

DESIGN OF ERGONOMIC CHAIR FOR GRINDING OPERATION

DESAIN KURSI ERGONOMI UNTUK OPERASI GRINDING

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ABSTRAK

Banyak kegiatan produksi dilakukan melalui banyak proses terutama operasi penggerindaan. Penggerindaan digunakan untuk mengikis permukaan agar lebih halus atau lebih rata, untuk memotong bagian, untuk membuat profil seperti sudut dan lengkungan, untuk mengasah alat pemotong, dan untuk menyelesaikan produk akhir. Sementara itu, tingkat risiko pekerja yang mengerjakan penggerindaan tersebut belum dievaluasi dan tidak ada kursi khusus yang dirancang untuk proses tersebut. Oleh karena itu, penelitian ini bertujuan untuk mengevaluasi tingkat risiko karyawan yang bekerja di bagian penggerindaan dan merancang kursi ergonomis yang dapat disesuaikan, nyaman, tahan lama, dan kuat untuk digunakan. Tingkat risiko pekerja dievaluasi menggunakan REBA. Sedangkan desain kursi ergonomis menggunakan data antropometrik yang diambil dari 4 pekerja yang bekerja di bagian penggerindaan di Bantul, Daerah Istimewa Yogyakarta, Indonesia. Langkah-langkah antropometrik yang dipilih untuk membuat desain kursi untuk operasi gerinda adalah panjang bokong-poplitea (kedalaman dudukan), panjang kaki bagian bawah (tinggi poplitea) dan lebar pinggul, duduk. Setelah itu, desain kursi yang sudah ada di pasaran juga dipertimbangkan dan dievaluasi untuk mendapatkan desain kursi ergonomis yang dapat disesuaikan untuk operasi gerinda. Hasil penelitian ini menunjukkan bahwa sebagian besar operasi penggerindaan membutuhkan tindakan perbaikan oleh para pemangku kepentingan. Selain itu, desain kursi yang digunakan untuk operasi gerinda dapat disesuaikan, nyaman, tahan lama, dan kuat. Ketinggian kursi dapat disesuaikan dari 361-414 mm untuk beradaptasi dengan pengguna dan variasi ketinggian produk untuk mencegah tekukan pada punggung. Pada akhirnya, kursi gerinda tersebut mampu menurunkan risiko kerja dari tinggi dan medium ke postur kerja yang memiliki risiko kerja yang rendah.

Kata Kunci: *Kursi Adjustable-Ergonomis; Data Antropometrik; Operasi Penggilingan; REBA; Yogyakarta*

ABSTRACT

One of essential production activities is grinding process. This process mainly involves the constant activity of eroding a surface to be smoother or more evenly, cutting a workpiece, creating profiles like angles and arches, sharpening a cutting tool, and finishing a final product. Meanwhile, there is no study evaluating the risk levels of workers working on grinding, and there is no unique chair specifically designed for the process. Therefore, this study aims to assess the risk levels of a grinding worker and to propose the design of an ergonomic chair that is

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adjustable, comfortable, durable, and keen to be used. The risk levels of the grinding workers were evaluated using REBA, while the ergonomic chair design was based on anthropometric data taken from 4 grinding workers in Bantul, Special Region of Yogyakarta, Indonesia. The researchers selected a buttock-popliteal length (seat depth), lower leg length (popliteal height) and hip breadth sitting as anthropometric measures to make a chair design for the grinding operations. After that, the existing adjustable chair designs were also considered and evaluated to get better adjustable-ergonomic chair design for the grinding operations. The results show that it is important that the stakeholders improve most of the grinding operations of the workers, especially by using an ergonomic chair design for grinding operation that is adjustable, comfortable, durable, and reliable. The chair height can be adjusted from 361-414 mm to adapt with the users, and the variation in product height aims to prevent bending on the back. Finally, the grinding chair can reduce the risk level from the high and medium level to the low-risk levels of working postures.

Keywords: Adjustable-Ergonomic Chair; Anthropometric Data; Grinding Operation; REBA; Yogyakarta

INTRODUCTION

One of the most frequently used processes in production activity is grinding operation. This process aims to erode a surface to makes it smoother or more evenly, cut a workpiece, create a profile like angles and arches, sharpen a cutting tool, and finish a final product. It processes many products ranging from a small handicraft product until heavy equipment.

