A Study on Push-Pull Analysis Associated with Awkward Posture among Workers in Aerospace Industry

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Abstract

In aerospace industries, many working tasks required their workers to perform their works in push-pull activity. It is associated with an awkward posture. The awkward posture is a practical working posture when joints are not in neutral position. Furthermore, the workers need to push or pull the mould in a long distance into a workplace. If the workers perform the activity continuously throughout the working hours, they may be experienced back pain problem. The objective of this study is to measure the maximum acceptable initial force and sustained force for push-pull activity while workers perform their tasks. Besides that, this study also wants to identify which activity can endure longer between push or pull activity. Moreover, this study also measures the comfort level of working posture. The acceptable initial force and sustained force were measured using Push-Pull Analysis, expressed in Newton, N. The comfort level is measured using Rapid Upper Limb Assessment (RULA) Analysis, expressed in scoring level. Both of these assessments are analysis tools Computer-Aided Three-Dimensional Interactive Application (CATIA) software. Six production workers from manufacturing department were participated as subjects. The results show the maximum acceptable initial force for push task is 433.942N and pull task is 396.691N. While, the sustained force for push task is 333.465N and pull task is 318.317N. Referring to the results, pushing activity can endure longer than pulling activity while workers perform their tasks. While the comfort level for this working posture is seven. Based on this study, the authors concluded that push-pull activity can lead to the back pain problem for workers in aerospace industry. It's was influenced by the work activity, work load, work duration of awkward posture and distance between workplace.

Keywords
Push-pull activity, awkward posture, acceptable initial force, acceptable sustained force, comfort level

1. Introduction
Manual material handling (MMH) such as lifting heavy products, reaching materials, bending forward their back when doing tasks, and pushing or pulling excessive loads because those tasks require a stable position and large degree of freedom. Pushing and pulling activities are one of the activities for MMH that can increase the risks of back pain problem (Kuijer et al. 2007). The pushing and pulling activities is a frequent activity for a great segment of the workforce, including hospital workers, manufacturing workers, construction workers, forest workers, etc (Hoy et al. 2005, Smith et al. 2006, Kee and Seo 2007, Vieira and Kumar 2007, Canjuga et al. 2010, Scuffham et al. 2010, Jellad et al. 2013). Moreover, both of these activities are associated with the awkward posture. Awkward posture can be theorized as a discomfort posture because it is harmful position for human body when a joint is not in its neutral range of postures and make muscles are either shorter or longer than resting length. When joints are exposed to postures that involve range of movement near the extreme positions, the muscles around the joint are stretched or compressed. If the exposure to extreme postures is prolonged, the muscles do not immediately return to their resting length (Hayot et al. 2012). In manufacturing workplaces, numerous processes jobs are recommended to be performed in awkward posture. For example, they need to bend their neck forward greater than 30 degrees, raise their elbow above their shoulder, bend their wrist downward with palm facing downward greater than 30 degrees, bend their back forward greater than 45 degrees, squatting, etc (T-Krajewski et al. 2009).

The Ergonomics Design and Analysis tool of Computer-Aided Three-Dimensional Interactive Application (CATIA) software is one of the ergonomics analysis tool that have been applied to analyze pushing and pulling activities of workers while performing tasks in awkward posture (Vieira and Kumar 2007, Landau et al. 2008, Sheikhzadeh et al. 2009, Daraiseh et al. 2010, Govindu et al. 2012). The tool quantifies the push-pull activity in two different forces which is maximum acceptable initial and sustainability force in terms of Newton, N corresponding to contraction of the awkward posture while handling the jobs. For instance, if the maximum acceptable sustainability force is high, it means that the workers can endure longer while performing the particular tasks. But, if the tasks are continuously performed over the limit, they will experience back pain problem. Besides that, this ergonomics analysis tool also can quantify comfort level of working posture while workers perform their tasks using Rapid Upper Limb Assessment (RULA) feature. Several epidemiology studies used this feature because they wanted to know whether the working posture in comfort or discomfort condition (Hoy et al. 2005, Shuval and Donchin 2005, Jones and Kumar 2007, Hwang et al. 2010, Öztürk and Esin 2011, Dockrell et al. 2012, Meksawi et al. 2012).

