Head, School of Chemistry, Institute of Science, SUT

Prof. Dr. Dietmar Haltrich
University of Natural Resources and Life Sciences, Austria

Prof. Dr. Masaki Kawano
Tokyo Institute of Technology, Japan

Prof. Dr. Yoshiyuki Kawazoe
Tohoku University, Japan

Prof. Dr. Frank Roessner
Carl von Ossietzky Universität Oldenburg, Germany

Prof. Dr. Akiko Takasaki
Toho University, Japan

Prof. Dr. Georgi N. Vayssilov
University of Sofia, Bulgaria

Prof. Dr. Hristiyan A. Aleksandrov
University of Sofia, Bulgaria

Prof. Dr. Lima Angor
International University, Cambodia

Prof. Dr. Yoshihira Honda
Kyushu University, Japan

Assoc. Prof. Dr. Do Quang Thien
Hue University of Sciences, Vietnam

Assoc. Prof. Dr. Chinnapat Panwisawas
University of Leicester, United Kingdom

Assoc. Prof. Dr. Sutthipong Srigrarom
National University of Singapore

Asst. Prof. Dr. Thongchart Kerdphol
Kyushu Institute of Technology, Japan

Asst. Prof. Dr. Sinan Kufeoglu
University of Cambridge, UK

Asst. Prof. Dr. Fathin Saifur Rahman
Institut Teknologi Bandung, Indonesia

Asst. Prof. Dr. Gaber Magdy
Aswan University, Egypt

Asst. Prof. Dr. Khairudin
Lampung University, Indonesia

Asst. Prof. Dr. Emad Abdelnabi Mohamed Younis
Aswan University, Egypt

Asst. Prof. Dr. Yaser Qudaih
Higher Colleges of Technology, United Arab Emirates

Dr. Vito Tagarielli
Imperial College London, United Kingdom

Dr. Nattapong Thammasan
University of Twente, Netherlands

STEERING COMMITTEE

Assoc. Prof. Dr. Weerapong Pairsuwan
Rector, Suranaree University of Technology

Assoc. Prof. Dr. Kontorn Chamniprasart
Vice Rector for Academic Affairs and Internationalization

Prof. Dr. Yoshiyuki Kawazoe
Tohoku University, Japan

Prof. Dr. Kazumasa Oida
Fukuoka Institute of Technology, Japan

Prof. Dr. Anne Duittoz
University of Tours, France

Professor Richard Gray
La Trobe University, Australia

Professor Benno Von Bormann
Distinguished Professor, Institute of Medicine

Prof. Dr. Jatuporn Wittayakun
Assistant Rector

Prof. Dr. Avirut Chinkulkijniwat
Head of Research Department, Institute of Engineering

Assoc. Prof. Sachiko Makabe
Akita University, Japan

Assoc. Prof. Do Quang Thien. Dr. Eng.
Hue University of Sciences, Vietnam

Assoc. Prof. Dr. Rapee Utke
Head of Research Department, Institute of Science

Assoc. Prof. Dr. Sirapat Boonkrong
Head of Research Department, Institute of Social Technology

Assoc. Prof. Dr. Panlada Tittabutr
Head of Research Department, Institute of Agricultural Technology

Assoc. Prof. Dr. Nares Chuersuwan
Head of Research Department, Institute of Public Health

Assoc. Prof. Dr. Peerapong Uthansakul
Director of Institute of Research and Development

Asst. Prof. Dr. Thara Angskun
Director of The Center for Educational Innovation and Technology

Asst. Prof. Dr. Nitinat Suppakarn
Assistant Rector

Asst. Prof. Dr. Naruemol Singha-dong
Head of Research Department, Institute of Nursing

Asst. Prof. Dr. Suparpit Maneesakorn Von Bormann
Institute of Nursing

Asst. Prof. Dr. Veena Phunpeng
Deputy Director of The Center for International Affairs

Dr. Bui Van DUC
Hanoi University of Mining and Geology, Vietnam

Dr. John Taylor, M.D.
Medical Doctor

Dr. Nancy B. Hopf
University of Lausanne, Switzerland

Dr. Kritphudis Suttasattakrit
Head of Research Department, Institute of Dentistry

Dr. Phichayasini Kitwatthanathawon
Chief of SUT-MIS Database Unit

Dr. Wutthipong Srirattanarak, M.D.
Institute of Medicine

Committee

SPECIAL SESSION COMMITTEE (Workshop on Robotics and Mobility)

Prof. Toshio Ito
Department of Machinery and Control Systems, Shibaura Institute of Technology, Japan

Prof. Nobuto Matsuhira
Department of Machinery and Control Systems,Shibaura Institute of Technology, Japan

Asst. Prof. Dr.Supachai Vongbunyong
Deputy Director for Academic Affairs, Institute of Field Robotics, King Mongkut's University of Technology Thonburi, Thailand

Dr. Jittima Varagul
School of Manufacturing Engineering, Suranaree University of Technology, Thailand

Mr.Thanacha Choopojcharoen
Adjunct Lecturer, Institute of Field Robotics, King Mongkut's University of Technology Thonburi, Thailand

LOCAL ORGANIZING COMMITTEE

Assoc. Prof. Dr. Kontorn Chamniprasart
Vice Rector for Academic Affairs and Internationalization

Prof. Dr. Jatuporn Wittayakun
Assistant Rector

Asst. Prof. Dr. Thara Angskun
Director of The Center for Educational Innovation and Technology