One of the most essential tools to help people to do their duties properly is a chair. Therefore, a chair should be easy and convenient to use, could reduce physical and mental load, should increase productivity and efficiency, and could avoid injuries. For example, un-ergonomic chair designs for students can lead to fatigue joint and muscle pain, neck or shoulder tension, headache, neck pain, back pain, pain on legs joints, shoulder and muscle pain, and pain at the elbow (Taifa & Desai, 2017). Another example is the chairs used by people with physical disabilities and those working in universities. Such chairs are

redesigned to accommodate better working postures so people may have higher productivity and better health (Ramalho-Pires de Almeida et al., 2018). Wearable exoskeletons can reduce peak load imposed to shoulder on the overhead drilling task (Alabdulkarim & Nussbaum, 2019) perceived discomfort, and muscular loading. There are a lot of ergonomic chair designs for optimizing human activities. The wheelchair is designed for helping people who cannot walk well (Jatmiko & Dharmastiti, 2018), but it is not designed for a person with disabilities who is doing a grinding operation. A motorized wheelchair evaluated using RULA in CATIA is made for disabled and older people but also is not for a grinding worker (Paul, Gnanaraj S, & Paul, 2019). There is also an ergonomic chair designed for supporting pedicurists and manicurists to do their jobs appropriately (Alojado, Custodio, Lasala, & Marigomen, 2015)there has been a growing population of businesses engaging in the industry of providing personal care services. From the statistics provided by the Bureau of Labor and Employment Statistics, in 2008 to 2010, there has been a 34.7% increase in the people employed in this sector.[1] These services include that of salons, with pedicure and manicure services consisting 23% and 19% respectively.[2] Manicurists and pedicurists suffer severe discomfort and pain due to the awkward posture and repetitive motions involved in their work. Manicurists and pedicurists are commonly seen hunching over, bowing and tilting their heads, and sitting in stools lower than their popliteal height. Because of this, the proponents of this study aim to design an ergonomically-fit chair suitable for manicurists and pedicurists. In line with this goal, the proponents conducted a survey in areas near the University of the Philippines Diliman to backup observations regarding the workers??? working posture and ailments occurring due to this. The need to change their working posture was analyzed through Rapid Entire Body Assessment (REBA, but the table attached to the chair is too big, which may confuse them and make them feel awkward to

sit on the chair. There has been research investigating the correlation between movements and dis(comfort) perceived by college students, in that there is a decrease in discomfort when the subject changed position. However, there is no research to examine the correlation between discomfort and activity with higher movement like grinding operation (Fasulo, Naddeo, & Cappetti, 2019) mobility, and stability to measure comfort or discomfort when seated. Most of these discuss the relations between subjective comfort/discomfort and objective measurements (e.g. body pressure distribution, body movement and EMG. A lightweight seat has a higher level of comfort in an aircraft (Vanacore, Lanzotti, Percuoco, Capasso, & Vitolo, 2019). Any seat movement introduced to the driving seat is slow, smooth, and small to minimize the effect on the driving task (Varela et al., 2019) a control (no movement. A design table for printing bricks and a redesigned wood powder table enable the workers to work with a comfortable work posture, and their movement can be optimized in a manual brick workstation (Siska, Saputra, & Candra, 2019). There is also available chair used by the worker to take a rest (Siska et al., 2019).

The chair can be adjustable, comfortable, durable, and reliable. The movable parts of the chair can be on the headrests (Torres-Pérez & Caballero-Reyes, 2017), trunk support (Torres-Pérez & Caballero-Reyes, 2017), leg supports (Torres-Pérez & Caballero-Reyes, 2017), footrests (Ansari, Nikpay, & Varmazyar, 2018; Torres-Pérez & Caballero-Reyes, 2017), backrest (Ansari et al., 2018; Curran, O'Sullivan, O'Sullivan, Dankaerts, & O'Sullivan, 2015; Hong, Cooper, Pearlman, & Hargroder, 2016), armrests (Ansari et al., 2018; Torres-Pérez & Caballero-Reyes, 2017), desk (Ansari et al., 2018), and height (Park, You, & Kim, 2019; Torres-Pérez & Caballero-Reyes, 2017), and height (Park, You, & Kim, 2019; Torres-Pérez & Caballero-Reyes, 2017). A chair having high adjustability can improve the comfort of the work (Kushwaha & Kane, 2016; Underwood & Sims, 2019; Workineh & Yamaura, 2016).

There have been many efforts to develop the comfort of chairs. A comfortable chair can use molded PUR foam, slab-stock PUR foam, and springs (Vlaović, Domljan, Župčić, & Grbac, 2016). Chair model (shape, configuration) affects the comfortability of the user (Singh et al., 2016). Research needs to determine whether softer foam or more flexible materials could reduce discomfort (Vink & Lips, 2017). An office chair equipped with thermal control over the seat and the back improves user overall thermal comfort (Shahzad, Calautit, Aquino, Nasir, & Hughes, 2017) which is a current challenge in the workplace addressed by limited research. The main difficulty in an open plan setting is that changing the room temperature in an area affects all occupants seated nearby. This issue in addition to individual differences in perceiving the thermal environment create a great challenge to satisfy all occupants in the workplace. This study investigates the application of an advanced thermal system, a user-controlled thermal chair, which allows individual control over their immediate thermal environment without affecting the thermal environment and comfort of other occupants. The performance of the chair was further analysed through Computational Fluid Dynamics (CFD).

