International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 10, October 2016
www.ijates.com
ijates
ISSN 2348 - 7550

DESIGN AND EVALUATION OF TONGS FOR METAL POURING DURING CASTING

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ABSTRACT

Manual material handling, one of the major causes of severe industrial injury, is routinely carried out in small scale casting industries. Manual pouring of the molten metal is one such task which involves not just lifting of heavy loads and improper postures but exposure to hot metal as well. It is carried out using tongs which require the worker to twist his/her wrist repetitively, which may result in MSD's like soreness and pain in neck arm shoulder, hand etc., and fatigue, numbness and muscle inflammation. Further, the positions of hand on lifting tool is also said to have an effect on operator performance in MMH. In the present study the conventionally used tongs was evaluated against two proposed designs. Subjects were asked to carry out a simulated pouring task. Sand was used in place of molten metal. The three designs were evaluated on the basis of subjective scores on perceived exertion, heart rate increase and task completion times. It was found that the proposed design of tongs resulted in lower scores of perceived exertion and task completion times.

Keywords: Metal pouring, Tong Design

I. INTRODUCTION

Work related musculoskeletal disorders (WMSDs) are a group of conditions involving the nerves, tendons, muscles, and supporting structures of the body such as intervertebral discs, attributed to or exaggerated by the work environment. They are painful and in the long run may lead to disability. Highly repetitive work, forceful exertions, awkward postures, and exposure to whole-body or hand arm vibrations are some of risk factors that have been associated with increase in WMSDs[1][2]. The metal casting industry, is a typical industry with complex work processes that generate most, if not all of the risk factors associated with WMSD's, particularly high physical loads[3].

In the light of the high loads lifted and awkward postures adopted during MMH by the workers installations of mechanical aids and/or automated material handling equipment have been recommended for decreasing the risk of MSD's in foundries. However, the high cost of automating metal pouring operations may be prohibitive, especially in the small scale foundries[4].

Manual pouring of the molten metal, one of the most hazardous task in casting industry involves lifting of heavy loads, improper postures and exposure to hot metal[4]. It is carried out using tongs which require the worker to twist his wrist repetitively, thereby resulting in repetitive stress finally MSD's like soreness and pain in neck arm shoulder, hand etc., and fatigue, numbness and muscle inflammation.

The positions of hand on lifting tool is also said to affect on operator performance in MMH. John F Bennett reported that conventional handles which are usually of straight configuration, requires the operator to rotate his / her wrist and may result in fatigue and injury to wrist[5]. Wrist deviations (ulnar/radial & flexion/extension) reduce the maximum finger and hand-grip strength as compared to neutral wrist positions. Bent-handle designs have been found to be superior to conventional as they allow the workers to maintain their forearm and hand in a neutral position thereby reducing the risk of work related MSD's [5][6]. Further, the type of grip is said to have bearing on task performance. Different types of grips added to the conventional pliers were found to have an effect on peak grip force required for task completion and hand comfort [8].

Tong is perhaps the most widely used load lifting tool in small foundry or casting industry for pouring as well as for lifting of molten metal. In an industrial survey of small foundry units in Aligarh, it was observed that the crucible containing molten metal was handled with the help of tongs. The tong had bare handles with no provision for protection against heat.

II. METHODOLOGY

2.1 Experimental Design

The present study, aims at investigating the effect of tong type, grip position and grip type on worker's performance in manual metal pouring operation. The conventionally used tongs were compared against two proposed designs (Appendix). Further, different grips types namely bare rod, wooden grips with smooth finish and wooden handles with grooves were used for the present set of investigations. Grip positions at three different levels namely, at the end, at 35 cm and at 55 cm from the end of the tong were used.

The effect of independent variable on heart rate, time for task completion and a subjective rating of perceived exertion were observed.

