Redesign Ladle-Kowi Considering Improvement of Work Organization to Decrease Postural Stress in Working Posture of Casting Liquid Metal into Mold in Molding Metal Industry

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Abstract—Posture of casting liquid metal into mold in molding metal industry performed manually using human muscles. Working by relying on human muscle will result not optimum working product, more over using of working tools that have not supported by appropriate standard operating procedures, new designs that have not considered the functions, and have not position human as the main factor. Therefore, standard operating and procedures should be created by considering human as the main factor in using working tools. Comfortability, safety, ability and limitation of human are considered in redesigning new handle ladle. Improvement of ladle would not result an optimal impact to improvement of physical condition of the workers if not supported by improvement of work organization simultaneously. Working tools are created to be operated optimally and could reduce complain of muscle workers. There are 14 working postures in casting liquid metal into mold. Each activity is analyzed using the Rapid Upper Limb Assessment (RULA) technique, continued by simulation of improvement of work organization in order to decrease postural working stress. RULA score analyzed statistically. Result shows that there are significant differences between conventional working posture before and after using new design of ladle which is shown by α <0,05. Repairment of ladle and improvement of working posture prioritizing ability, capacity, and limitation of workers could decrease postural stress on working posture in carrying liquid metal materials from category of immediately improvement to can be postponed improvement.

Index Terms—Redesign ladle, improvement of working organization, postural stress, working posture

1 INTRODUCTION

Work station of casting in molding metal industry is one of vitals station. Activities in this station are designing molding, turning liquid metal into semi-finished product, compacting metal fluid, and unloading product. Those activities categorized as hard workload [14]. When casting process did not meet the standard or design as requested by consumers, it will resulted defect product. When quality of metal fluid have meet characteristic of consumer request but the design hve not meet the dimention, the product called defect or failed. When this happened, company should repeat casting activities that consumed more cost and times. Thus, this station needs high skill in order to finish the task of casting liquid metal.

There are some tasks in activity of pouring liquid metal into mold using ladle with empty weigh in average is 15 kg, while if ladle has been filled by liquid metal, it will be 50 kg. The function of ladle is to pour liquid metal from the kitchen of steel melting for a while, then distributed into molding which have been created before. Activity of pouring liquid metal into molding always using ladle as working tools, thus ladle is a vital and very needed tool. Development of industry tools should be considered in order to minimize complains of worker disorder [4],[9],[12].

Design model of ladle for this time only consider it function. Operating this ladle, need 2 workers with 10 to 13 minutes speed to pour liquid metal into molding in order to produce high quality product. Hot fluid metal which reachs over 1100^0 C give radiation impact to body of workers. This heat exposure speeds up dehydration that could increase working accident [13]. Working condition with high heat exposure need comfort and save mechanism of casting liquid metal wich minimizing direct contact of the workers to heat exposure. Thus, design of ladle should consider comfotability and safety of users especially in molding metal.

Ladle has not been equipped with comfort handle. Handle that used in this time only iron pipe with diameter of 21 to 35 mm. This handle has not considered anthropometry measure of Indonesian workers. Interaction of human and machine should be balance in order to get a high efficiency of work [18].

The good machine and tools should be supported by simple and clear operational direction. Some informations could be informed in the directions are safety and reminding system, clear display, and simple maintenance by considering limitation of users [15].

Ladle operation that needs two operators, needs work organization that could simplify its operation. Idle time

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often happened as result uncoordinated working organization, worker that waiting each other in filling metal fluid into molding that extend processing time. There are some uncomfortable movements such as over bending to adapt to ladle movement, holding liquid steel in static conditions which there are some unbalance turning movement between load of right and left hand. Workload of human should be adjusted by ability, capacity, and limitation of human [1] in order to get improvement of efficiency and productivity of work[5], If this condition have not been meet, there will be decrease of work capacity and endurance of workers [6].

2 METHODS

2.1 Subject

Subjects of this research are 14 workers which rundom sampling, male, with 2 years experiences in casting liquid metal into molding, age between 20 to 40 years old. Subjects are given explanation about the objectives of the research then asked to fill the informed consent.

