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Design of Noise Insulator for Metal Stamping Operation in Manufacturing Sector

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Abstract: Metal stamping is one of the processes involved in metal manufacturing industry in which dies are used to cut or form flat metal sheets into desired shapes. Consequently, noise is produced from the process. Prolonged exposure to the noise can lead to the health problems, hinder productivity and low performance of workers. The aim of this study was to design a noise insulator prototype for noise level reduction in a metal stamping operation. This study applied workplace observation, questionnaire survey and noise mapping at the metal stamping workstations. A prototype design of noise insulator was developed through brainstorming among the metal stamping workers, questionnaire survey and morphological chart. Recycled papers and coconut fibers were used as materials of the noise insulator. Noise level assessment was conducted to determine the effectiveness of the developed noise insulator. The noise levels have been effectively reduced to 70.3 dBA by 17.2%. This study concluded that application of materials such as recycled papers and coconut fibers in making of noise insulator was able to reduce noise levels in metal stamping operation. This study suggests that the real fabrication and application should be implemented in the metal stamping operation to reduce the risk of noise exposure to the workers.

Keywords: Noise insulator prototype, coconut fiber, metal stamping, occupational safety

1. Introduction

Metal manufacturing sector plays a significant part in industrial and economic developments of Malaysia. One of the nation's important manufacturing sub-sector focuses in production of fabricated metal products from raw materials. Non-metallic products has been recorded as one of the highest output growth among other sub sectors in manufacturing [1].

Metal stamping is a process in metal product fabrication in which sheet metals are formed and cut into designated shapes using dies [2]. High intensity sound is produced when the die hits and then cuts or forms the flat metal sheets into shapes. Any sound which is annoying or level of sound exceeds 75 dBA is conceived as noise [3]. According to Department of Occupational Safety and Health of Malaysia, the permissible noise level in working environments should be less than 82 dBA [4]. Thus, the stamping process is basically noisy, and radiates large amounts of sound energy directly to the surrounding areas [5]. The excessive of noise is a general occupational hazard that brings adverse effects, including hearing defects, increased blood pressure, abnormality of heart beats, ulcers, low working performance or work quality, shallow sleep, irritation, high stress level and noise-induced hearing loss (NIHL) [6], [7].

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The most critical effect is permanent damage of NIHL [8]. Most cases of NIHL are due to irreversible damage of hair cells in the cochlea called stereocilia, which act as sound vibration receptors [9]. Immediate measures should be taken to prevent such incidences in a noisy workspace via noise level detection, evaluation, and methods of intervention.

A sound level meter (SLM) is used for measurement of noise level and identification of high-noise areas. Engineering controls normally is done to the physical changes of the workplace like redesigning machine to eliminate or reduce the noise sources and fabricating barriers or covers to prevent the noise exposure by workers. Noise insulation is one of the measures to counter the excessive noise exposure. The noise insulators generally use various materials together to improve sound absorption such as rock wool, fiberglass, and acoustic foam. However, the potential of sound insulator made from recycled papers, coconut fiber and tapioca flour mixture remains unexplored. The objective of this study was to design a noise insulator from these natural materials for metal stamping workstation in manufacturing sector. Additionally, this study compared the noise levels between before and after improvement using noise insulator made of these natural materials.

2. Methodology

A cross-sectional study was conducted among 20 workers in a metal manufacturing factory in Malaysia. A questionnaire was distributed among them with permission given through written consent. A SLM was used to measure noise level at workstations in the factory. Furthermore, a noise mapping was constructed followed by noise insulator design and testing to minimize the noise level.

2.1 Noise Measurement Procedures

Noise level in in the factory was measured using a SLM model 407730 (Extech, Massachusetts). The five workstations are classified by the different types of machines used in metal manufacturing, namely metal stamping, lathe machine, forging machine, grinding machine, and welding machine. The calibrated SLM was positioned 1.5 m above the ground on a tripod, and at least 1 m away from the noise source and any reflective surface. Batteries and environmental factor like wind were checked prior to measurement. The measurement sampling was taken for 5 minutes in every 1 hour during a day shift. At the end of the noise measurement, a noise map was constructed in accordance to First Schedule of noise level dBA [10].