Durability and reliability are critical variables of the chair quality. Durability affects a chair quality (Pambudi, Suryoputro, Sari, & Kurnia, 2016). Chassis is a key element to support a chair structure (Torres-Pérez & Caballero-Reyes, 2017) weights, heights and diseases. However, most have the same problem as the chassis and postural support elements are fixed which creates several problems: poor posture, overruns to suit the measurements of each person, deformation in the column and in the case of growing children, wheelchair chance not comply with the new measures. In this Project, works in the design of a chassis and the postural support elements of a wheelchair for children in motor disability condition in their lower extremities. The design was developed considering the state of the art of wheelchairs, anthropometric measures of Colombian population of

children 5 to 9 years, determining functional requirements (needs. Chair material can use mild steel (Ajao et al., 2016).

Nonetheless, there is no study evaluating the risk levels faced by grinding workers, and there is no unique chair, specially designed for the grinding process. Therefore, this study aims to evaluate the risk levels of the grinding workers and to propose an ergonomic chair design that is adjustable, comfortable, durable, and reliable for the grinding workers.

Method
REBA

First, the workloads of grinding workers were assessed using Rapid Entire Body As-

essment (REBA). The risk level of grinding operation was assessed using REBA. If the risk level is high, the working postures of the employee need to be improved (Hignett & McAtamney, 2000). There are several steps for assessing the risk levels of the working postures. The first step was measuring the scores for group A, i.e., trunk (Table 1), neck (Table 2), and legs (Table 3) (Hignett & McAtamney, 2000). The next step was getting the group A score from Table 4. After that, the group A score was added by a load of group A (0 for load < 5 kg; 1 for 5-10 kg; 2 for load >10 kg; +1 for shock or rapid build-up of force (Hignett & McAtamney, 2000)).

Table 1
The REBA scores for trunk (Hignett & McAtamney, 2000)

| Picture | Movement | Score | Change score |
|---------|------------------|-------|-------------------------------|
| | Upright | 1 | +1 if twisting or side flexed |
| | 0°-20° flexion | 2 | |
| | 0°-20° extension | 2 | |
| | 20°-60° flexion | 3 | |
| | >20° extension | 3 | |
| | >60° flexion | 4 | |

Table 2
The REBA scores for neck (Hignett & McAtamney, 2000)

| Picture | Movement | Score | Change score: |
|---------|-------------------------------|-------|-------------------------------|
| | 0°-20° flexion | 1 | +1 if twisting or side flexed |
| | >20° flexions or in extension | 2 | |

Table 3
The REBA scores for legs (Hignett & McAtamney, 2000)

| Picture | Position | Score | Change score |
|---------|--|-------|---|
| | Bilateral weight-bearing, walking or sitting | 1 | +1 if knee(s) between 30° and 60° flexion |
| | Unilateral weight bearing | 2 | +2 if knee(s) are >60° flexion (n.b. not for sitting) |
| | Featherweight bearing or an unstable posture | | |

Table 4
The REBA score for group A (Hignett & McAtamney, 2000)

| Trunk | Neck | | | | | | | | | | | |
|-------|------|---|---|---|------|---|---|---|------|---|---|---|
| | 1 | | | | 2 | | | | 3 | | | |
| | Legs | | | | Legs | | | | Legs | | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 3 | 3 | 5 | 6 |
| 2 | 2 | 3 | 4 | 5 | 3 | 4 | 5 | 6 | 4 | 5 | 6 | 7 |
| 3 | 2 | 4 | 5 | 6 | 4 | 5 | 6 | 7 | 5 | 6 | 7 | 8 |
| 4 | 3 | 5 | 6 | 7 | 5 | 6 | 7 | 8 | 6 | 7 | 8 | 9 |
| 5 | 4 | 6 | 7 | 8 | 6 | 7 | 8 | 9 | 7 | 8 | 9 | 9 |

Second, the scores for group B were measured, i.e., upper arms (Table 5), lower arms (Table 6), and wrist (Table 7). Then, Table 8 calculated score B, and added the score obtained from Table 9 by coupling (0 = good, well-fitting handle and a mid-range, power grip; 1 = fair, handhold acceptable but not

ideal or coupling is acceptable via another part of the body; 2 = poor, handhold not acceptable although possible; 3 = unacceptable, awkward, unsafe grip, no handles, coupling is unacceptable using other parts of the body (Hignett & McAtamney, 2000)).