The purpose of this study is to measure the maximum acceptable initial force and maximum acceptable sustainability force for push or pull activity among six manufacturing workers in aerospace industry while workers performed their tasks in awkward posture. Additionally, the maximum acceptable sustainability force between push and pull activity was compared to find out which can endure longer while workers perform their tasks. Furthermore, the level of comfort also measured to figure out whether the working posture in comfort or discomfort condition.

2. Methodology

An aerospace company situated in Malaysia was selected to perform the data collection. In the production department of the company, all workers are males and national citizenship. They worked in two shifts based on a 12-hour shift schedule. A main working activity in this company is MMH activities. One of the MMH activities is pushing and pulling activity. All manufacturing workers related with pushing and pulling activity performed their tasks in awkward posture especially in lay-up process line. Moreover, the tasks require workers to push or pull with awkward posture because the nature of jobs is repetitive, frequent movement, and large degree of freedom.

Six production workers were recruited as subjects in this study. They are selected from lay-up process lines. To fulfill the basic requirement of this study, selected workers who performed pushing or pulling activity in awkward posture and no injuries for the past 12 months were allowed to participate in the experimental work. Demographic of the selected workers from lay-up process line are described in Table 1.

Table 1: Demographic of the workers participated in the study

Criteria	**Mean (SD)**
Gender	Male
Age	25.7 (5.0)
Mass (kg)	64.5 (10.9)
Height (cm)	174.2 (7.3)
Experience (year)	4.7 (2.7)

An Ergonomic Design and Analysis tool of Computer-Aided Three-Dimensional Interactive Application Version 5 Release 19 (CATIA V5R19) software were used to analyze the pushing and pulling activity associated with awkward posture of the workers. Besides that, the comfort level of working posture also measured using this tool. The capture posture of workers was captured based on real job monitoring. The measurement of distance between workplace was measured by using measuring tape. The distance is about 2.1 meters from furnace (Autoclave) to workplace (Clean Room). This distance is the furthest distance for pushing and pulling activity in this working area. On the other hand, the real time monitoring also needs to be considered for this working activity. It is because one of the requirements from the ergonomics analysis tool is time consumption for pushing and pulling activity per mould. Other than that, the weight of panel also required which is 500 kilogram, kg per panel. After all the data needed are ready, the design can now start to analyze. Figure 1 shows the worker with awkward posture for pushing and pulling activity.