2.2 Noise Insulator Design Method

Three sketches of conceptual design were drawn from collected observational data, survey and brainstorming. A morphological chart was developed with cost, material, ease of maintenance, sustainability, safety, ergonomics, and practicality as criteria. A weight was assigned to each criterion based on the brainstorming session. A rank was given to the concepts at each criterion with the worst at 1 and the best at 5. Weighed score for each criterion was calculated by multiplying weight and rank. The weighed scores for each concept were added to a total score. The final conceptual design was selected by the highest total score. A prototype of noise insulator was fabricated. The prototype was tested using an SLM was placed 10 cm from an audio speaker with and without the prototype surrounding. An average of ten readings was calculated for each test.

Table 1 - Socio-demographic background of employees (N=20)

Variables	Category	n
Designation	Management staff	7
	General worker	3
	Operator	10
Gender	Male	12
	Female	8
Age	20-29	5
	30-39	12
	40-49	3
Working experience (years)	0-4	4
	5-9	11
	10-14	5
Noise-related health problems	Hearing problem	7
	Ear pain	5
	Headache	4
	None	4

3. Results and Discussion

Five variables on respondent background were collected as shown in Table 1. The majority of the workers are operators, males between the ages of 30 and 39 years old with working experience using the metal stamping machine between 5 to 9 years. The average working hour was 8 hours with off job activities reported. The working hour could be extended if there were any high demand from the customer. Most workers (80%) claimed to experience health problems due to noise exposure at work such as hearing problem (35%), ear pain (25%) and headache (20%).

Based on the survey, a consensus of respondents (65%) claimed that metal stamping workstation was the noisiest out of five workstations listed in Fig. 1.

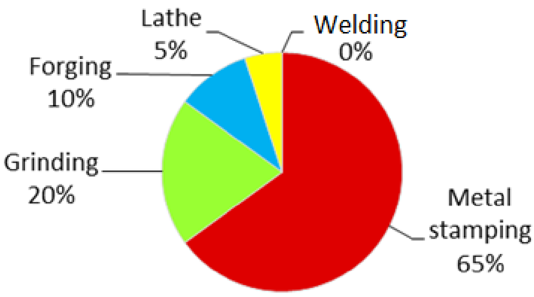


Fig. 1 - Percentage of workstation that produces noise

Noise level assessment was performed on machines solely in metal stamping workstation due to survey result (Fig. 1). There were eight metal stamping machines in the workplace and the machines are known as ST250-1, ST110-1, ST100, ST63-1, ST63-2, ST63-5, ST63-6 and ST40-2. Based on Table 2, ST100 recorded the highest average noise level at 107.0 dBA with a range of 8.9 dBA to maximum of 110.5 dBA. The noise level was at minimum when the machines were in standby mode and at maximum when stamping the metals. The machine with the smallest design and capacity, ST63-5 recorded the lowest minimum noise level, lowest average noise level, and lowest maximum noise level at 90.6 dBA, 95.7 dBA, and 99.8 dBA respectively. The lowest range was recorded by ST40-2 at 5.7 dBA due the materials processed by the machine was the thinnest metals.

Fig. 2 showed that the almost the whole workplace was covered with yellow code which is exceeding noise level of 70 dBA. All the machines were coded by orange color as their noise level fell into the range between 90 dBA to 110 dBA except the machine ST100. The machine ST100 was coded as red color due to its noise level exceeding 110 dBA. Based on the noise meter from the National Institute of Occupational Safety and Health (NIOSH), noise exposure should not exceed 2 minutes in the red zone but the workers were exposed throughout their 8-hour working shift daily. Breakdown in the noise map referred to each broke-down machine in the factory. The Department of Occupational Safety and Health of Malaysia (2019), Occupational Safety and Health (Noise Exposure) Regulations 2019 is clearly mentioned that the permissible noise exposure limit (PEL) at 85 dBA is 8 hours and the action level is at 82 dBA [4]. The noise levels measured from the workplaces in this study are higher than similar industrial sites from Egypt between 70 to 100 dBA and Kenya at 93.8 dBA [11], [12]. Fig. 2 showed that the noise level was at least between 90 to 110 dBA for all functional machines including those not specialized in metal stamping process, exposing the workers to high risk of NIHL. Based on the measurement results, the company administrators should initiate remedy action when the noise level exceeds 82 dBA in a work setting [4].