Table 5
The REBA scores for upper arms (Hignett & McAtamney, 2000)

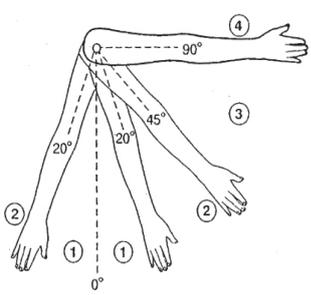
| Picture | Position | Score | Change score |
|---|--------------------------------|-------|---|
|  | 20° extension to 20° flexion | 1 | +1 if an arm is: • abducted • rotated |
| | >20° extension 20°-45° flexion | 2 | |
| | 45°-90° flexion | 3 | +1 if the person raises shoulder |
| | >90° flexion | 4 | -1 if leaning, supporting the weight of the arm or if posture is gravity assisted |

Table 6
The REBA scores for lower arms (Hignett & McAtamney, 2000)

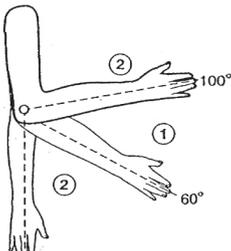
| Picture | Movement | Score |
|---|-------------------------------|-------|
|  | 60°-100° flexion | 1 |
| | <60° flexion or >100° flexion | 2 |

Table 7
The REBA scores for wrists (Hignett & McAtamney, 2000)

| Picture | Movement | Score | Change score |
|---------|------------------------------|-------|---------------------------------------|
| | 0°-15° flexion/ extension | 1 | +1 if wrist is deviated or twisted |
| | >15° flexion/ extension | 2 | |

Table 8
The REBA score for group B (Hignett & McAtamney, 2000)

| | Lower arm | | | | | |
|-----------|-----------|---|---|-------|---|---|
| | 1 | | | 2 | | |
| | Wrist | | | Wrist | | |
| Upper arm | 1 | 2 | 3 | 1 | 2 | 3 |
| 1 | 1 | 2 | 2 | 1 | 2 | 3 |
| 2 | 1 | 2 | 3 | 2 | 3 | 4 |
| 3 | 3 | 4 | 5 | 4 | 5 | 5 |
| 4 | 4 | 5 | 5 | 5 | 6 | 7 |
| 5 | 6 | 7 | 8 | 7 | 8 | 8 |
| 6 | 7 | 8 | 8 | 8 | 9 | 9 |

Third, the score A and score B were combined to result in score C, as presented in Table 9. The final REBA score is the total result of score C and activity score (+1 for 1 or more body parts are static, e.g. held for longer than 1

min; +1 for repeated small range actions, e.g., repeated more than 4 times per minute (not including walking); +1 for action causes rapid, significant range changes in postures or an unstable base (Hignett & McAtamney, 2000)).

Table 9
Score C of REBA (Hignett & McAtamney, 2000)

| | | Score B | | | | | | | | | | | |
|---------|----|---------|----|----|----|----|----|----|----|----|----|----|----|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Score A | 1 | 1 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 6 | 7 | 7 | 7 |
| | 2 | 1 | 2 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 7 | 8 |
| | 3 | 2 | 3 | 3 | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 8 | 8 |
| | 4 | 3 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 8 | 9 | 9 | 9 |
| | 5 | 4 | 4 | 4 | 5 | 6 | 7 | 8 | 8 | 9 | 9 | 9 | 9 |
| | 6 | 6 | 6 | 6 | 7 | 8 | 8 | 9 | 9 | 10 | 10 | 10 | 10 |
| | 7 | 7 | 7 | 7 | 8 | 9 | 9 | 9 | 10 | 10 | 11 | 11 | 11 |
| | 8 | 8 | 8 | 8 | 9 | 10 | 10 | 10 | 10 | 10 | 11 | 11 | 11 |
| | 9 | 9 | 9 | 9 | 10 | 10 | 10 | 11 | 11 | 11 | 12 | 12 | 12 |
| | 10 | 10 | 10 | 10 | 11 | 11 | 11 | 11 | 12 | 12 | 12 | 12 | 12 |
| | 11 | 11 | 11 | 11 | 11 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |

REBA action levels vary from ‘not necessary’ to ‘necessary NOW’ depending on REBA score (Table 10). An activity having REBA score of 11-15 is categorized as a very

high-risk level and needs to be revised now. However, an activity that has a REBA score of 2-3 is classified as a low-risk level and may probably be improved.

Table 10
REBA action levels (Hignett & McAtamney, 2000)

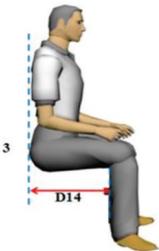
| Action level | REBA score | Risk level | Action (including further assessment) |
|--------------|------------|------------|---------------------------------------|
| 0 | 1 | Negligible | Not necessary |
| 1 | 2-3 | Low | May be necessary |
| 2 | 4-7 | Medium | Necessary |
| 3 | 8-10 | High | Necessary soon |
| 4 | 11-15 | Very high | Necessary NOW |

Anthropometric measurement

Second, the researchers choose the body measurements that are suitable for designing a chair. The body measurements are a

buttock-popliteal length (seat depth), lower leg length (popliteal height), and hip breadth (sitting) (Table 11).