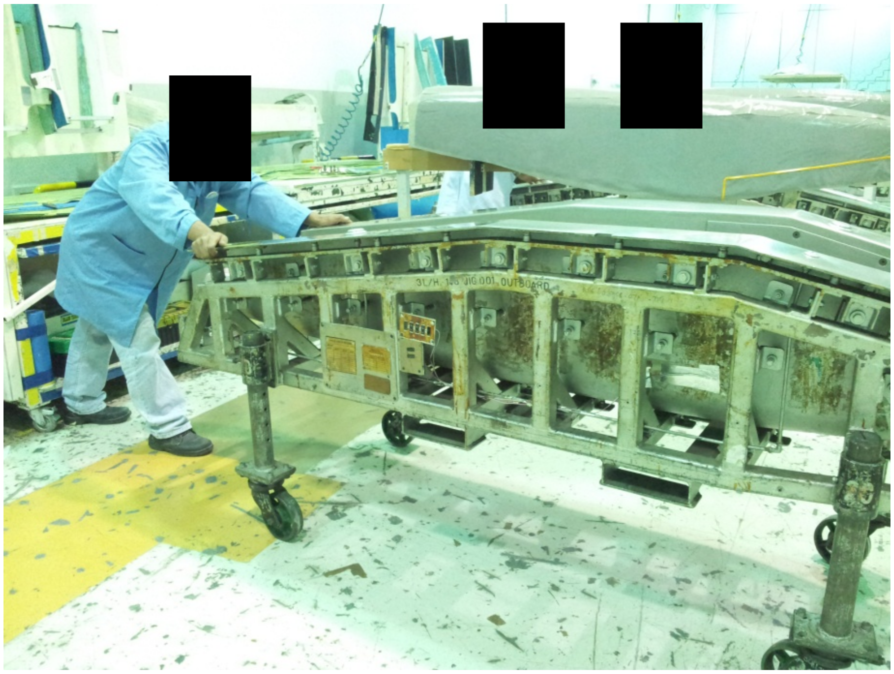
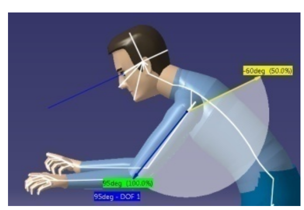
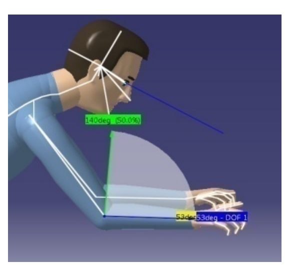
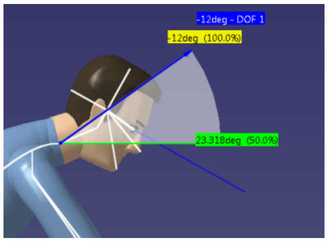
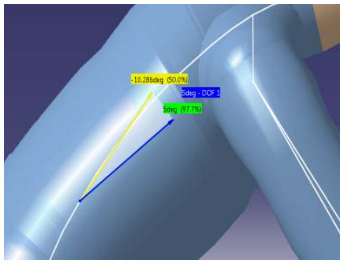
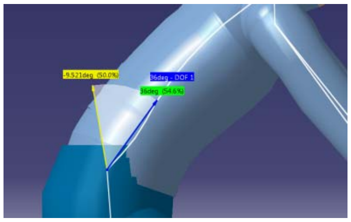
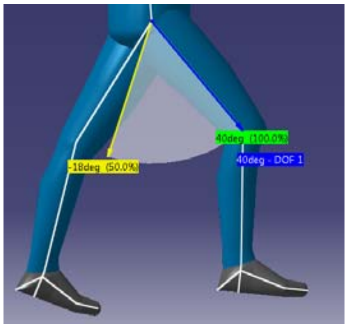
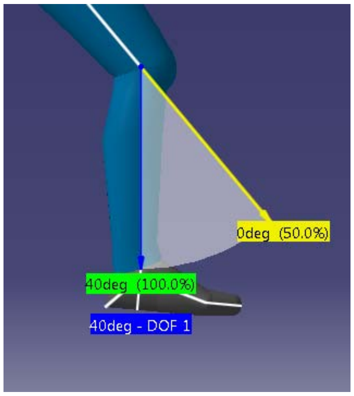


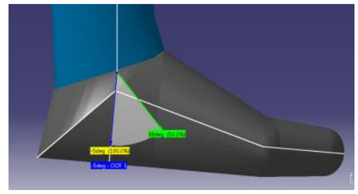
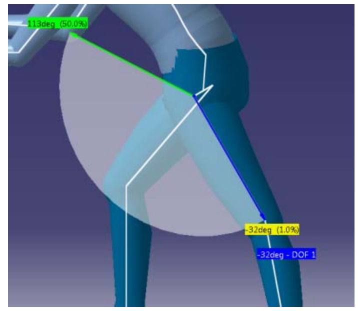
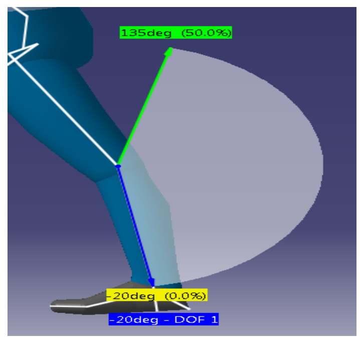
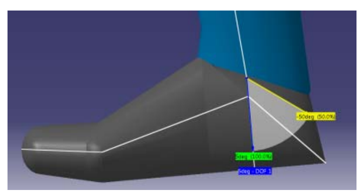
Figure 1: Awkward posture for pushing and pulling activity

By using ergonomics analysis tool from CATIA V5R19, the pushing and pulling activity can be analyzed. The analysis is used to analyze the maximum acceptable and sustainability force when workers push or pull each mould. The feature used from this tool to do the analysis is Push-Pull Analysis feature. Besides that, the comfort level of the working posture also analyzed by using this tool. But, the comfort level is analyzed by using RULA feature. The working posture for this analysis is same with the posture shown in Figure 1. However, the analysis needs to be done in three different height of mould which is 50 centimeter, 47 centimeter, and 45 centimeter. For this analysis, the workers is separated into three group which is taller (the height above 180.0 centimeter), medium (the height between 170.0 centimeter to 179.9 centimeter), and shorter (the height below 170.0 centimeter). Besides that, in this analysis, all the angles involved in working posture are same for each worker as shown in Table 2. The angles in analysis are same with the angles in real case study as in Figure 1.