Asst. Prof. Dr. Issra Pramoolsook
Assistant Rector

Asst. Prof. Dr. Parinya Noisa
Assistant Rector

Asst. Prof. Dr. Kiattisak Batsungnoen
Lecturer

Asst. Prof. Dr. Chitapong Wechtaisong
Lecturer

Asst. Prof. Dr. Pantip Piyatadsananon
Lecturer

Asst. Prof. Dr. Veena Phunpeng
Acting Deputy Director of The Center for International Affairs

Dr. Worawat Lawanont
Lecturer

Dr. Patcharawat Charoen-amornkitt
Lecturer

Mr. Akkapon Wongkoblap
Lecturer

Ms. Manutsswee Banluesab
Chief for Division of Public Relations

Ms. Sirirat Kanchananimman
Center of International Affairs

SCIENTIFIC COMMITTEE

Prof. Dr. Jatuporn Wittayakun
Assistant Rector

Prof. Dr. Avirut Chinkulkijniwat
Head of Research Department, Institute of Engineering

Assoc. Prof. Dr. Kontorn Chamniprasart
Acting, Director of The Center for International Affairs

Assoc. Prof. Dr. Rapee Utke
Head of Research Department, Institute of Science

Assoc. Prof. Dr. Sirapat Boonkrong
Head of Research Department, Institute of Social Technology

Assoc. Prof. Dr. Panlada Tittabutr
Head of Research Department, Institute of Agricultural Technology

Assoc. Prof. Dr. Schawanya Rattanapitoon, M.D.
Head of Research Department, Institute of Medicine

Assoc. Prof. Dr. Nares Chuersuwan
Head of Research Department, Institute of Public Health

Assoc. Prof. Dr. Peerapong Uthansakul
Director of Institute of Research and Development

Asst. Prof. Dr. Naruemol Singha-dong
Head of Research Department, Institute of Nursing

Dr. Chalermpan Keawkumay
Researcher

Dr. Nattawut Osakoo
Researcher

Committee

PROGRAM COMMITTEE

Ms. Manutswee Banluesab
Chief for Division of Public Relations

Ms. Chantharus Boonmak
Division of Public Relations

Ms. Kwanjai Thoopkaew
Division of Public Relations

Ms. Nantita Asavesna
Division of Public Relations

Ms. Nopawan Trisonsri
Division of Public Relations

Ms. Kayaphak Wongsanga
Division of Public Relations

Ms. Jiraporn Khunworaphat
Division of Public Relations

Mr. Worawut Dewonwong
Division of Public Relations

Mr. Panu Srunyakup
Division of Public Relations

Ms. Pennapa Nakdee
Division of Public Relations

Ms. Jintawadee Pidhayapakdee Sanitwong Na Ayutthaya
Division of Public Relations

Ms. Suchada Wattanakul
Division of Public Relations

TECHNICAL COMMITTEE

Asst. Prof. Dr. Thara Angskun
Director of The Center for Educational Innovation and Technology

Assoc. Prof. Dr. Peerapong Uthansakul
Director of The Institute of Research and Development

Dr. Sorachai Kamollimsakul
Deputy Director of The Center for Educational Innovation and Technology

Asst. Prof. Dr. Veena Phunpeng
Deputy Director of The Center for International Affairs

Asst. Prof. Dr. Nitinat Suppakarn
Assistant Rector

Dr. Phichayasini Kitwatthanathawon
Chief for SUT-MIS Database Unit

Ms. Manutswee Banluesab
Chief for Division of Public Relations

Mr. Amorntep Thepvichit
Center for Library Resources and Educational Media

Mr. Wanchai Noimanoo
Center for Educational Innovation and Technology

Mr. Vissanu Kularb
Center for Educational Innovation and Technology

Mr. Metee Prasomsup
Center for Educational Innovation and Technology

Mr. Wattana Wechviriyakul
Center for Computer Services

Mr. Saravut Aimsupamongkol
Center for Library Resources and Educational Media

Ms. Issaree Dunn
Center for Educational Innovation and Technology

Ms. Tidarat Raiphimai
Center for Educational Innovation and Technology

COORDINATING COMMITTEE

Assoc. Prof. Dr. Kontorn Chamniprasart
Acting, Director of The Center for International Affairs

Asst. Prof. Dr. Veena Phunpeng
Deputy Director of The Center for International Affairs