Table 11
Body measurement for designing a chair (Taifa & Desai, 2017)
(Antropometri Indonesia, 2017)

| D14: buttock-popliteal length (seat depth) | D16: lower leg length (popliteal height) | D19: hip breadth, sitting |
|---|---|---|
|  |  |  |

Designing the chair

The chair used for the grinding process elaborates on three anthropometric measurements. *First*, the seat depth uses the 5th percentile of buttock-popliteal length and minus 6.75 cm. It makes the chair more compact in the grinding room. *Second*, the seat width uses the 95th percentile of hip breadth (sitting) and adds by 1.575 cm for allowance. The seat depth and the seat width construct the overall seat chair. *Third*, the adjustable seat height uses the 5th-95th percentile of lower leg length (popliteal height) so it can accommodate the grinding worker to adjust the chair height following the workpiece height so it can

avoid back bending. The chair design process uses CAD software (Autodesk Inventor). The chair consists of seven main parts. The main parts are foam, metal base, pin one, pin two, side-beam, lower beam, and upper beam.

After the CAD design of the chair is ready, the next step is making the real object of the chair using a 1:1 ratio so the chair can be tested to the grinding worker. The foam is made from foam with 4 cm thickness and coated by vinyl plastic. The metal base, pin one, pin two, side beam, lower beam, and upper beam are made from metal. It makes the chair to have high reliability. Neverthe-

less, the handle of the pin two is made from plastic for better grip. The unmoved parts are assembled using a welding machine.

RESULTS AND DISCUSSION

Table 12 shows the demographic data of the employees used for designing the er-

gonomic chair for the grinding operation. Four employees are working on grinding operations in Bantul, Special Province of Yogyakarta. All of these grinding workers are Javanese, with the mean length of working experiences in grinding operation of 7.5 years.

Table 12
Demographic data of the grinding workers

| Employee number | Ethnic | Age (years) | Working experience (years) | D14: buttock-popliteal length (seat depth) | D16: lower leg length (popliteal height) | D19: hip breadth, sitting |
|-----------------|----------|-------------|----------------------------|--|--|---------------------------|
| 1 | Javanese | 33 | 8 | 46 | 36.5 | 33.5 |
| 2 | Javanese | 33 | 9 | 47 | 36 | 32 |
| 3 | Javanese | 38 | 10 | 50 | 42 | 33 |
| 4 | Javanese | 28 | 3 | 41 | 38 | 31 |

Working postures evaluation of the grinding workers shows that all of the grinding operations need corrective working postures. In particular, the working posture A and B should be corrected immediately (Table 13). On working posture, A, the employee does not use a chair. It bends his trunk between 20°-60° and twists. His legs are in an unstable posture. The lower arms flex more than 100°. The wrist's extensions are more than 15° and twisted.

On the working posture B, the employee bends over himself extraordinarily. The trunk flexes more than 60°. The neck is flexed more than 20° flexion -The legs are in unilateral weight-bearing. Lower arms and wrists are in very bad postures.

In addition, working posture C, D, E, F, and G also require corrective actions. The worker on the working posture C has a lower risk level (medium) because he uses a small chair that makes him have a good-enough-stand-up position. This represents that a chair could help the employee to provide better working postures. On posture C, the trunk, lower arms, and wrists are in the worst conditions.

The risk level of posture D is medium and needs improvement of work postures. The trunk flexes between 20°-60° and is twisted. The neck is twisted. The upper arms are extended in 20° extensions, and rotated; it raises the shoulder. Moreover, it flexes the wrist more than 15° and deviates.

Working posture E also needs refinement because it flexes the trunk extremely. It flexes the upper arms between 45°-90° and rotates. Even more, the wrists are in the most unsatisfactory position. Therefore the risk level is categorized in a medium level.

Grinding posture F also has a medium risk level. It twists the trunk, neck, and upper arms. The worker uses an emergency chair to rest his buttock. This condition also shows that the worker needs an ergonomic chair.

The incidental-additional chairs are used not only in posture C and posture F but also in posture G. The risk level of posture G is lower than the risk level of posture A because the worker in posture G uses the chair. The chair supports the body mass of the worker so the worker could grind the workpiece more conveniently.