2.2 Procedure of the Survey

This research directly observes and record worker movement in pouring liquid metal into molding in the floor of the production metal melting. Recording working posture of pouring liquid metal into molding using video f=2,9-116 mm with exposure 1:1,8, 40 X optical zoom. Some stabil study state are selected from result of recording in some cycles, played in slow motion, pictured are cut based on working movement resulting different 14 movements of working cycles. Picture processed using Adobe.

2.3 Procedure of the analysis

Statistical analysis using SPSS. RULA score in the beginning or when using conventional ladle and after redesigning are tested using statistic paired sample t test with normality test using shapiro wilk test on α =0,05.

Analysis of movement and working organization using manequin picture from software CATIA V5R17, continued by analysis of Rapid Upper Limb Assessment (RULA) to calculate score of each step of working activities which resulting score of 14 steps of different movement in right and left side of body posture. !4 steps of working posture of pouring liquid metal into molding are started by holding ladle handle and finished by releasing ladle handle. The average process of pouring is between 10 to 13 minutes / working cycles with weight of full ladle 50 kg and empty weight 15 kg which operated by two operators in each ladle.

3 RESULT AND DISCUSSION

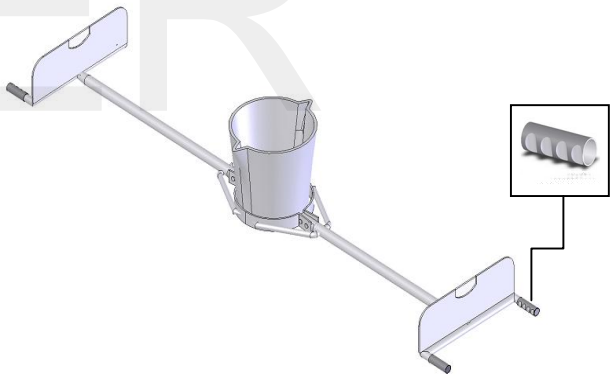
Ladle designed by considering partisipatory of workers and every party in the company. Workers are given change to express idea of blue print design. Each party took part in finding solution [2],[10],[16].

Inputs from users are needed to guaranty using of tools continuously. Some tools have been perfectly designed but did not considering user desire and interest so humans are forced to be adapted to the new tools. The good design is design which considering ability, capacity and limitation of human.

The criteria of right to technology implemented in Indonesia as developing country should meet[11]: a) technical, redesigning of ladle should function optimally as it objective, b) economic, cost to create and maintain is affordable, c) ergonomic, design considering anthropometry measure and prioritizing convenience, comfortability and safety of users so they can work effectively, comfort, save, healthy, and efficiently, d) socio cultural design is not contradict to value system in the society so it would not causes social problems further, e) saving-energy, use of materials utilizing available renewable resources and saving human muscle power, f) environmental friendly, no side effect such as chemical reactions that causes danger [11], g) trendy, design should follow the trend.

3.1 Redesain Ladle

Below is picture of ladle design. Some additional designs are: 1) bulkhead of barrier on two sides, 2) ladle handle equipped by foam adjusted to anthropometry measure sample human hands. Design could be seen clearly at picture 1 below:



Picture 1. Redesign Ladle

Dimension of redesign of ladle is 2.090 mm length, 400 mm width, empty weight 130 g, full weight 500 g, ladle handle (Φ handle 25 mm, Φ thick of iron pipe 2,5 mm, length:120 mm), iron frame (Φ 35 mm, Φ thick of iron pipe 2,5 mm, length 760 mm), while dimension of container (Φ 270 mm, height 45 mm).

3.2 Working Posture

Working posture of pouring liquid metal into molding influenced by dimension of ladle. More simple, save, and comfort when using it, then ergonomic working posture shown by minimizing postural stress caused by unnatural

working posture. Unnatural working posture cause pain on certain part of body [7],[8].