Asst. Prof. Dr. Sorada Khaengkarn
Lecturer

Dr. Phichayasini Kitwatthanathawon
Chief for SUT-MIS Database Unit

Dr. Kontorn Thammakul
Lecturer

Mr. Kanaphol Amornrattanaket
SUT-MIS Database Unit

Mr. Siriwat Sapsurit
SUT-MIS Database Unit

Mrs. Kornnika Chotklang
Center for International Affairs

Ms. Sirirat Kanchananimman
Center for International Affairs

Ms. Wachira Keeratipianlerd
Center for International Affairs

Ms. Orathai Senmai
Center for International Affairs

Ms. Sumittra Vichaikammart
Center for International Affairs

Ms. Hataikan Tongjareon
Center for International Affairs

Mrs. Jirapha Wijakprasert
Institute of Research and Development

List of Reviewers

No	Name	Topics	Affiliation
1	Prof.Dr. Avirut Chinkulkijniwat	EAT	Suranaree University of Technology, Thailand
2	Prof.Dr. Nobuto Matsuhira	EAT	Shibaura Institute of Technology, Japan
3	Assoc.Prof.Dr. Duangarthit Srimoon	EAT	Rangsit University, Thailand
4	Assoc.Prof.Dr. Peerapong Uthansakul	EAT	Suranaree University of Technology, Thailand
5	Asst.Prof.Dr. Akkhapun Wannakomol	EAT	Suranaree University of Technology, Thailand
6	Asst.Prof.Dr. Apinya Deekaikam	EAT	Rajamangala University of Technology Isan, Thailand
7	Asst.Prof.Dr. Bantita Terakulsatit	EAT	Suranaree University of Technology, Thailand
8	Asst.Prof.Dr. Decho Phueakphum	EAT	Suranaree University of Technology, Thailand
9	Asst.Prof.Dr. Den Kogphimai	EAT	Rajamangala University of Technology Isan, Thailand
10	Asst.Prof.Dr. Duangdao Watthanaklang	EAT	Nakhonratchasima Rajabhat University, Thailand
11	Asst.Prof.Dr. Pongnarin Sriploy	EAT	Nakhonratchasima Rajabhat University, Thailand
12	Asst.Prof.Dr. Sakrawee Saweekul	EAT	Rajamangala University of Technology Isan, Thailand
13	Asst.Prof.Dr. Songkeart Phattarapattamawong	EAT	King Mongkuts University of Technology Thonburi, Thailand
14	Asst.Prof.Dr. Thirawat Mueansichai	EAT	Rajamangala University of Technology Thanyaburi, Thailand
15	Asst.Prof.Dr. Thossaporn chanpuek	EAT	Nakhonratchasima Rajabhat University, Thailand
16	Asst.Prof.Dr. Veena JanePhunpeng	EAT	Suranaree University of Technology, Thailand
17	Asst.Prof.Dr. Thongchart Kerdphol	EAT	Kyushu institute of Technology, Japan
18	Dr.Patcharawat Charoen-amornkitt	EAT	Suranaree University of Technology, Thailand
19	Dr.Rattasat Laikanok	EAT	Nakhonratchasima Rajabhat University, Thailand
20	Dr.Somjai Yubonchit	EAT	Rajamangala University of Technology Isan, Thailand
21	Dr.Surachai Wongfukiat	EAT	Nakhonratchasima Rajabhat University, Thailand
22	Dr.Teerasak Yaowarat	EAT	Suranaree University of Technology, Thailand
23	Dr.Tosporn Arreeras	EAT	Mae Fah Luang University, Thailand
24	Prof.Dr. James R.Ketudat-Cairns	PLS	Suranaree University of Technology, Thailand
25	Prof.Dr. Yupeng Yan	PLS	Suranaree University of Technology, Thailand

List of Reviewers

No	Name	Topics	Affiliation
26	Assoc.Prof.Dr. Eckart Schulz	PLS	Suranaree University of Technology, Thailand
27	Assoc.Prof.Dr. Sanchai Prayoonpokarach	PLS	Suranaree University of Technology, Thailand
28	Assoc.Prof.Dr. Sayan Kaennakham	PLS	Suranaree University of Technology, Thailand
29	Assoc.Prof.Dr. Sineenat Siri	PLS	Suranaree University of Technology, Thailand
30	Assoc.Prof.Dr. Visit Vao-soongnern	PLS	Suranaree University of Technology, Thailand
31	Asst.Prof.Dr. Anyanee Kamkaew	PLS	Suranaree University of Technology, Thailand
32	Asst.Prof.Dr. Arisara Charoenpanyanet	PLS	Chiang Mai University, Thailand
33	Asst.Prof.Dr. Nathkapach Kaewpitoon Rattanapitoon	PLS	Parasitic Disease Research Center, Thailand
34	Asst.Prof.Dr. Natkanin Supamathanon	PLS	Rajamangala University of Technology Isan, Thailand
35	Asst.Prof.Dr. Sirinuch Loiha	PLS	Khon Kaen University, Thailand
36	Asst.Prof.Dr. Theeranun Siritanon	PLS	Suranaree University of Technology, Thailand
37	Dr. Siripon Kamontum	PLS	Suranaree University of Technology, Thailand
38	Dr. Wonchalerm Rungswang	PLS	SCG Chemical Co. Ltd., Thailand
39	Dr.Chalermpan Keawkumay	PLS	Suranaree University of Technology, Thailand
40	Dr.Nattawut Osakoo	PLS	Suranaree University of Technology, Thailand
41	Dr.Pongtanawat Khemthong	PLS	National Nanotechnology Center (NANOTEC), Thailand
42	Assoc.Prof.Dr. Chantira Chiaranai	HES	Suranaree University of Technology, Thailand
43	Asst.Prof.Dr. Apiporn Thinkhamrop	HES	Khon Kaen University, Thailand
44	Asst.Prof.Dr. Khanidtha Meevasana	HES	Suranaree University of Technology, Thailand
45	Asst.Prof.Dr. Krajaang Talabnin	HES	Suranaree University of Technology, Thailand
46	Asst.Prof.Dr. Kulthida Vaeteewoottacharn	HES	Khon Kaen University, Thailand
47	Asst.Prof.Dr. Naruemol Singha-Dong	HES	Suranaree University of Technology, Thailand
48	Asst.Prof.Dr. Nathkapach Kaewpitoon Rattanapitoon	HES	Parasitic Disease Research Center, Thailand
49	Asst.Prof.Dr. Prasert Saichua	HES	Khon Kaen University, Thailand
50	Ms. Jirapa Chansangrat	HES	Suranaree University of Technology, Thailand