Table 13
The REBA scores of working posture A, B, C, D, E, F, and G before revision

| Working Posture | | | | | | | REBA Score | Risk Level | Action |
|---|----------------------------|------------|-------|---------|-------------|---------|------------|------------|----------------|
|  | Group A | | | | | | 8 | High | Necessary soon |
| | Trunk | Neck | Legs | Table A | Load/ Force | Score A | | | |
| | 3+1=4 | 1 | 2 | 5 | 1 | 6 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 2-1=1 | 2 | 2+1=3 | 3 | 1 | 4 | | | |
| | Score C and Activity Score | | | | | | | | |
| 7 +1 | | | | | | | | | |
|  | Group A | | | | | | 9 | High | Necessary soon |
| | Trunk | Neck | Legs | Table A | Load/ Force | Score A | | | |
| | 4 | 2 | 2 | 6 | 0 | 6 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 3 | 2 | 2+1=3 | 5 | 1 | 6 | | | |
| | Score C and Activity Score | | | | | | | | |
| 8 +1 | | | | | | | | | |
|  | Group A | | | | | | 4 | Medium | Necessary |
| | Trunk | Neck | Legs | Table A | Load/ Force | Score A | | | |
| | 2 | 2 | 1+1=2 | 2 | 0 | 2 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 2-1=1 | 2 | 2+1=3 | 3 | 1 | 4 | | | |
| | Score C and Activity Score | | | | | | | | |
| 3 +1 | | | | | | | | | |
|  | Group A | | | | | | 7 | Medium | Necessary |
| | Trunk | Neck | Legs | Table A | Load/ Force | Score A | | | |
| | 3+1=4 | 1+1=2 | 1 | 4 | 0 | 4 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 1+1+1=3 | 1 | 2+1=3 | 5 | 1 | 6 | | | |
| | Score C and Activity Score | | | | | | | | |
| 6 +1 | | | | | | | | | |

**ANDREAN EMAPUTRA, TAUFIK HIDAYAT, DAN GUNAWAN BUDI SUSILO ❖ DESIGN OF
ERGONOMIC CHAIR FOR GRINDING OPERATION**

| Working Posture | | | | | | | REBA Score | Risk Level | Action |
|---|------------|------------|-------|---------|-------------|---------|------------|------------|-----------|
|  | Group A | | | | | | 7 | Medium | Necessary |
| | Trunk | Neck | Legs | Table A | Load/ Force | Score A | | | |
| | 4 | 1 | 1+1=2 | 4 | 0 | 4 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 3+1=4 | 1 | 2+1=3 | 5 | 1 | 6 | | | |
| Score C and Activity Score | | | | | | | | | |
| 6 +1 | | | | | | | | | |
|  | Group A | | | | | | 7 | Medium | Necessary |
| | Trunk | Neck | Legs | Table A | Load/ Force | Score A | | | |
| | 2+1=3 | 2+1=3 | 1 | 4 | 0 | 4 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 3+1=4 | 1 | 2 | 5 | 1 | 6 | | | |
| Score C and Activity Score | | | | | | | | | |
| 6 +1 | | | | | | | | | |
|  | Group A | | | | | | 5 | Medium | Necessary |
| | Trunk | Neck | Legs | Table A | Load/ Force | Score A | | | |
| | 2 | 1 | 1 | 1 | 0 | 1 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 3-1=2 | 2 | 2 | 6 | 1 | 7 | | | |
| Score C and Activity Score | | | | | | | | | |
| 4 +1 | | | | | | | | | |

Table 14 shows the anthropometry data percentile, and standard deviation also can be seen in the same table.

Table 14
The anthropometry data of the three-body measurements

| | D14: buttock-popliteal length (seat depth) in cm | D16: lower leg length (popliteal height) in cm | D19: hip breadth, sitting in cm |
|-----------------|--|--|---------------------------------|
| Employee 1 | 41 | 36 | 31 |
| Employee 2 | 46 | 36.5 | 32 |
| Employee 3 | 47 | 38 | 33 |
| Employee 4 | 50 | 42 | 33.5 |
| Mean | 46.000 | 38.125 | 32.375 |
| 5 th | 41.750 | 36.075 | 31.150 |

| | D14: buttock-popliteal length (seat depth) in cm | D16: lower leg length (popliteal height) in cm | D19: hip breadth, sitting in cm |
|------------------|--|--|---------------------------------|
| 50 th | 46.500 | 37.250 | 32.500 |
| 95 th | 49.550 | 41.400 | 33.425 |
| SD | 3.240 | 2.355 | 0.960 |

Similar to the students' research suggesting to use ergonomic furniture to avoid the harmful effect of poor sitting posture (Taifa & Desai, 2017) the employee doing grinding

operations ought to use an adjustable-ergonomic chair to accommodate their job. Table 15 represents the determinant criteria for the adjustable-ergonomic chair.

