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Ergonomics Hazard Identification and Risk Assessment of Visual Inspection Process in a Semiconductor Manufacturing Industry

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Abstract: This research deal with the ergonomics hazard in the semiconductor manufacturing industry. Lack of ergonomics safety often causes the presence of hazards to the workers. The purpose of hazard identification and risk assessment in this study is to highlight the critical operations of tasks that pose significant risks to workers' health and safety and highlight those ergonomics hazards pertaining to working conditions or activities performed. In order to assess the presence of hazards, its risks and its preventive measures, Hazard Identification, Risk Assessment and Risk Control (HIRARC) assessment was done. The risk assessment's results presented in a risk matrix are essential to make decisions on risk control. The results show that the final process, which was checked on the bonded unit under the microscope and destroyed the reject unit by using tweezers was classified as extreme risk level. This shows that ergonomics safety is an essential aspect that needs to be prioritised to produce productive workers.

Keywords: Ergonomics, hazards, HIRARC, likelihood, risk, severity

1. Introduction

The manufacturing industries in Malaysia are facing problem with high workplace accident rate, which may reflect how they handle risk management system in their organisations (Agwu, 2012). Thus, an accident is defined as an unfortunate that happens unpredictably and inadvertently, resulting in harm or injury. The accident occurs depending on the situations, either result in minor fatalities or having the potential for but do not result in a loss (Kleindorfer et al., 2012). Risk management consists of various activities and strategies that an organisation can use for protection from situations, circumstances, or events that may encounter its security. It is a process of thinking systematically about all possible risks, problems or disasters before they occur and setting up procedures that will avoid the risk, minimise its impact, or cope with its impact. In order to obtain a safe workplace in manufacturing industries, an efficient and appropriate system of safety and health is considered upmost importance. Therefore, the use of Hazard Identification, Risk Assessment, and Risk Control (HIRARC) are effective in identifying, assessing, managing and mitigating the hazards faced by employees (Malaysia., 2014). In order to achieve the objectives of Occupational Safety and Health Act (OSHA) 1994, it is needed to look into HIRARC which is the basis of occupational safety and health (Ahmad et al., 2016). In order to obtain a safe workplace in manufacturing industries, an efficient and appropriate system of safety and health is considered as upmost importance. Therefore, the use of HIRARC is effective in identifying, assessing,

managing and mitigating the hazards faced by employees. In order to achieve the objectives of Occupational Safety and Health Act (OSHA) 1994, it is needed to look into HIRARC, which is the basis of occupational safety and health.

Hazard identification recognises of things that may cause injury or harm to a person while risk assessment is looking at the possibility of injury or harm occurring to a person if exposed to a hazard. Risk control measures the problem and starts to act to reduce the risk of a person being exposed to a hazard. Hazard identification, risk assessment and risk control identify the types of hazards that occurred, to make a risk assessment on hazards that have been identified, to suggest risk control to the organisation management team and to take action and implementing the control to the problem and improve performance that is going to be achieved. This is the process of examining each work area and work task to identify all the hazards inherent in the job (Ahmad et al., 2016). The purpose of hazard identification and risk assessment in this study is to highlight the critical operations of tasks that pose significant risks to employees' health and safety, also highlight those hazards pertaining to certain equipment due to energy sources, working conditions or activities performed. Then risk level is assigned to each hazard for identifying required corrective action to minimise the risk or eliminate the hazard.