Table 2: Analysis angle involved in working posture for each worker

Body Segment	**Angle**
Shoulder • Both left and right 95^o	
Hand arm • Both left and right 53^o from origin, 0^0	

Neck • -12^{o} from origin, 0^{0}	
Upper back • 5^{o} from origin, 0^{o}	
Lower back • 36^{o} from origin, 0^{0}	
Right thighs • 40^{o} from origin, 0^{0}	
Right calf • 40^{o} from origin, 0^{0}	

Right ankle • -5^{o} from origin, 0^{0}	
Left thighs • -32^{o} from origin, 0^{0}	
Left calf • -20^{o} from origin, 0^{0}	
Left ankle • 5^{o} from origin, 0^{0}	

Based on selected angle in Table 1, the whole body working posture for push-pull activity has been designed in CATIA V5R19 software by using ergonomics analysis tool. Figure 2 shows the design of whole body working posture for push-pull activity by using ergonomics analysis tool in CATIA V5R19 software.

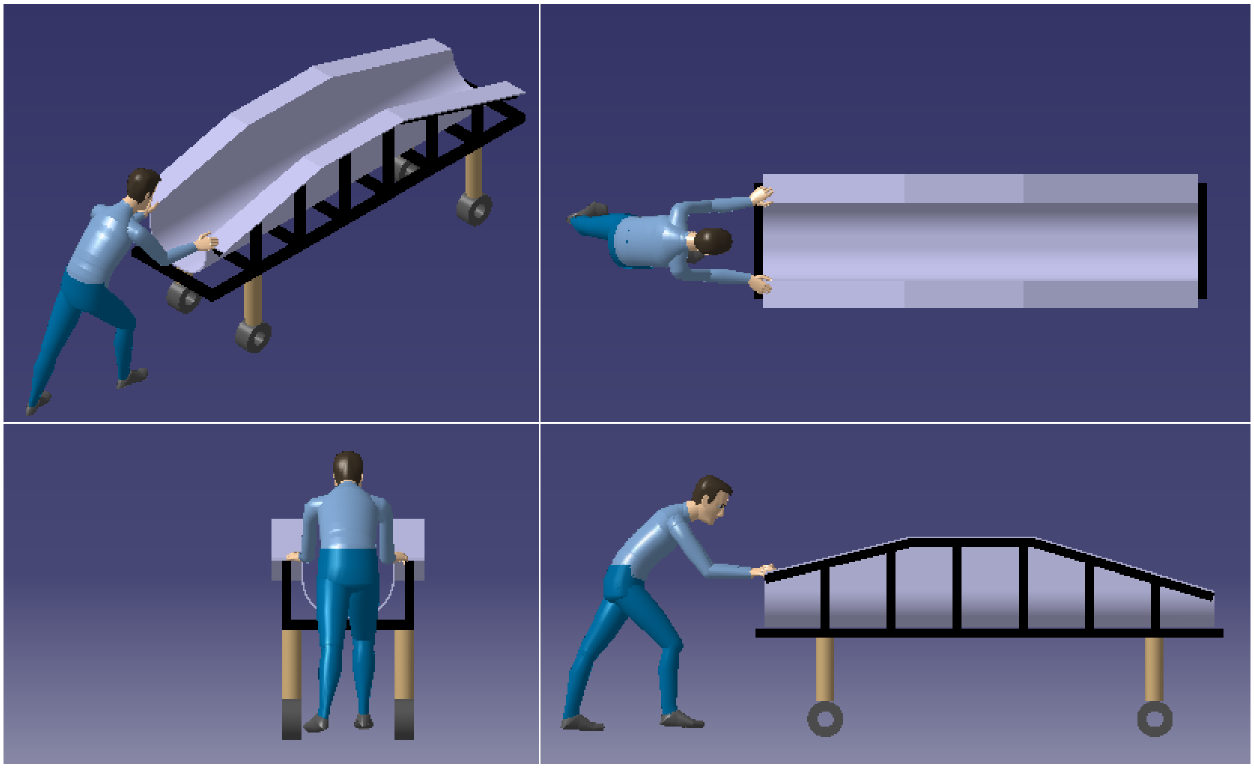


Figure 2: Whole body working posture for push-pull activity

After the whole body working posture with the mould has designed, the Push-Pull Analysis now can be analyzed. The output parameter from the analysis is the value of maximum acceptable initial and sustained force that is expressed in Newton (N). While the output parameter from RULA feature is final score for comfort level of awkward posture. Graphical analyses associated with descriptive and comparative analysis were used to interpret the data.

3. Results and Discussion

This study has conducted an analysis of pushing and pulling activity associated with awkward posture of manufacturing workers in aerospace company. Besides that, this study also quantifies the comfort level of working posture among the workers while they are doing their tasks. In the company, a main manufacturing process is coming from lay-up process line. This lines required workers to perform pushing and pulling activity in awkward posture for period of time. All workers worked on a 12-h shift schedule. The shift is changed every week which is worked both; day and night shift. It was observed that the workers spent about 80% of the working hours in awkward posture to do their tasks (only neutral standing during setup ply and sitting during breaks) throughout the 12-h working period. This is due to the activities that required the workers to push or pull the panel every 45 minutes with awkward posture from furnace (Autoclave) to workplace (Clean Room). For instance, workers also need to push or pull the panel in the workplace (Clean Room) before the panel is fixing to the floor. Thus, the process would be practicable in awkward posture as it requires frequent bending forward of the workers back. This study observed that the back pain problem occurred particularly in the lower back due to above mentioned working conditions. Furthermore, there were complaints of intense pain in those body parts from the workers of lay-up process lines which is upper back, shoulder, hand arm, wrist, and fingers.

Through Push-Pull Analysis as shown in Figure 3, this study identified that the maximum acceptable initial force when the workers do the pushing activity is 433.942N. While the maximum acceptable initial force for pulling activity is 396.691N. According to the results, the workers must either use the initial force of 433.942N to push the mould or use 396.691N to pull the mould. The initial force is the primary effort needed for workers to do their works (Kuijer et al. 2007).