2.2 Subjects

Five male volunteers participated in the study. All subjects were the students of Z.H College of Engineering & Technology; A.M.U. The participant had no history of MSD's. Further, they had no industrial experience. This ensured that there was no bias in subjective reporting. In order to familiarize them training were given to the subjects

Subjects	Mean	Std. Deviation
Age	21.66	0.5163
Height	172.83	9.1031
Weight	75.67	12.2256

Table 1: Descriptive Statistics for Precipitants

2.3 Experimental Task and Set Up

The subjects were required to carry a sand filled crucible with the help of a tong from station 1(from where crucible is kept) to station 2 (where the molds were kept). There they filled the molds before returning back to station 1. The carrying distance between the station 1 and station 2 was constant i.e. 3m for whole experiment. The crucible had a dry weight of 3.6 kg and could hold upto 10 kg of aluminum.

Sand was chosen over molten metal because of two reason i.e. the density of sand (2.32g/cm3) is very close to the density of molten aluminum and the second reason is that the experiment can be performed safely by non-industrial worker. Similar material substitution had been used by Fredericks et al. [4].

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Heart rates at rest and immediately after completion of experiment and time taken were measured. Further, the subjects were also asked to rate their perceived exertion on a scale of 1 to 10

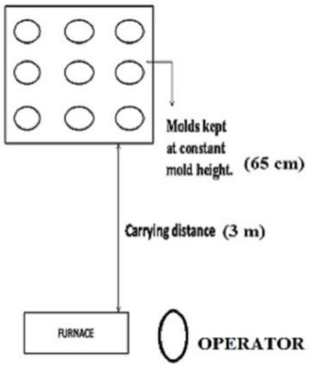

Figure 1: Experimental Setup

III. RESULTS

ANOVA analysis was carried out on the data generated using the SPSS software. The results obtained have been summarized below:

TABLE 2: ANOVA results for the effect of tong type, grip type and grip position on task duration

Source	F	Sig.
Grip Type	13.758	.000
Tong Type	115.997	.000
Grip Position	17.230	.000
Grip Type* Tong Type	3.638	.008
Grip Type * Grip Position	.722	.579
Tong Type* Grip Position	9.656	.000
Grip Type* Tong Type* Grip Position	2.838	.007

It was found that all the three independent factors namely grip type, tong type and grip position had a significant effect on the time taken for task completion. Also the two way interactions of grip type & tong type and tong type & grip position and three way interaction of grip type & tong type & grip position were statistically significant for the task performed.

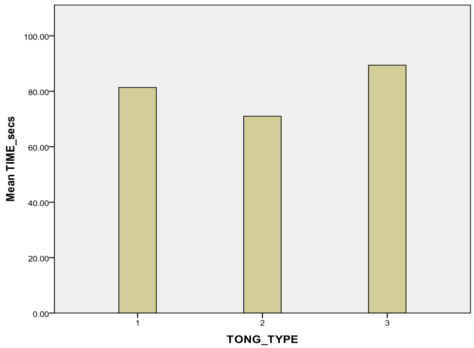

Figure 2: Bar chart showing the effect of tong type on task duration

It was observed that time taken to complete the task using tong 3 was maximum while tong 2 resulted in least task duration.

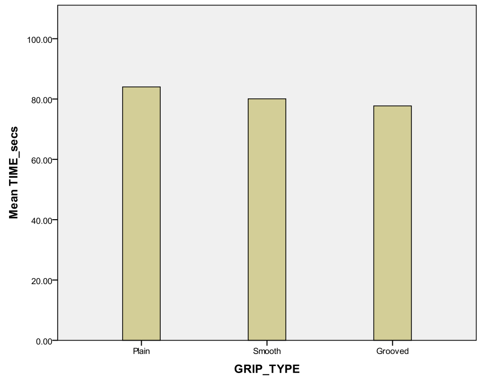

Figure 3: Bar chart showing the effect of grip type on task duration

Further, it was observed that task completion time was least for a grooved grip design while bare rods resulted in maximum time taken to complete the task.