ds: -

List of Reviewers

No	Name	Topics	Affiliation
51	Asst.Prof.Dr. Anyamanee Auvuchanon	AGT	Kasetsart University, Thailand
52	Asst.Prof.Dr. Choochad Santasup	AGT	Chiang Mai University, Thailand
53	Asst.Prof.Dr. Jittra Singthong	AGT	Ubon Ratchathani University, Thailand
54	Asst.Prof.Dr. Mallika Chantarangsee	AGT	Khon Kaen University, Thailand
55	Asst.Prof.Dr. Surachai Rattanasuk	AGT	Roi Et Rajabhat University, Thailand
56	Asst.Prof.Dr. Tiyakhon Chatnaparat	AGT	Kasetsart University, Thailand
57	Asst.Prof.Dr. Wachiraya Imsabai	AGT	Kasetsart University, Thailand
58	Dr. Nakarin Jeeatid	AGT	Chiang Mai University, Thailand
59	Dr. Thewika Keeratiburana	AGT	Suranaree University of Technology, Thailand
60	Dr.Kamolchanok Umnajkitikorn	AGT	Suranaree University of Technology, Thailand
61	Dr.Piyaporn Phansak	AGT	Nakhon Phanom University, Thailand
62	Dr.Wanploy Jinagool	AGT	Suranaree University of Technology, Thailand
63	Dr.Worawikunya Kiatponglarp	AGT	Synshrotron Light Research Institute, Thailand
64	Assoc.Prof.Dr. Kwankamol Donkwa	HSS	Suranaree University of Technology, Thailand
65	Assoc.Prof.Dr. Nattama Pongpairoj	HSS	Chulalongkorn University, Thailand
66	Assoc.Prof.Dr. Sirapat Boonkrong	HSS	Suranaree University of Technology, Thailand
67	Dr.Sirinthorn Seepho	HSS	Suranaree University of Technology, Thailand
68	Dr.Sorachai Kamollimsakul	HSS	Suranaree University of Technology, Thailand
69	Dr.Suopor Hiranchiracheep	HSS	Nakhonratchasima Rajabhat University, Thailand
70	Dr.Yusop Boonsuk	HSS	Prince of Songkla University, Thailand

EAT0002

Biomechanical Evaluation of Body Posture of Workers During the Wax Removing Process on Batik Sandals: A Case Study

Agung Kristanto[1, *], and Yulinda Sakinah Munim[2]

[1]Industrial Engineering Department, Faculty of Industrial Technology, Universitas Ahmad Dahlan, Yogyakarta, 55166, Indonesia
[2]Industrial Engineering Department, Faculty of Engineering, Universitas Khairun, Ternate, 97719, Indonesia

* Corresponding Author: agung.kristanto@ie.uad.ac.id

Abstract. The process of wax removal was recognized to trigger a high occurrence of back injuries amongst workers. The current investigation intended to evaluate the L5/S1 forces during actual wax removing activities and deciding the factors that fundamentally contributed to these forces. Examinations included 30 workers. The Three-Dimensional Static Strength Prediction Program (3DSSPP) was used to calculate the estimated compression and shear forces at L5/S1. About 16.67 percent of wax removing activities exceeded the safe limit for 3400 N L5/S1 compression force (mean: 3263.40 N, min-max: 3062 – 3465 N). About 98 percent of the difference could be predicted from a combination of some factors, especially the height of workers (mean: 166.13 cm) and right upper arm angle (mean: 40.54 degrees). The results of this investigation recommended that the wax pressing machine design should be modified ergonomically to decrease the physical stress on workers' right upper arm during the activity of resin removal. Another preventive measure (for example, training) should be defined and implemented to lessen the risk of right upper arm musculoskeletal disorders during the wax removing task. Training should concentrate on the upper arm, forearm, and hand posture, teamwork, and waxy workpiece placing under the pressing plate.

Keywords: Biomechanical evaluation; Wax removal process; 3DSSPP; L5/S1 back compression; Shear forces.

1. Introduction

Indonesia is one of the groups of developing countries in the world. As a result, many industries have expanded rapidly in Indonesia. This development exists both in large-scale sectors and in small and medium-sized enterprises (SMEs). Relating to SMEs, because of their significant position as the backbone of Indonesia's economy, the Indonesian government has given them a great deal of concern. The presence of SMEs accounts for as many as 99.99 percent of the overall industries in Indonesia. They contribute up to 61.07 percent to Indonesia's Gross Domestic Product (GDP) and hire up to 97 percent of workers in the SME market [1].

The rising number of small and medium-sized companies (SMEs) affects the increasing amount of injuries and injuries involving these SMEs. A lot of recent research on the most common accidents found in SMEs has been investigated. The most frequent back pain source has also been identified as uncomfortable body postures while working (e.g., folding or twisting). It could happen because the tools' location was lower than the hand's position [2]. Another research defined the uncomfortable working pose, such as the knees folded because the worker did the job in a sitting position on a narrow workbench, prolonged elbow bent [3], the back bent due to the position of the workpiece being lower than the worker's side [4]. A dimensional difference in the human-machine system's work has been the primary cause of all such events and injuries [2]. It will ultimately impact the welfare [2], health [5], comfort [6], the safety of labor [5], and productivity of workers [7].