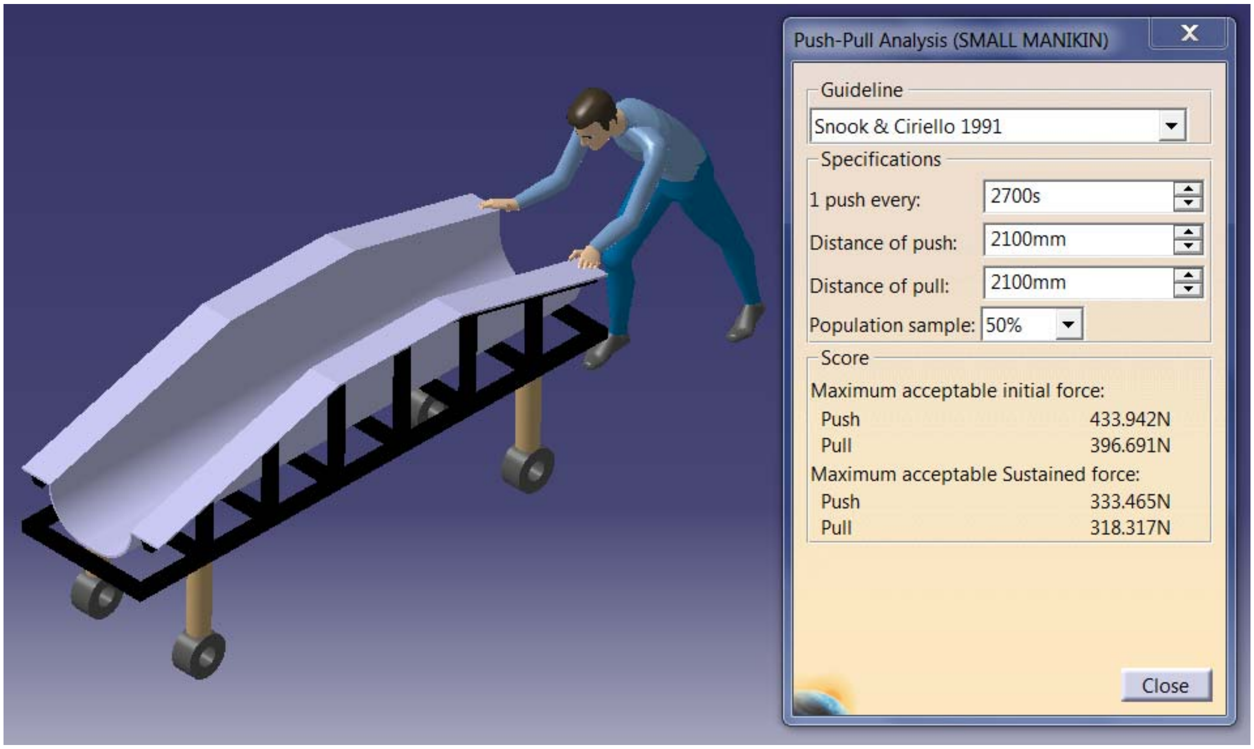


Figure 3: Push-Pull Analysis from CATIA V5R19 software

Based on Figure 3, the time consumption used is 2700 seconds is equally 45 minutes. Besides that, the distance of push or pull the mould is 2100 millimeters is equally 2.1 meters. Other than that, the population sample is 50% because the subjects for this experiment are six workers among 12 workers. Hence, the population sample is half of the overall workers.

Referring to the result of maximum acceptable sustained force for pushing activity is 333.465N. While the result for pulling activity is 318.317N. According to the results, the workers used 333.465N to push the mould or use 318.317N to pull the mould along the activity is performed. The sustained force is the gross effort needed when the workers do their works along working hours (Kuijer et al. 2007).

This analysis pointed that working activity, distance of push-pull activity, and weight of mould can influence the initial force needed to push or pull the mould. Other than that, it's also influence the sustained force which is the gross force needed during the activity is performed. When the worker used the sustained force in a long period of time, their energy will decrease. Due to energy diminish, the muscles will involve with contraction and this condition can lead to discomfort and back pain problem (Theado et al. 2007).

Moreover, according to ergonomics analysis tool using RULA feature from CATIA V5R19 software, the working posture is discomfort posture because the level of comfort for this awkward posture is 7 score. Figure 4 shows right body region from RULA analysis for push-pull activity using average shortest worker with 45 centimeter height of mould. Whereas Figure 5 shows left body region from RULA analysis for push-pull activity using average shortest worker with 45 centimeter height of mould. Both left and right need to analyze because the working posture is not in symmetric position. Thus, the analysis needs to be done in both body regions because the comfort level will different. By referring to Figure 6, the score from comfort level of RULA analysis will easily understand using RULA standard from NIOSH (Meksawi et al. 2012).