Meanwhile, ergonomic workplace assessment survey was used to look into the common work and health problems associated with ergonomic hazards at work. The data will assist regulatory bodies and manufacturers for an overview of health and work issues in the manufacturing sector which should be addressed to obtain both healthy work environment and productivity (Del Prado-Lu, 2007). Previous researchers reviewed several postures and activities utilised by the beverage delivery employees, including sitting, kneeling, squatting, pushing, pulling, lifting, lowering, stacking or unstacking items, walking, and stair or ramp climbing. The investigation showed that knee discomfort symptoms were the most reported by employees (Reid et al., 2010). Although various problems of an ergonomic nature of the job under study have been identified, the use of the tools of analysis and the results were adequate so that recommendations could be put forward to minimize the problems and provide a better quality of life and safety for the workers (Barros et al., 2015). Many factors influence the effects of the visual environment, such as factors related to the physical environment lighting, ergonomics, and workplace design, the tasks such as the work object, visibility, contrasts and readability, and the individual's visual ability such as visualacuity, age, and visual defects (Long, 2014; Zetterberg et al., 2019). While other factors causing occupational accidents include an unsafe environment, unsafe equipment, hazardous substances, unsafe work attitudes, and lack of orderly use of personal protective equipment (Junaidi et al., 2020).

Visual inspection task provides a means of detecting and examining various surface flaws, such as corrosion, contamination, surface finish, and surface discontinuities on joints, such as welds, seals, and solder connections. Visual inspection is also the most widely used method for detecting and examining surface

cracks that are particularly important because of their relationship to structural failure mechanisms. Even when other inspection techniques are used to detect surface cracks, visual inspection often provides a useful supplement. The methods of visual inspection involve a wide variety of equipment, ranging from examination with the naked eye to the use of interference microscopes for measuring the depth of scratches in the finish of finely polished or lapped surfaces. Ergonomics interventions were made to rectify the problems such as reduced usage of a magnifying glass, less glaring inspection templates, an inspection of only electrically non-tested components and introduction of a visual inspection sequence. The interventions produced savings in rejection cost, reduced workers' eye strain, headaches and watery eyes lowered the defect percentage at customers' sites and increased the factory's productivity and customer satisfaction (Yeow & Sen, 2004).

This research was conducted according to the basic safety procedure which is hazard identification and risk survey, to assess the ergonomics risk during the task performed by the workers of visual inspection process in a semiconductor manufacturing industry.

2. Research Methodology

2.1 Observation

This observation method uses an informal interaction with the workers and a supervisor to identify the frequent problems happened. The visual inspection workstation is shown in Fig. 1.

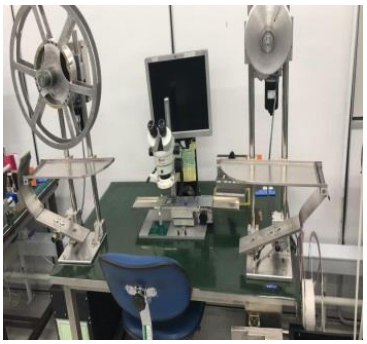

Fig. 1. Visual inspection workstation

2.2 Hazard Identification, Risk Assessment and Risk Control (HIRARC)

Hazard Identification, Risk Assessment and Risk Control (HIRARC) have become fundamental to the practice of planning, management and the operation of a business as a basic of risk management in recent years. HIRARC is a structured approach for

identifying, evaluating and controlling hazards in the workplace to achieve better organisational performance of no harm or damage to people, assets, environment and reputation. It may also be defined as a process of determining the probability and consequences of an identified hazardous event and its risks to workers (Agwu, 2012). It entails evaluating the risks associated with the identified hazards, so that appropriate controls may be taken based on the probability and severity of the potential hazard. The important steps taken for this assessment is shown in Fig. 2.