Table 15
The determinant criteria for the adjustable-ergonomic chair

| Features | Anthropometric measure | Design dimension | Criteria determinant |
|------------------------|-------------------------------------|------------------|---|
| Seat depth | buttock-popliteal length | 35 cm | 5 th percentile of buttock-popliteal length - 6.75 cm to accommodate employees' easy-movement |
| Seat width | hip breadth, sitting | 35 cm | 95 th percentile of hip breadth (sitting) + 1.575 cm for allowance |
| Adjustable seat height | lower leg length (popliteal height) | 36.1-41.4 cm | 5 th -95 th percentile of lower leg length (popliteal height) to make the chair having an adjustable height because they manufacture products having different heights. The chair has a pin used to change the chair height (Figure 15) |

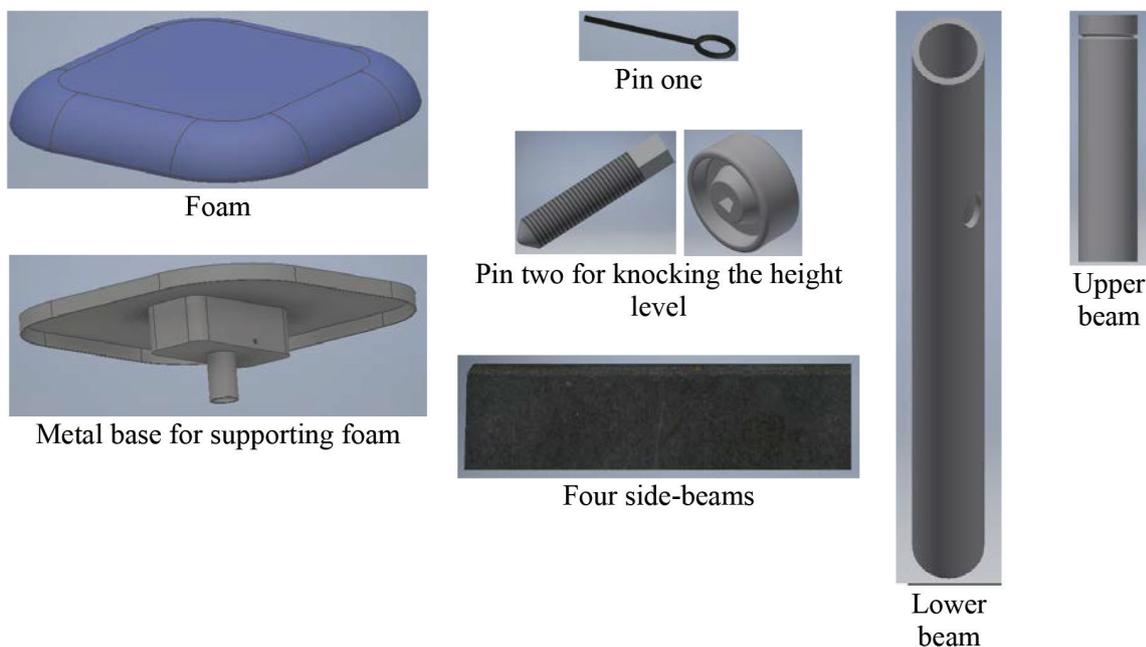


Figure 1.
Parts of the Chair for Grinding Operation

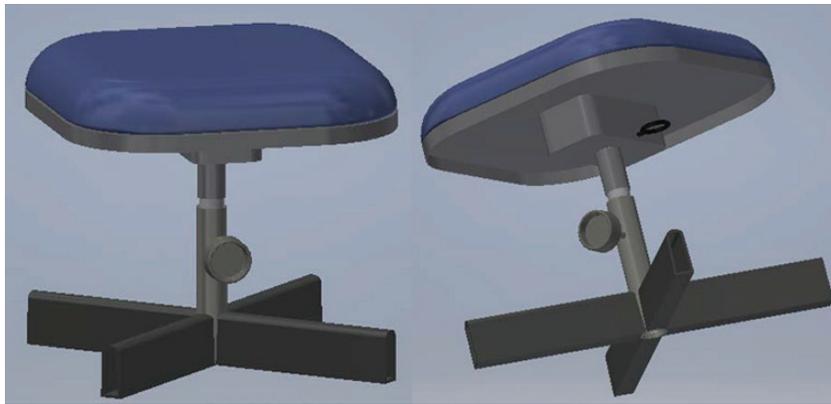


Figure 2.
The 3D Model of the Adjustable-Ergonomic Chair

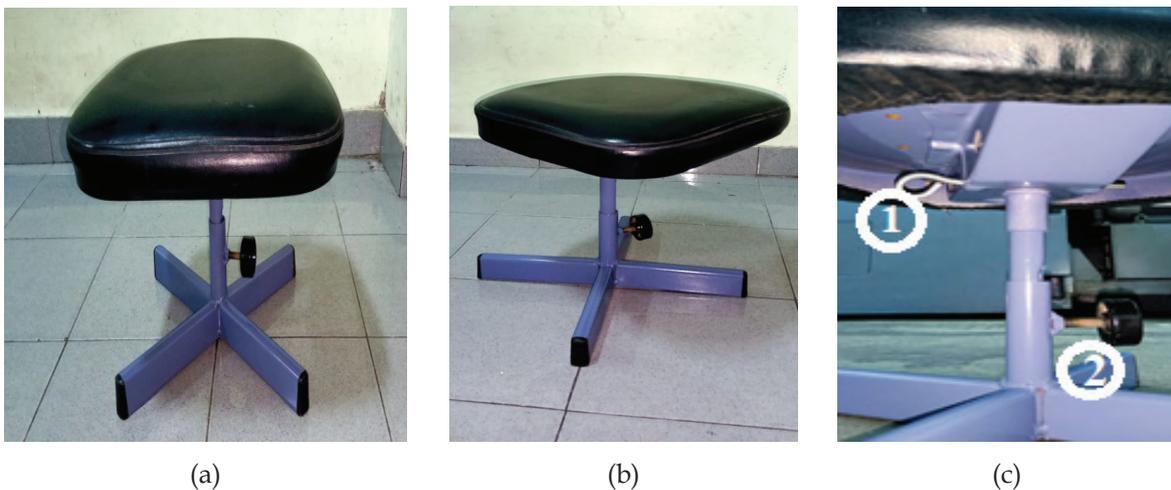


Figure 3.
The Real Object of the Adjustable-Ergonomic Chair
(a = lowest height, b = highest height, c = pin one and pin two)

The adjustable-ergonomic chair (Figures 15 and 16) is appropriate for grinding operation. This is because the chair has adjustable height to accommodate the worker doing workpiece with different sizes and heights. The result is in line with a chair design having an adjustable-height mechanism for accommodating the different body heights of the users (Wang, Lin, & Lin, 2018; Wills & Louw, 2015). This chair uses a metal pin entered into the holes which are available in lower metal beam whereas Wang et al. (2018) used a different type of joints based on user's height and made mild adjustments by rotating the

regulator to a height suitable for them. The pin one assembles the metal base and the upper beam. Besides that, the pin one enables the metal base to rotate around the upper beam. It makes the grinding worker can turn to many sides. The pin two (bolt) presses the beam for locking the chair height. The adjustable-ergonomic chair design has a lower chair height to prevent the employees from bending their back when they are grinding a small-sized and low-heightened workpiece.

In addition, the chair is comfortable for the grinding workers who grind workpiece for long working hours. The chair has a soft