In Indonesia, the handicraft industry is one of the SMEs that faces severe problems related to the dimensional difference in the man-machine system. One of the manufacturing steps in the batik sandals handicraft industry is the wax removing process. The dimensional mismatch can be seen in the process of wax removal. The wax-removing activity entangles an awkward working position. The worker has to work with the body in a continuously bent posture in a sitting position, the neck and back curved, and the legs and knees folded, as shown in figure 1A. These risk conditions may cause a biomechanical malfunction and chronic musculoskeletal disorders (MSDs), especially of the lower extremities, which is further highlighted by prior research informing the high incidence of back injuries among paramedics [8]. Besides, heavy physical activity can lead to disc degeneration, specifically discs L4/L5 and L5/S1 [9-12]. The back compressive force on the spine, especially at the L5/S1 intervertebral disk, is believed to lead to low-back pain and injury [13]. A previous manual handling study indicates that L4/L5 or L5/S1 intervertebral disk compression results in a low back injury [14].

One of the important steps of the leather production process is the removal of wax. The wax removing process is a process for releasing the resin from the leather surface. This process is typically done manually by crumpling the wax. Then, the crumbles can be rubbed with little pressure on its surface to clear the wax [15]. In traditional wax removal operations, workers must perform in a bent working pose for an average working hour length of 8 hours per day, which is ergonomically unsuitable for prolonged activity due to poor positioning, resulting in serious injury. The previous research stated that the body parts with the most significant pain were the spine, shoulder, back, waist, buttocks, knees, calves, feet, elbows, and wrists of descending rank, as reported by the employees [15]. The body parts' discomfort is primarily caused by the bending posture adopted while pressing the wax crumbles for release from the leather surface [15]. New processing machinery and wax-release equipment gain popularity among employees to address the work station's unergonomic issue. It includes wax removing tool using appropriate technology, which the workers manually operate by pulling the pressing machine's lever by hand, as shown in figure 1B [15]. In fact, some workers still face significant problems in the implementation of high technology apparatuses and equipment because of the misalliance of the design matching their requirements [16]. According to the previous report, a dimensional discrepancy in the human-machine system in the working process could affect employees' well-being, fitness, comfort, and safety [2].

The typical wax removing tool using appropriate technology is a single-lever wax pressing machine. The worker works on a wax pressing station consisting of a resin pressing machine and a chair. The worker sits on the chair while pulling the pressing lever downward by the right hand. The improper mechanical system, especially on the lever part, and the unstable pressing plate cause the workers to exert a massive force of 20 N to pull the lever [15]. These risk conditions may cause biomechanical malfunction and chronic MSDs and may involve loads that surpass the standard safety levels for pulling the pressing machine's lever by hand. No previous studies have been undertaken on the biomechanical assessment of workers during the wax removal operation. Therefore, the purpose of this analysis is to perform a biomechanical evaluation of workers at semi-mechanized wax removal process using the Three Dimensional Static Strength Prediction Program (3DSSPP) software for the assessment of compression and shear forces.

Figure 1. The wax removing process (A) traditional process; (B) machine-based process

2. Materials and methods

2.1 Participants

Thirty experienced employees (males between the ages of 21-30) were recruited from some batik sandal handicraft SMEs based in Yogyakarta, Indonesia. The workers were required to have at least one year of experience using a single-lever wax pressing machine in the wax removal process and have no previous medical history affecting the upper and lower extremities' alignment, such as surgery and/or a fracture. In this analysis, the wax removal activity was performed on the actual production floor of the SME.

2.2 Data collection

Anthropometric measurements (height in cm and weight in kg) of workers were made. The height measuring tape was used to mark the height of the workers standing against the wall. The weight-measuring instrument measured the weight of the workers in kilograms as they stepped onto it. Anthropometric data for individual workers have been entered into the 3DSSPP software. The angles of the forearm, upper arm, and hand (all right side) were used as inputs for 3DSSPP models. These sagittal segmental angles were determined manually based on the static picture split by the captured film. Another set of input data included employee gender, weight, height, and hand load.

2.3 Equipment

A digital video recorder has been used to monitor all events. Quantitative data was compiled using 3DSSPP tools. The University of Michigan 3DSSPP app is designed to model joint moments and low back muscle forces using body position angles and hands-lifted weights [17]. The researcher captured videos and still photographs of the workers when releasing the wax. Then, the wax removal footage was split up into a series of still pictures. The 3DSSPP software program was used to analyze each of these persons' still images to measure the moments of the shoulder and the low back compressive force of each worker.

2.4 Description of the activity

The workers were instructed to conduct a wax removing process using a single-lever wax pressing machine. The worker works on a wax pressing station consisting of a resin pressing machine and a chair. The worker sits on the chair while pulling the pressing lever downward by the right hand, as shown in figure 1B.

2.5 Data and statistical analysis

2.5.1 Operator hand load

Calculating approximately the workers' hand load, the static moments around the wax pressing machine's lever hinge were calculated according to the lever's weight (F_L). The moment equilibrium equations (1) were applied to evaluate the hand load F_{hand}, as expressed below.

$$F_{hand}= \frac{F_{UA}\left(D_L \cos\theta + D_F \sin\beta + \frac{1}{2} D_U \sin\alpha\right) + F_{LA}\left(D_L \cos\theta + \frac{1}{2} D_F \sin\beta\right) + \frac{1}{2} F_L \ D_L \cos\theta}{D_L \cos\theta + D_F \sin\beta + D_U \sin\alpha} \tag{1}$$

F_L represented the weight of the lever. The weight of the lever was 2 kg and was considered constant for all the workers. F_{UA} described the weight of the upper arm. F_{LA} described the total weight of the forearm and hand. According to a prior study, the weight of the upper arm and the total weight of the forearm and hand for males was 3.25 percent and 2.52 percent of total body weight, respectively [18]. D_L was the length of the lever of 515 millimeters. D_F was the entire length of the forearm and hand of the workers.