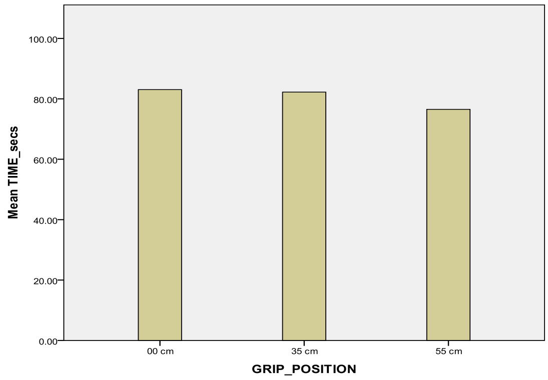

Figure 4: Bar chart showing the effect of grip position on task duration

Also, time taken to complete the task was least when the tongs were handled from a distance of 55 cm from end resulted while grip position at end and at 35 cm from end, resulted in longer task completion times.

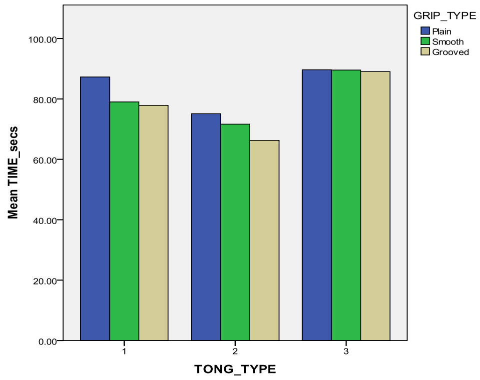

Figure 5: Bar chart showing the effect of tong type and grip type on the task duration

A bar graph was plotted for mean task completion time vs. tong type for different types of grip. It can be clearly seen from the graph that for all tong type, bare rod resulted in maximum task time while, the time taken to complete the task was minimum when grooved design of grip was used.

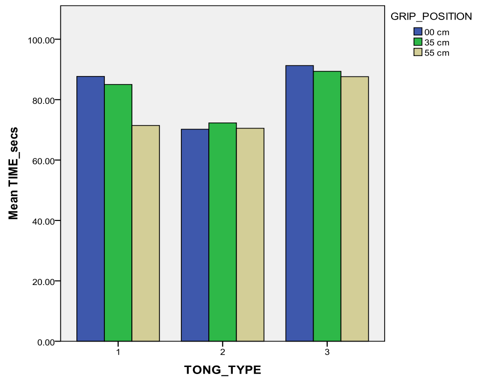

Figure 6: Effect of tong type and grip position on the time taken for completing a metal pouring task

For all tong types, task duration was least when the subjects handled the tongs from the farthest position, i.e. at a distance of 55 cm from the end. Further, the time taken to complete the task was maximum when the tongs were handled from the end position.

TABLE 3: ANOVA Results for the effect of tong type, grip type and grip position on heart rate for a metal pouring operation

Source	F	Sig.
Grip Type	1.565	.214
Tong Type	4.574	.012
Grip Position	.111	.895
Grip Type* Tong Type	1.497	.208
Grip Type * Grip Position	1.042	.389
Tong Type* Grip Position	1.480	.213
Grip Type* Tong Type* Grip Position	1.307	.248

Results of the analysis indicate that only tong type has a significant effect on increase in heart rate during task performing. All other factors viz. grip type and grip position as well as their two interactions and three way interactions did not show any significant effect on heart rate for the task undertaken.