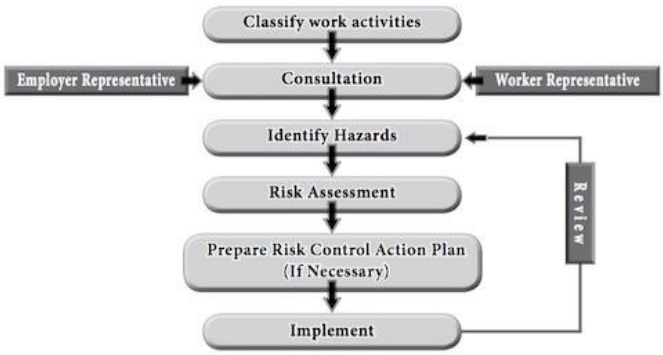

Fig. 2. Flowchart of HIRARC Process

2.2.1 Hazards Identification

Hazard is defined as anything that has the potential to cause harm, including injury, disease, death, environmental, property and equipment damage. This is the process of examining each work area and work task for the purpose of identifying all the hazards which are inherent in the job. The identification of hazards was conducted by observing the work activities of each workstation throughout the department, and the hazards associated with the work activities were listed. General workplace inspection checklist has been applied to observe other areas such as work environment and housekeeping, training, the usage of personal protective equipment (PPE), facilities, and noise. The interview was conducted with all workers. The interview questions were divided into seven variables which are training, environment, mechanical, ergonomics, PPE, electrical, and noise. The interview was conducted to examine the workers' perception towards implementing safety and health practices in their workplace.

2.2.2 Risk Assessment

After the hazards in the system were identified, all hazards were quantified by using a quantitative numerical value. Risk assessment consists of processes related to risk analyses, assessment of risk magnitude (high, medium, or low), judgement on

whether the risk is acceptable or unacceptable, and evaluating risk control options. The listed hazards were given the severity and likelihood ratings. The risks are labelled as low, medium or high based on the severity and likelihood rating, as shown in Table 1 and Table 2.

Table 1. Likelihood values in hazard identification

Likelihood (L)	Example	Rating
Most likely	The most likely result of the hazard/ event being realised	5
Possible	Has a good chance of occurring and is not unusual	4
Conceivable	Might be occurring at some time in future	3
Remote	Has not been known to occur after many years	2
Inconceivable	Is practically impossible and has never occurred	1

Table 2. Severity values in hazard identification

Severity (S)	Example	Rating
Catastrophic	Numerous fatalities, irrecoverable property damage and productivity	5
Fatal	Approximately one single fatality major property damage if hazard is realised.	4
Serious	Non-fatal injury, permanent disability	3
Minor	Disabling but not permanent injury	2
Negligible	Minor abrasions, bruises, cuts, first aid type injury	1

Hazard is a closed relationship with the risk. Risk is a measurement to analyse and evaluate the hazard (Ahmad et al., 2016). The measurement is made by identification on how severe and when likely of the hazard. In other words, the risk assessment is an in depth look to specify situations, process and other harmful activities or hazard at workplace. Risk is presented in various ways to communicate the distribution of the risk throughout a plant and area in a workplace. The results of risk assessment presented in a risk matrix are essential to decide on risk control. Risk can be calculated by using the formula in Eq. 1,

$$\text{Risk} = \text{Likelihood (L)} \times \text{Severity (S)} \quad (1)$$

The magnitudes of risks were determined using the risk matrix table, as shown in Table 3, and the identification of risk level is shown in Table 4.

Table 3. Risk assessment matrix level

Likelihood of Hazards	Severity of Hazards				
	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Fatal (5)
Rare (1)	1	2	3	4	5
Unlikely (2)	2	4	6	8	10
Possible (3)	3	6	9	12	15
Likely (4)	4	8	12	16	20
Almost certain (5)	5	10	15	20	25

Table 4. Identification of risk level

Risk Level	
1 to 2	LOW
3 to 6	MEDIUM
7 to 12	HIGH
More than 12	EXTREME

2.2.3 Risk Control

Risk control is the elimination or inactivation of hazard in a manner such that the hazard does not pose a risk to workers. Hazards should be controlled at their source where the problem is created. The rating of four characteristics of risk that are commonly identified, according to the measures taken is shown in Table 5.