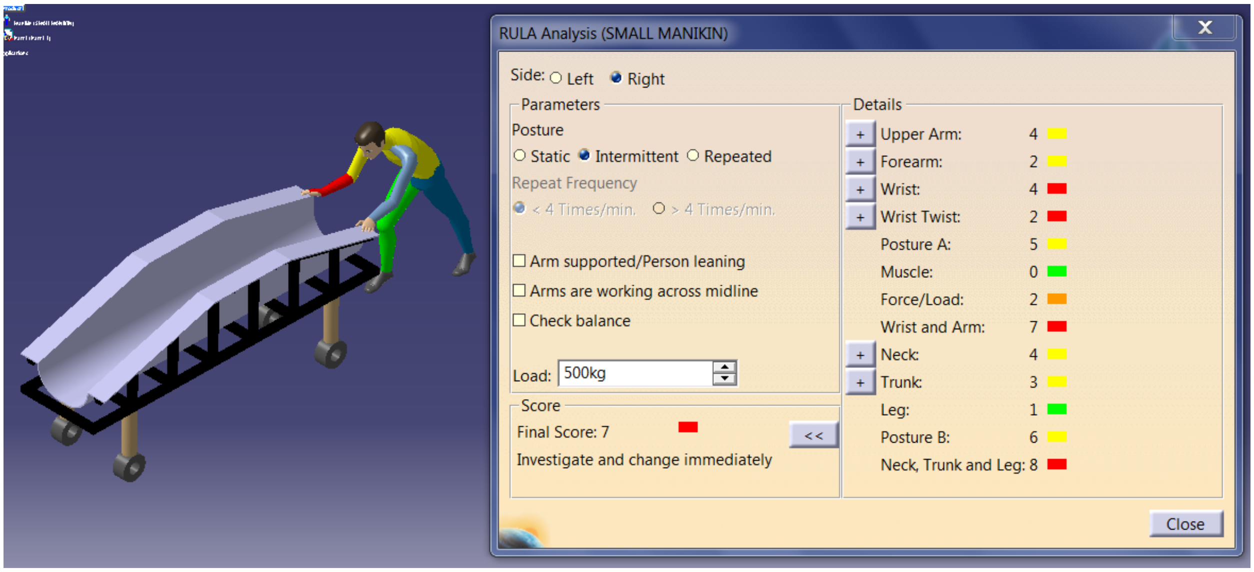


Figure 4: Right body region from RULA analysis for push-pull activity using average shortest worker with 45 centimeter height of mould

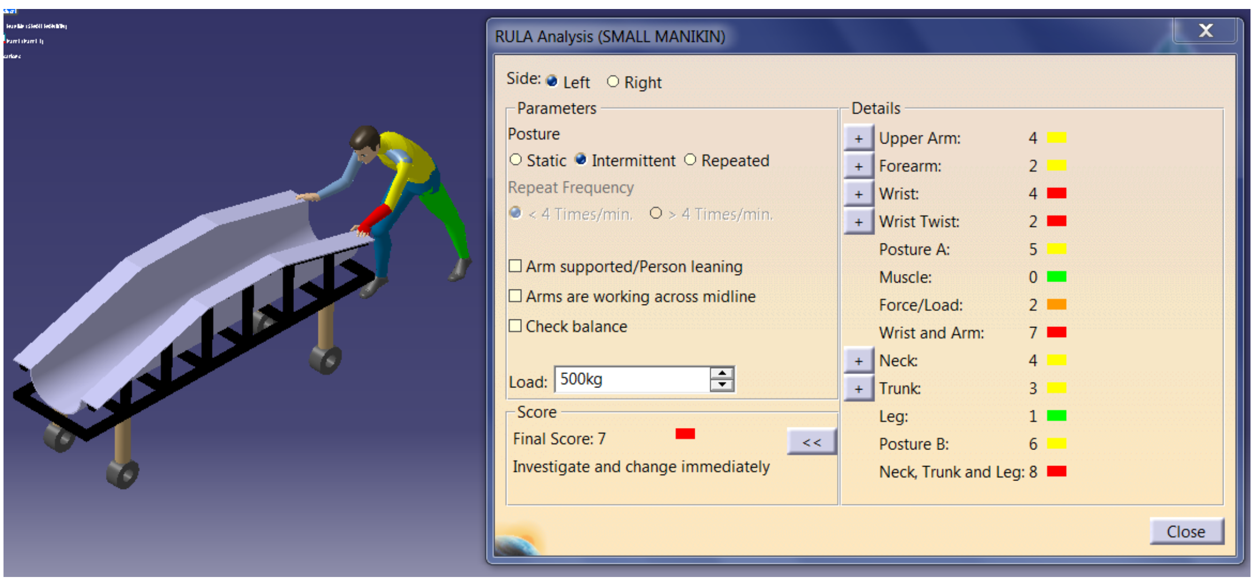


Figure 5: Left body region from RULA analysis for push-pull activity using average shortest worker with 45 centimeter height of mould

Score	Level of MSD Risk
1-2	negligible risk, no action required
3-4	low risk, change may be needed
5-6	medium risk, further investigation, change soon
6+	very high risk, implement change now

Figure 6: Standard score from NIOSH for comfort level of RULA analysis

Based on Figure 4 and Figure 5, both of body regions which is right and left are in very high risk working posture. Changing is immediately needed for that working posture. The changing only needed for right and left hand arm. Based on the results, wrist and arm is in discomfort posture because the wrist is in twist position for both hand arms. Thus, placed more stress in the wrist for both hand arm (Schaub et al. 2007). Table 3 shows summary RULA analysis for 3 different groups of workers with three different height of mould.