Dimension of ladle fit to users anthropometry could make users comfort and save when operating it. Working posture in operating ladle are vary which shown by 14 activities with different RULA score.

In conventional method, RULA recommend that improvement should be done immediately while in redesign of ladle, RULA recommend that improvement could be delayed. Repairement of working tool "ladle" and improvement of working organization based on RULA recommendation have shown good impact to postural stress.

3.3 Results of The Statistical Test

Statistical test using paired sampel t test with normality test using uji shapiro wilk with $\alpha = 0{,}05$. Output of this test between conventional and ladle of redesign are below:

TABLE 1
RULA SCORE (LEFT)

Postures	Konv	Re-Handle	Org	Diff- a	Diff-b
LL-1	3	2	2	-1	-1
LL-2	3	2	2	-1	-1
LL-3	7	6	6	-1	-1
LL-4	7	6	6	-1	-1
LL-5	7	6	6	-1	-1
LL-6	7	7	6	0	-1
LL-7	7	7	4	0	-3
LL-8	7	7	5	0	-2
LL-9	7	7	6	0	-1
LL-10	7	7	6	0	-1
LL-11	7	7	6	0	-1
LL-12	7	7	6	0	-1
LL-13	7	7	6	0	-1
LL-14	5	3	3	-2	-2
Average	6,3	5,8	5,0		
Std Dev	1,1	1,5	1,3		

LL-1 = Layers-1 Left, Konv= Konventional, Re-Handle = Redesign handle Ladle, Org = Organization. Diff-a = RULA Score Konventional Methods – RULA Score redesign Handle Ladle, Diff b= RULA Score Konventional Methods – RULA Score Organization.

TABLE 2
RULA SCORE (RIGHT)

Postures	Konv	Re-Handle	Org	Diff- a	Diff-b
LR-1	3	2	2	-1	-1
LR-2	3	2	2	-1	-1
LR-3	7	6	6	-1	-1
LR-4	7	6	6	-1	-1
LR-5	7	6	6	-1	-1
LR-6	7	7	6	0	-1
LR-7	7	7	4	0	-3
LR-8	7	7	4	0	-3
LR-9	7	7	6	0	-1
LR-10	7	7	7	0	0
LR-11	7	7	7	0	0
LR-12	7	7	7	0	0
LR-13	7	7	7	0	0
LR-14	4	3	3	-1	-1
Average	6,2	5,8	5,2		
Std Dev	1,2	1,5	1,6		

LR-1 = Layers-1 Right, Konv= Konventional, Re-Handle = Redesign handle Ladle, Org = Organization. Diff-a = RULA Score Konventional Methods – RULA Score redesign Handle Ladle, Diff b= RULA Score Konventional Methods – RULA Score Organization.

TABLE 3
PAIRES SAMPLE TEST FORDESAIN LADLE

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1	.50000	.65044	.17384	.12445	.87555	2.876	13	.013

Result shows that Sign 0,013 < 0,05, then Ho rejected or t table 2,160 < t count 2,876 which means that Ho rejected, so the conclusion is there is different between use of conventional ladle and new ladle of redesign.

TABLE 4
PAIRES SAMPLE TEST FOR IMPROVEMENT OF WORKING ORGANIZATION

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1	1.00000	.87706	.23440	.49360	1.50640	4.266	13	.001

Result shows that Sign 0,01 < 0,05, then Ho rejected, or t table 2,160 < t count 4,266 which means that Ho rejected, so the conclusion is there is different between old working organization and new working organization.

4 CONCLUSION

Conclusion resulted from this research are design that consider 6 criteria of right to technology affect to decrease of postural stress which shown by decrease of RULA score, working tools need to be repaired along with improvement of working organization. Redesigning ladle along with improvement of working organization decrease category of RULA from immediately category to could be delayed category. Design of working tools besides using users anthropometry, also should position human as the main factor of improvement.

Participation of all of stakeholders is needed since the beginning of design improvement. Beside as media to encompass input of working tools improvement, this participation also used to guaranty function and willingness of user could be met.

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