seat made from foam coated with vinyl plastic that is different from other chairs having hard seats made from wood or plastic. A comfortable chair may use molded PUR foam or slab-stock PUR foam (Vlaović et al., 2016).

The last reason is that the chair is durable and robust so that the employees can use it for an extended time. The chair is made from hollow steel that makes durable and light enough to be moved. Chair durabil-

ity contributes significantly to chair quality (Pambudi et al., 2016).

Table 16 shows the REBA evaluation for the grinding chair. The grinding chair is capable of reducing the working postures having the high and medium risk level to the working postures having the low-risk level. Therefore, the chair is very beneficial for the worker to get healthy working postures.

Table 16
The REBA scores of working posture after revision

| Working Posture | | | | | | | REBA Score | Risk Level | Action |
|---|------------|------------|-------|---------|------------|---------|------------|------------|------------------|
|  | Group A | | | | | | 3 | Low | May be necessary |
| | Trunk | Neck | Legs | Table A | Load/Force | Score A | | | |
| | 2 | 1 | 1 | 2 | 0 | 2 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 2 | 1 | 1+1 | 2 | 0 | 2 | | | |
| Score C and Activity Score | | | | | | | | | |
| 2+1 | | | | | | | | | |
|  | Group A | | | | | | 3 | Low | May be necessary |
| | Trunk | Neck | Legs | Table A | Load/Force | Score A | | | |
| | 3+1 | 1 | 1 | 3 | 0 | 3 | | | |
| | Group B | | | | | | | | |
| | Upper Arms | Lower Arms | Wrist | Table B | Coupling | Score B | | | |
| | 2 | 1 | 1 | 1 | 0 | 1 | | | |
| Score C and Activity Score | | | | | | | | | |
| 2 + 1 | | | | | | | | | |

CONCLUSION

A worker working on the grinding operation that has bad postures need posture evaluation and refinement. One of the ways to solve the problem is to provide an adjustable-ergonomic chair. The chair should be adjustable to accommodate the full range of the product size, and comfortable to be used in the working hours. Besides that, the chair

should be durable and robust to sustain the weight of the employee. Moreover, it should have a long lifecycle.

The stakeholder of the enterprises using grinding operations in their production process should accommodate the employees to have an appropriate-adjustable-ergonomic chair since the chair could reduce the risk level into a low-risk level. Therefore, their

employees would work safely and would not suffer from adverse effects that come from bad-working postures.

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