Noise exposure above PEL would cause NIHL in long term. Majority of the workers (80%) in this study suffered from early symptoms of NIHL which are hearing problem, ear pain and headache as shown in Table 1. Previous studies revealed that working above PEL resulted in similar health risks which include hearing loss, vertigo, nausea, tinnitus, dizziness and noise in the ear [13], [14]. The workers began to show symptoms after at least 4-year service in the sector based on data analysis from Table 1. Besides occupational noise exposure, age has been proven to be a factor in the development of NIHL [15]. The symptoms are more apparent in middle age as the age-related hearing impairment overruled the occupational NIHL [16]. Noise insulator acts as a barrier to reduce direct noise which improves employee's well-being in industrial settings [17], [18]. Three conceptual noise insulator designs were proposed and compared as shown in Table 3. Cubic concrete wall is proposed, as shown in Design A. Design B used coconut fibers which attached to the wall of workstation. Meanwhile soundproofing curtains are suggested in Design C. Highest weights of 15 were given by company administrators to cost, material, sustainability, safety, and practicality from brainstorming session as shown in Table 2. A coconut fiber layer wall design (Design B) was selected based on the highest total score of 435. Noise insulator with coconut fiber layer walls scored the highest due to the highest rank given to all criteria ranging from 3 to 5 among three designs. The best features are from cost and material availability aspects. The Design B utilizes recycle paper and coconut fiber which are available at a low and reasonable cost. The materials are light in weight and easy to reinstall and maintained. Incorporation of natural fiber has low adverse environmental impact which is considered as a waste product of agriculture is recycled with used papers [19]. Coconut fiber is a good sound absorbent at low and medium frequencies which insulates noise [20], [21]. Addition of a porous layer made from natural materials such as coconut fibers significantly increases noise absorption coefficient as the sound dissipated when it travels through the wall [22]. The grooves on the interior walls of the design provides more surface area than flat surface for the sound waves to be absorbed by the materials at a time [23].

Table 2 - Noise level of metal stamping machines

No.	Machine	Minimum (dBA)	Maximum (dBA)	Average (dBA)	Range (dBA)
1	ST205-1	92.4	104.3	97.4	11.9
2	ST110-1	97.8	106.7	100.6	8.9
3	ST100	101.6	110.5	107.0	8.9
4	ST63-1	98.0	109.0	104.7	11.0
5	ST63-2	93.5	101.4	98.1	7.9
6	ST63-5	90.6	99.8	95.6	9.2
7	ST63-6	94.6	104.6	99.5	10.0
8	ST40-2	94.1	99.8	97.5	5.7

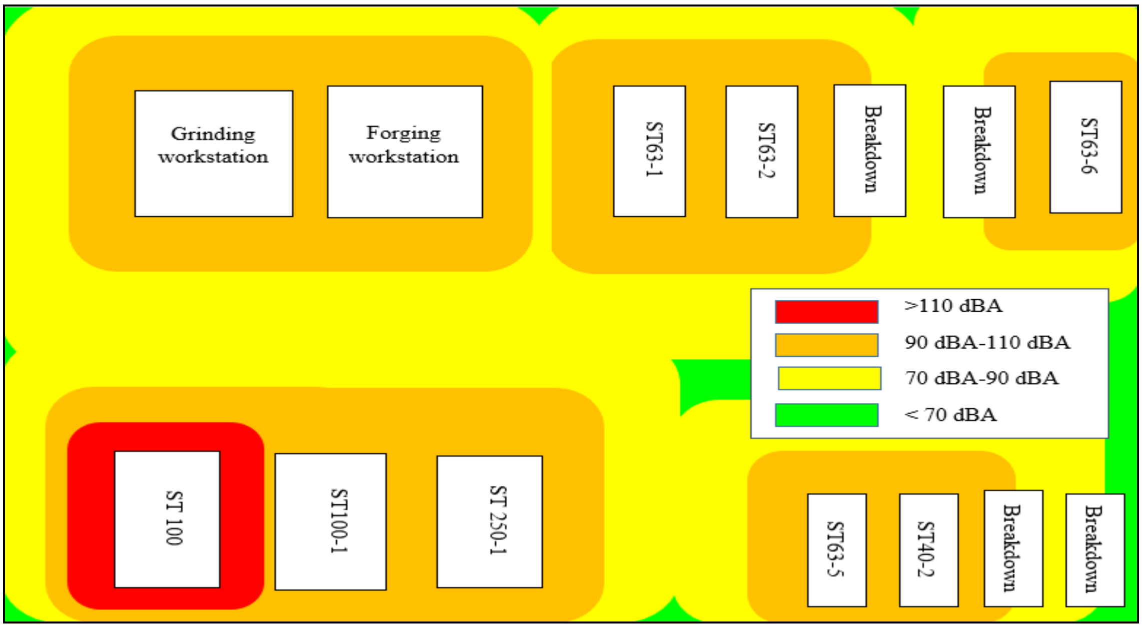
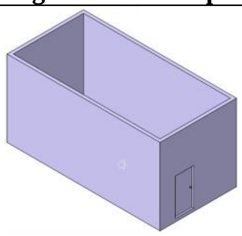
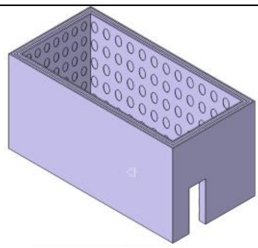