Table 5. Control measure matrix

Control Measures	Level	
Control measures exceeding industry standards and the best practices. Loss potential is considered significant reduced.	Excellent	3.1 – 4.0
Control measures that are consistent with industry standards and best practices. Loss potential is considered to be average	Good	2.1 – 3.0
Control measures that approach industry standards and best practices, however deficiencies exist. Loss potential is considered somewhat increased.	Fair	1.1 – 2.0
A control measure has major deficiencies and does not approach industry standards and best practices. Loss potential is considered to be significantly increased.	Poor	0 – 1.0

3. Results and Discussion

3.1 Work Operation

This research study is carried out at the visual inspection workstation with regard to ergonomics, health and safety factors. The visual inspection process, including checking on units which passed through die bond and wire bond and destroy rejected units. This visual inspection process was carried out by the workers by using microscope starting from 7.00am to 7.00pm for the morning shift, or 7.00pm to 7.00am for the night shift. Out of 12 hours of the working period, the allocated overall break time is 70 minutes, including morning, lunch and tea break. For approximately 10 hours, workers were prolonged seated at their workstation to do their inspection task. They will only spend several minutes to move around when changing the reel of LED once they finished with the previous one. Consequently, prolonged sitting will lead to many health issues or musculoskeletal disorders (MSDs), and it will be risky to the workers to perform their task in hazardous working environment.

3.2 Hazards Identification

There are many types of hazards present in surrounding, but only three main types of hazards are studied in this research such as work environment, manual handling and mechanical. Table 6 explains the hazards according to the task description. The next step was risk analysis and risk control. This analysis was done based on the three main processes involved in the visual inspection task.

Table 6. Presence of Hazards According to Job Description

Process	Posture	Duration	Hazard Identified
Worker will take out 2 production lots from the pass box/desiccators, labelled as "Waiting 100%VI" and send the 2 lots to one visual inspection workstation	• Have to bend his/her trunk to check the correct lot (metal reel that consists of 57000 units of LED that must undergo 100% VI to check for rejected units) • Have to stand straight and bring the lot to the workbench.	2-3 minutes	• Work environment - Might hit anyone or anything due to the confined area and less spacious. • Mechanical- The edge of the lot is very sharp • Manual Handling- must be careful carrying the weight of 4kg per lot
Load production lot reel onto the left hand side coiling/ uncoiling station and also load another empty reel onto the right hand side coiling station.	• Standing in a bent forward position • Hand is above head (over reach)	5-10 minutes	• Working environment- less spacious workbench. • Mechanical- Heavy lot with sharp edges. • Manual Handling- Must handle with care when placing the lot as it is heavy and sharp.
Start to check the bonded unit under the microscope. When the reject unit is identified, check the reject category and type based on visual/mechanical failure catalogue specification. Destroy the reject unit by using tweezers.	• Sitting • Head in bent posture towards the microscope • Both hands on the metal reel (lot) • Bended knee	Minimum 3 hours per lot	

3.3 Risk Assessment

For the first process in the Visual Inspection workstation, the risk level is 1-3 and 4-6, as shown in Table 7. This risk level can be categorised as low and moderate risk. The task of check for the production lot is at a low risk since it is not much hazardous if the employee can alert and not being careless while performing the task. The task where the employees have to send two production lot to visual inspection workstation is at a moderate risk level because the lot is heavy and has sharp edges. However, if the space at the workstation is more spacious, and the employees handle the task carefully, the risk level can be reduced.

Table 7. HIRARC Result for the First Visual Inspection Task

Hazard Identification				Risk Analysis			Risk Control Measure
No.	**Task**	**Hazard**	**Body parts involved**	**Likelihood**	**Severity**	**Risk**	**Recommended Control Measure**
1.	Check for the production lot	Bending forward	Back Knee	3	1	3	1.Keep feet firm on the ground. 2. Sit and check for the production lot that kept the bottom part of the pass box to knee bending.
2.	Send two production lot to Visual Inspection station	Carry the heavy metal reel lot Less space between work benches and worker Sharp edges of the metal reel lot.	Arm Wrist Knee Fingers	3	2	6	1.Management can increase the space of the workstation. 2.Sharp edges covered with plastics. 3.Workers must alert with the surrounding

Table 8 shows the HIRARC result for the second process, the risk level is 4-6, which a moderate level is also. There were two similar tasks performed during the second process which were load production lot reel onto the left-side coiling/ uncoiling station load another empty reel onto the right-side coiling station. In this case, the employees must be very careful with their body posture while loading since the metal reel is heavy. But at the same time, the employer must also take any control measure related to the less spacious workbench or table. They can redesign it with more suitable measurement. But temporarily, the workers should be more alert on the task by taking care of the body postures.