Meanwhile, D_U was the length of the upper arm of the workers. Both D_U and D_F were obtained through the anthropometric dimension measurements of each farmer's shoulder-grip (SG) length and elbow-fingertip (EF) length. The angles of α, β, and θ were the upper arm, forearm, and hand angles of the workers, respectively.

2.5.2 L5/S1 intervertebral disc of compression and shear force

The L5/S1 disk of back compression and shear forces were measured using the 3DSSPP program. These forces were then evaluated with the standard compression threshold of 3.4 kN [8] and the standard shear threshold of 1 kN [19] in order to determine the safety of the tasks.

2.5.3 Statistical Analysis

All dependent variables obtained descriptive statistics. Besides, multiple regression analyzes were conducted to evaluate predictor sets affecting L5/S1 of compression and shear forces. The indicator factors included those related to (1) height (cm) and weight (kg); (2) the segmental angle (degree) of the right upper arms, right forearms, and right hand during the wax removal process; and (3) hand load (N). The whole analysis was conducted by IBM SPSS 26 (IBM, New York, US). The significance value accepted in this research was $p < 0.05$.

3. Results

3.1 Participants

The demographic characteristics of the participants are outlined in table 1. Seventy-seven percent of all workers held a normal index of body mass.

Table 1. Workers demographic characteristics (n = 30)

	Mean	SD	Maximum	Minimum
Age (years)	24.53	2.71	29.00	21.00
Experience (years)	4.63	1,83	8.00	2.00
Weight (kg)	60.10	6.17	71.00	50.00
Height (cm)	166.13	3.34	173.00	160.00

SD = standard deviation

3.2 Workers hand load

The workers' hand load was calculated using equation 1. All required hand load calculation variables were presented on the free body diagram of force during wax removing activity (figure 2A) and in table 2. The mean hand load force was 32.47 ± 2.72 N (37.58 N maximum and 27.89 N minimum). The workers' typical posture during the wax removing process was presented in table 2 and figure 2B.

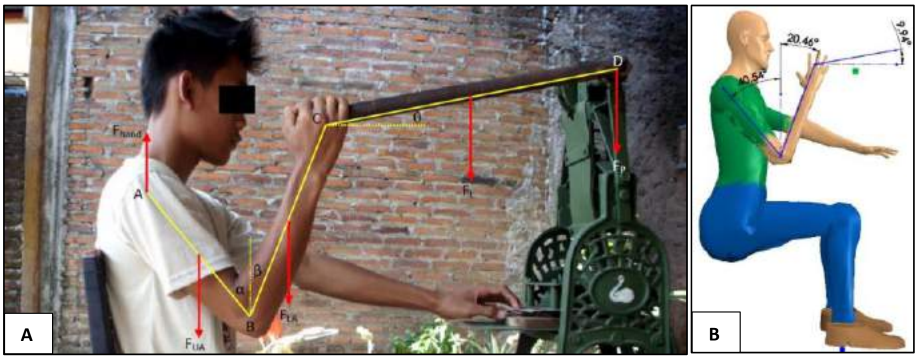

Figure 2. (A) The free-body diagram; (B) Mean segmental angles of the workers

Table 2. Workers hand load variables

Variables	Formula	Value			
D_L (m)	Direct measurement	0.52			
F_L (N)	Direct measurement	19.61			
Variables	Formula	Mean	SD	Max	Min
D_F (m)	Direct measurement	0.70	0.03	0.73	0.65
D_U (m)	Direct measurement	0.33	0.01	0.34	0.31
F_{UA} (N)	3.25 percent of body weight	19.15	1.97	22.63	15.94
F_{LA} (N)	2.52 percent of body weight	14.85	1.53	17.55	12.36
The angle of the hand, θ (degree)		9.94	0.35	10.72	9.40
The angle of the forearm, β (degree)		20.46	0.98	22.27	18.78
The angle of the upper arm, α (degree)		40.54	0.85	41.75	37.87
F_{hand} (N)		32.47	2.72	37.58	27.89

3.3 L5/S1 intervertebral disc of back compression and shear force

At L5/S1, the average compression and shear forces on a worker's back were 3263.40 113.34 N (3465 N maximum and 3062 N minimum) and 139.00 ± 13.67 N (163 N maximum and 116 N minimum) respectively. In the 30 wax removing activities analyzed, 16.67 percent surpassed the standard compression threshold, and no one surpassed the standard shear threshold (figure 3A and 3B).