Table 3: Summary RULA analysis for 3 different groups of workers with three different height of mould

Group of Workers	Height of Mould (centimeter)	Average Score (Right and Left)
Small	50	7
Medium	45	7
Tall	47	6
Small	45	5
Medium	47	5
Tall	50	5
Small	47	6
Medium	50	6
Tall	45	7

* Tall workers (the height above 180.0 centimeter), medium workers (the height between 170.0 centimeter to 179.9 centimeter), and short workers (the height below 170.0 centimeter)

After averaging both of the results (right and left body region), the average score for each group of workers shows the smaller size of workers not suitable to work using mould with 50 centimeters of height. While the medium and taller size of workers not suitable to work using mould with 45 centimeters of height. Figure 7 shows statistical data analysis of average score from RULA analysis for each group of workers. From the results, small workers experienced discomfort working posture when they are working using 50 centimeters height of mould. Other than that, medium and tall workers experienced discomfort working posture when they are working using 45 centimeters height of mould.

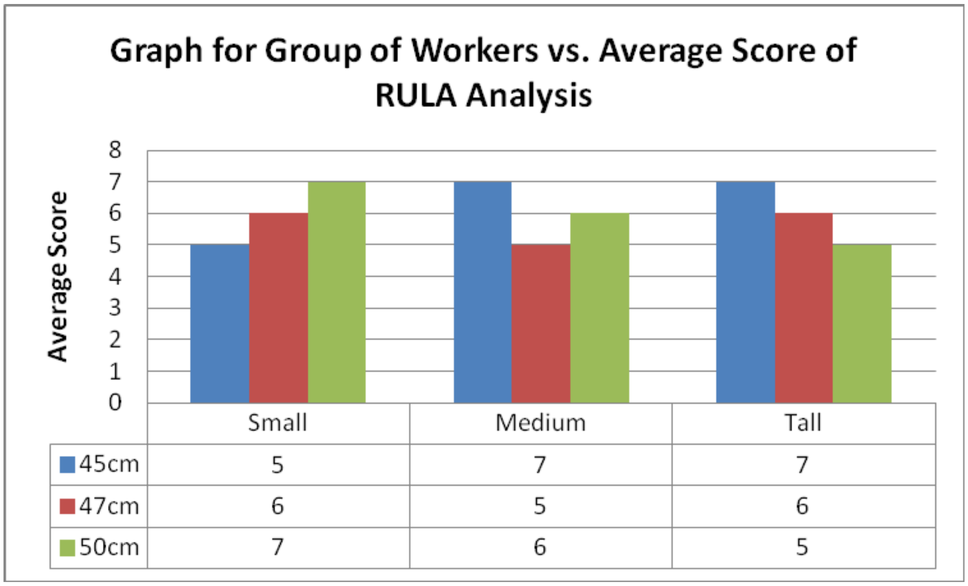


Figure 7: Statistical data analysis of average score from RULA analysis for each group of workers

This analysis pointed that the height of workers and height of mould can influence the level of comfort for working posture. When the worker is bending forward their back in a long period of time, static contraction of muscles can occur particularly in the back. Due to static contraction, performance of the muscles may decrease and this condition can lead to discomfort and back pain problem (Theado et al. 2007).

4. Conclusion

This study has performed Push-Pull Analysis and RULA Analysis for working posture of manufacturing workers at lay-up process line in aerospace company. All workers performed their tasks in awkward posture for prolonged time periods. The measurements of push-pull activity were conducted using 500 kilogram weight of mould and 2.1 meters of distance from furnace (Autoclave) to workstation (Clean Room). Besides that, the measurements of RULA activity were conducted using three different height of mould and three different height of worker. Regarding to the maximum acceptable initial force from Push-Pull Analysis, if the workers push the mould the force needed is 433.942N. If the workers pull the mould the force needed is 396.691N. On the other hand, if the workers push the mould the maximum acceptable sustained force needed is 333.465N. If the workers pull the mould the force needed is 318.317N. Both results show that if the workers used pushing activity they can endure longer to finish their tasks. Moreover, the highest result of discomfort score from RULA Analysis is level seven which is very high risk working posture and the changing should be implemented now. Therefore, this study concluded that back pain problem of the lay-up workers in aerospace industry was influenced by the work load, work activity and duration of awkward posture.

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Biography

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