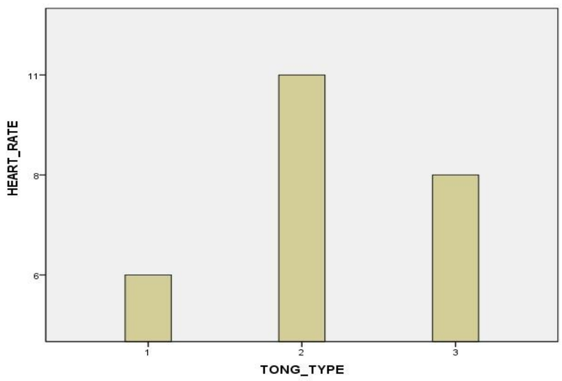

Figure7: Bar chart showing the effect of tong type on change in heart rate

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A bar graph was plotted for increased in heart rate vs. tong type. As is evident from the graph, increased in heart rate is found to be minimum for conventional tong (type 1) for pouring task while the maximum increase in heart rate is for tong type 2.

TABLE 4: ANOVA Results for the effect of different levels of tong type, grip type and grip positions for perceived exertion rating

Source	F	Sig.
Grip Type	2.494	.087
Tong Type	105.253	.000
Grip Position	8.322	.000
Grip Type* Tong Type	1.977	.103
Grip Type * Grip Position	.270	.897
Tong Type* Grip Position	.149	.963
Grip Type* Tong Type* Grip Position	.270	.974

Results of the analysis indicate that tong types and grip positions had a significant effect on the perceived exertion. The two way interactions as well as three way interactions are not statistically significant for the task performed. Further, grip type had no statistically significant effect on perceived exertion for the task performed.

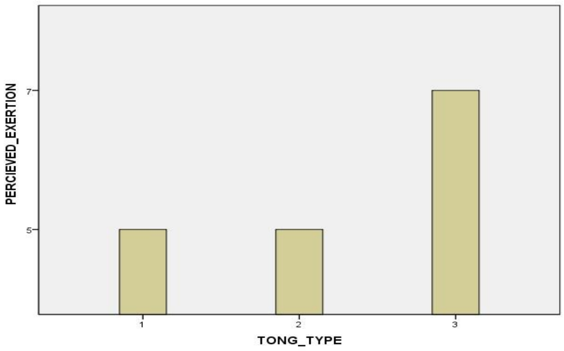

Figure 8: Bar chart showing the effect of tong type on perceived exertion for a metal pouring task

Bar graph plotted for perceived exertion vs. tong type clearly indicated that the minimum perceived exertion rating is for tong1 and tong 2 but maximum value for exertion for pouring task is for tong 3

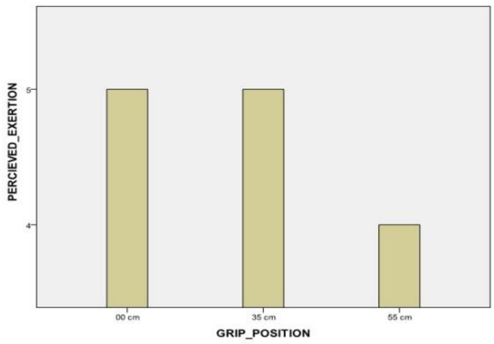

Figure 9: Bar chart showing the effect of grip position on perceived exertion

From the bar graph plotted between perceived exertion and grip position it is evident that the scores on perceived exertion was minimum for a grip position of 55 cm from the end where as maximum scores for perceived exertion were obtained at a position of at end and at 35 cm from end.

IV. DISCUSSION

It was observed that tong type had a statistically significant effect on time taken to complete the task, heart rate and perceived exertion. It was found that tong 2 resulted in minimum task duration and perceived exertion followed by tong 1 and 3 respectively. The findings may be attributed to the fact that different wrist and arm movements are associated with the tongs. For the conventional tong (1) as well as tong 3 the entire forearm moves while there is minimal change in the wrist position, for the tong type 2 however, the ulnar deviation of the wrist predominates.

A surprising finding of the present investigation is that the increase in heart rate was maximum for tong type 2, which also resulted in minimum task duration. It is worth noting however that many investigations have shown that the relationship between perceived exertion and heart rate is highly dependent upon the type of physical task involved. For e.g. at a given heart rate, perceived exertion is lower for running than for work on the bicycle ergometer or for walking [7]. It is important to note that the final heart rate in all cases was well within the acceptable limits. Thus we may conclude that of the three tongs considered in the study, tong 2 was most suitable for metal pouring task.