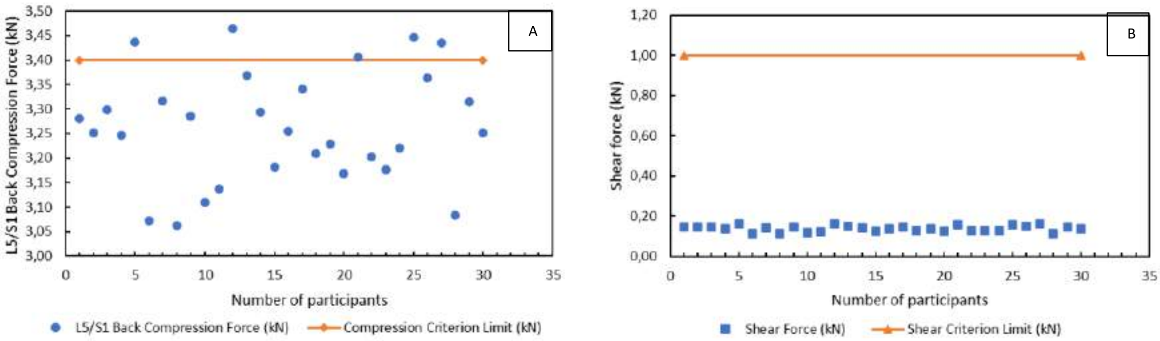

Figure 3. The L5/S1 of back compression force (A) and shear force (B) faced by the workers

3.4 Predictors of compression forces

All of the independent variables were conducted with multiple regression analysis. During wax removing operations, the combination of six variables prophesied 98 percent of the variance in compression forces at L5 / S1. There was a significant difference in weight, height, right upper arm angle, right forearm angle, right-hand angle, and hand load simultaneously on the compression force since the Sig. value < 0.05 and the F-value (188.008) > F-table (2.51). There was a significant difference in height and right upper arm angle partially on compression forces since the Sig. value < 0.05 and t-value > t-table (2.07) (table 3).

3.5 Predictors of shear forces

For all the independent variables, a further multiple regression analysis was conducted. During wax removing activity, the combination of six variables prophesied 96 percent of the variance in L5/S1 of shear forces. There was a significant difference in weight, height, right upper arm angle, right forearm angle, right-hand angle, and hand load simultaneously on the shear force since the Sig. value < 0.05 and the F-value (91.327) > F-table (2.51). There was only a significant difference in the right upper arm angle partially on shear forces since the Sig. value < 0.05 and t-value > t-table (2.07) (table 4).

Table 3. Multiple regression analysis for compression force

Variable	Regression Coefficients	t	Sig.
Constant	1737.237		
Weight	7.302	1.020	0.319
Height	4.182	3.848	0.001*
Right upper arm	-10.880	-2.139	0.043*
Right forearm	2.364	0.537	0.597
Right hand	-5.161	-0.497	0.624
Hand load	25.765	1.593	0.125
F-value	188.008		<0.0001**
R square		0.980	

The negative sign showed the angle direction.
* represented a significant difference partially.
** described significant difference simultaneously.

Table 4. Multiple regression analysis for shear force

Variable	Regression Coefficients	t	Sig.
Constant	88.035		
Weight	1.181	0.963	0.346
Height	-0.147	-0.792	0.436
Right upper arm	-1.764	-2.085	0.045*
Right forearm	0.488	0.647	0.524
Right hand	-0.746	-0.419	0.679
Hand load	2.261	0.816	0.423
F-value	91.327		<0.0001**
R square		0.960	

The negative sign showed the angle direction.
* represented a significant difference partially.
** described significant difference simultaneously.

4. Discussion

This current investigation stated that 16.67 percent of the 30 wax removing processes were believed at risk according to the compression standard safety threshold (≥ 3.4 kN; [8]). This result showed that workers were still unavoidably at risk of harm as completing this job due to exceeded the safe limit. When different field contexts of the wax removal process were considered, the difference in compression forces was primarily clarified by hand load, employee weight, and several postural factors. Furthermore, the wax removing process in the present study was performed by the workers in an actual situation involved in many different work environments, including the improper mechanical system, especially on the lever part, unstable pressing plate, differences in the thickness of the wax layer, climate/environmental conditions such as temperature, etc. All of these considerations may impact postural control throughout wax removal and, as a result, internal loading on the spine. During the wax removal task, the hand load was affected by the lever weight, an improper mechanical system, and an unstable pressing plate. The workers must exert a huge force to pull the heavy lever by hand. It is exacerbated by a poor mechanical system on the lever joint and an unstable pressing plate. This condition reveals the fact that workers still face significant problems in the implementation of high technology apparatuses and equipment because of the misalliance of the design matching their requirements [16].

Wax-removing tasks alone should be prohibited instead of in a squad, as this technique significantly increased the hand load and, therefore, the internal load on the workers' spine. This result underlined the significance of teamwork in various occupations. Various research had previously demonstrated its significance when performing a task [8]. The decision to implement a wax removal alone might reflect a habit formed with previous wax removing process systems. The job of wax removal alone could be changed as a team by two workers by modifying the design of single-lever wax pressing machine that could accommodate two workers.

Recent research on manual handling of materials found that overweight was associated with increased lumbar load [8]. Large body weight increased the moment force on the spines and the possibility of MSDs as a result. The current study also revealed that employees' body weight significantly impacted the back's compression force. According to recent studies [20, 21], obesity significantly increased the risk of MSDs, obstructive sleep apnea, cardiovascular disease, and socio-economic implications. In the current research, 10 percent of the workers were considered overweight. Therefore, a preventive approach focused on weight management should be discussed in future research, particularly for overweight and obese workers.