Table 8. HIRARC Result for the Second Visual Inspection Task

Hazard Identification				Risk Analysis			Risk Control Measure
No.	**Task**	**Hazard**	**Body parts involved**	**Likelihood**	**Severity**	**Risk**	**Recommended Control Measure**
1.	Load production lot reel onto the left-hand side coiling/ uncoiling station	Standing in a bent forward position Less spacious workbench Heavy and sharp metal reel lot	Shoulder Arm Fingers Knee	4	1	4	1.Design more comfortable and spacious workbench 2.Workers must handle metal reel lot with care to avoid injuries caused by sharp edges and prevent body aches. 3.Design better metal reel.
2.	Load another empty reel onto the righthand side coiling station.	Standing in a bent forward position Less spacious workbench Heavy and sharp metal reel lot	Shoulder Arm Fingers Knee	4	1	4	1.Design more comfortable and spacious workbench 2.Workers must handle metal reel lot with care to avoid injuries caused by sharp edges and prevent body aches. 3.Design better metal reel.

For the final process, Table 9 shows the HIRARC result of workers performing the checking task on the bonded unit under the microscope and destroys the reject unit by using tweezers. The risk level was in the range of 15-25. This is actually an extreme risk level. So, an immediate control measure should be taken. There were more hazards involved in this process, and also many body parts affected by it. Among the hazards involved in the final process, there were two hazards caused by the work environment and three hazards caused by mechanical. Thus, the control measures towards mechanical hazards must be taken where changes need to be done to the workbench and seat because the workers spend the most hours by sitting to perform their task. Therefore, the employees highly affected by MSDs.

Table 9: HIRARC Result for Final Visual Inspection Task

Hazard Identification				**Risk Analysis**			**Risk Control Measure**
No.	**Task**	**Hazard**	**Body parts involved**	**Likelihood**	**Severity**	**Risk**	**Recommended Control Measure**
1.	Start to check the bonded unit under microscope and destroy the reject unit by using tweezers.	Longer sitting time Bending forward Less space at workbench Uncomfortable placement of microscope on the workbench Uncomfortable chair All the sharp edges equipment placed nearer.	Shoulder Arm Fingers Knee Head Neck Wrist	5	4	20	1.Admin should allow workers to do light stretching exercise every at least two hours. 2.Keep shoulders aligned with the rest of the body 3.Design suitable chair and workbench at where the measurements are coherent with body dimensions of the workers.

From this HIRARC assessment, hazards could be identified, risk analysis done to determine the hazard that should be eliminated by taking corrective measures that will reduce the MSDs.

4. Conclusion

The three main sections of HIRARC have been successfully conducted in the visual inspection department of a semiconductor manufacturing industry. The results show that the final process, which was checked on the bonded unit under the microscope and destroyed the reject unit by using tweezers, was classified as extreme risk level. This shows that ergonomics safety is an essential aspect that needs to be prioritised as it can produce

productive workers. The main recommendation is to develop the workstation design if it is not ergonomically good. It is only can be done by the management of the company itself. Besides, workers must perform their task according to the correct Standard Operating Procedures (SOP) in order to prevent risk factors. The visual inspection department needs to assess the risk not only for the risk and control measures, but it will be conducted for cost if occurred accidents and near-miss incidents at the workstation. Hazard identification, risk assessment and control are an on-going process. Therefore, regularly review the effectiveness of hazard assessment and control measures is needed.

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