Fig. 2 - Noise map of metal stamping workstation

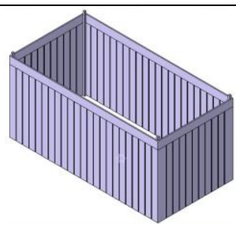
Table 3 – Scoring and selection process of noise insulator concepts



Concrete wall (Design A)



Coconut fiber wall (Design B)



Sound curtain (Design C)

Selection criteria	Weight	Rank	Weighted score	Rank	Weighted score	Rank	Weighted score
		Concrete wall (Design A)		Coconut fiber wall (Design B)		Sound curtain (Design C)	
Cost	15	2	30	5	75	3	45
Material availability	15	4	60	5	75	4	60
Ease of maintenance	10	1	10	4	40	2	20
Ease of manufacturing	10	2	20	4	40	3	30
Sustainability	15	4	60	4	60	3	45
Safety	15	3	45	3	45	3	45
Ergonomics	10	4	40	4	40	3	30
Practicality	15	3	45	4	60	3	45
Total score			310		435		320

A noise insulator prototype was built from four 23 x 30 cm partitions with thickness of approximately 3 cm (Fig. 3). The partitions were made using the mixture of recycled papers, coconut fiber and tapioca flour mixture. Testing on the prototype showed a noise level reduction by 17.2 % could be deduced in the prototype testing with the reading decreased from 84.9 dBA to 70.3 dBA as depicted in Fig. 4. The testing result indicates promising results for actual implementation of design in the company though further testing is recommended. Optimization of the design could increase performance of the noise insulator. Thicker wall could improve the design based on better sound absorption of coconut fiber layer wall from previous studies at 5 cm and 10 cm [23].

Fig. 3 - Prototype of noise insulator (Design B)

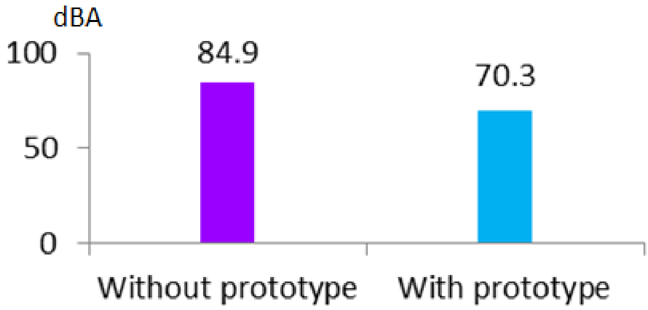


Fig. 4 - Comparison of noise level between with and without noise insulator prototype

4. Conclusion

This study has performed an assessment of noise level at a metal stamping company in Malaysia. Noise levels for 5 minutes in every 1 hour during a day shift were measured at different workstations and then tabulated in a noise mapping. Based on the noise mapping, metal stamping was identified as noisiest work process (average of 107.0 dBA). To reduce the noise level, this study designed and fabricated a noise insulator prototype using natural materials such as coconut fiber and tapioca flour mixture. A noise level comparison between before and after application of the insulator prototype showed that noise level has reduced by 17.2 %. This study is limited to early design process till prototype testing. Further optimization and testing of design properties such as perforation size of relevant sound absorbent material as suggested by Hamdan et al [24] should be conducted, as well as the Taguchi method implementation for selection of optimum material properties [25].

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