In L5 / S1, back sagittal flexion was the most significant postural indicator of differences in compression and shear forces. Because of their anatomical location, the upper arm's high angles, forearm, and/or back sagittal led to an increase in the L5 / S1 moment arm, and the moment arm directly affected the load implemented at L5 / S1 [22]. The moment arm and compression forces on the back were reduced by maintaining the forearm and upper arm close to the body and the back straight. During the wax removing operation, the wax pressing machine designs substantially affected the workers' posture. According to the results of the current study's regression analysis models, smaller and taller employees suffered risen L5/S1compression force when removing the wax, which could be clarified in part by the lever's fixed position joint heights. While releasing the resin, workers would advantage from better exercise on decreasing the moment arm at the back. The design of the wax pressing machine used as a team should also be reviewed to ensure that workers avoid uncomfortable postures, in particular by paying special attention to their backs.

This study still had several limitations worth noting. First, the findings found from 3DSSPP were built on the assumption that the activities under analysis were still or very slow, and also, the hand force was in the vertical direction. Therefore, in the shear and back compression forces computation, the effect of the rate increase, the influences of inertia, and a concurrent push/pull force element were unobserved. This unobserved could underrate the joints' muscles' actual forces [22]. However, these simplifying hypotheses were needed to address the environmental and technical problems of gathering data in a wide range of work tasks conducted in actual life without intervening with the workers' work. As shown in the prior investigations [23], using the 3DSSPP software was expected to provide a rational assessment of shear and back compression forces for the intervertebral L5 / S1 disc. Second, one problem not discussed was asymmetric load, which caused unequal backload dispersion and increased compression and shear forces [24]. In this analysis, asymmetric parameters were not assessed.

5. Conclusions

This investigation aimed to quantify the risk of back MSDs using compression and shear force standard limitations throughout the wax removing process. Interestingly, the vast majority of the wax removing behaviors detected on the job and evaluated at the L5 / S1 joint surpassed the compression force limit criterion. The most critical compression force predictors were height, right upper arm angle, and right forearm angle. Hand load also significantly influenced the compression force and was mainly affected by teamwork and workers' weight and lever. Preventive actions should be devised and implemented to minimize the risk of back MSDs during the wax removing task.

Acknowledgments

We would like to acknowledge the participants of this study for their time.

References

[1] Ministry of Cooperatives and Small and Medium Enterprises 2018 *Ministry of Cooperatives and Small and Medium Enterprises*, http://www.depkop.go.id/data-umkm (accessed Dec. 10, 2020).

[2] Sutalaksana I Z and Widyanti A 2016 *Int. J. Ind. Ergon.* **53** 299–305.

[3] Kristanto A and Saputra A 2020 *Agroindustrial J.* **6** no. 1.

[4] Kristanto A and Fanany F D 2014 *Improvement of Working Position on Frying Pan Lathing Process Using The Ergonomics Approach (A Case Study at WL Alumunium Metal Casting Yogyakarta)* Yogyakarta, Indonesia p. D-21.

[5] Del Prado-Lu J L 2007 *Int. J. Ind. Ergon.* **37** 497–503.

[6] Mokdad M and Al-Ansari M 2009 *Int. J. Ind. Ergon.* **39** 728–735.

[7] Battini D, Faccio M, Persona A, and Sgarbossa F 2011 *Int. J. Ind. Ergon.* **41** 30-42.

[8] Prairie J, Plamondon A, Hegg-Deloye S, Larouche D, and Corbeil P 2016 *Int. J. Ind. Ergon.* **54** 1–9.

[9] Baranto A, Hellström M, Cederlund C-G, Nyman R, and Swärd L 2009 *Knee Surg. Sports Traumatol. Arthrosc. Off. J. ESSKA* **17** 1125–1134.

[10] Hadjipavlou AG, Tzermiadianos MN, Bogduk N, and Zindrick MR 2008 *J. Bone Joint Surg. Br.* **9** 1261–1270.

[11] Hangai M *et al.*, 2008 *Spine J. Off. J. North Am. Spine Soc.* **8** 732–740.

[12] Saberi H, Rahimi L, and Jahani L 2009 *J. Spinal Disord. Tech.* **22** 507–510.

[13] Waters TR, Putz-Anderson V, Garg A, and Fine LJ 1993 *Ergonomics* **36** 749–776.

[14] Waters TR, Putz-Anderson V, and Garg A 1994 *US Dep. Health Hum. Serv. NIOSH*

[15] Kristanto A and Munim Y 2017 *Sci. Int. Lahore* **29** 675–680.
[16] Md. Khayer S, Patel T, and Dewangan 2017 *J. Ergon.* **7** pp. 1–9.
[17] Russell SJ, Winnemuller L, Camp JE, and Johnson PW 2007 *Appl. Ergon.* **38** 91–97.
[18] Plagenhoef S, Evans FG, and Abdelnour T 1983 *Res. Q. Exerc. Sport* **54** 169–178.
[19] Gallagher S and Marras W S 2012 *Clin. Biomech. Bristol Avon* **27** 973–978.
[20] Hegg-Deloye S *et al.*, 2014 *Emerg. Med. J. EMJ* **31** 242–247.
[21] Tsismenakis A J, Christophi C A, Burress J W, Kinney A M, Kim M, and Kales S N 2009 *Obes. Silver Spring Md*, **17** 1648–1650.
[22] Chaffin D B, Andersson G B J, and Martin B J, 2006 *Occupational Biomechanics*, 4th ed. New York: John Wiley & Sons,
[23] Cooper G and Ghassemieh E 2007 *Med. Eng. Phys.* **29** 775–787.
[24] Marras W S *et al.*, 1995 *Ergonomics* **38** 377–410.

IVCST 2021

Website

ivcst.sut.ac.th/2021