In the present research we have taken three different type of grip i.e., bare rod, smooth handle and groove grip. Many investigators have studied handle design characteristics like handle size, shape, and surface material and have reported that they have an effect on only maximum torque performance[8][9][10]. It is believed that tool grip, and tool surface are the major factors affecting performance of a tool grip task. Results obtained in the present study also corroborate the above findings as far as the statistical effect on time is concerned. In the present study, it was found that the grooved handle However, in the preset study it was found that the grooved handle resulted in slightly lower task duration as compared to a smooth handle, while the bare rod resulted in the maximum time for task completion. This is contradictory to the results obtained by previous researchers who have opined that cylindrical handles are better than grooved ones. This may be due to the fact that the finger spacing of each person is different and any design compromise on 'average' spacing will be a poor fit for a large part of the population. Rubarth found cylindrical handles with a rounded end better than more elaborately shaped handgrips in terms of maximum force exerted [8]. The contradictory findings may be due to the only 5 subjects participated in the study and it is possible that the handle proved to be a good/fair fit for them. A larger pool of subjects is needed to arrive at conclusive results.

It has been established that torque increases with increasing handle length. Magill and Konz tested seven screwdrivers to investigate the effects of grip length and grip volume on the maximum torque performance, task completion time and subjective preference. They reported that maximum torque and handle preference were related to grip length and volume, while task time was inversely related to grip volume and grip length[11]. Similar results have been obtained by us in our experimental investigations. Thus while the task duration was minimum when the tongs are handled from 55 cm away from the handle end and maximum when it is held from the end, the perceived exertion ratings show that while holding the tong from 55 cm away from the end was least strenuous. The effect would perhaps be compounded when the temperature of the molten metal is also considered, which may make it more difficult to control the crucible from a position close to it.

V. CONCLUSION

Tong design has an important effect on performance in a pouring task. The recommended design for the tong may be used instead of the conventional tong for enhanced productivity, without any change in perceived exertion.

Design of the handle significantly affects the time taken for task completion for a metal pouring operation. Preliminary investigations show that the grooved handle design gives best results. The experiments need to be repeated with more subjects so that the effect of handle grooves may be tested on a larger population.

Handle length affects task performance in a metal pouring operation. Our results based on simulated experiments indicate that pouring time as well as perceived exertion are lower when the handle length is longer.

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APPENDIX TYPES OF TONG

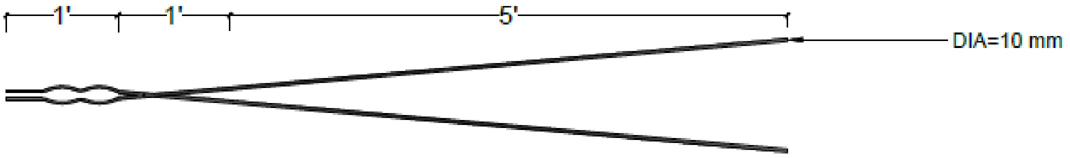

Fig 5: Tong 1 (Conventional)

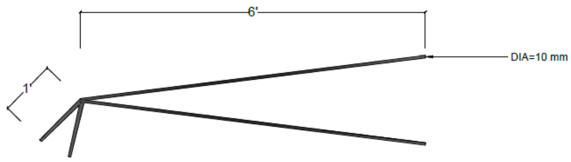

Fig. 6: Tong Type 2 (Proposed)

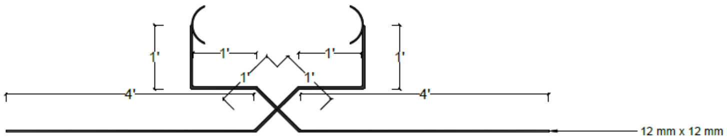

Fig. 6: Tong Type 3 (Proposed)