DESIGN AND DEVELOPMENT OF COMBINED HYDRAULIC AND MECHANICAL AUTOMOTIVE WORKSHOP CRANE

Jose D. Paat[1, a], Jimcel P. Pecaso[2,b], Jaime P. Pecaso Jr.[3, c]
[b]*jimcelpecaso@gmail.com*

ABSTRACT

Guided by the principles of ensuring safety, this project study is developed to provide a lifting device out of locally available materials. It relates generally to equipment needed for vehicle servicing but particularly designed and fabricated to back-up workers when working with vehicle.

The industrial design is a combined hydraulic and mechanical automotive workshop crane, a supporting bracket having a post and plurality of retractable leg members, a lifting boom pivotally connected to said post includes a bracket at its end provided with a chain block, and a hydraulic jack mounted on said post underneath said lifting boom.

The proponents adopted the Research and Development (R&D) process since the output is a project that will be useful to the instructor. Likewise, the descriptive method was also used since a survey questionnaire was administered while utilizing the safety device. This research study was conducted to design, construct, test, evaluate and revise a lifting mechanism as innovative instructional device.

Findings showed that the device exhibited high level of acceptability. The device enhances the teaching-learning outcome, provide an array of technology in automotive that enable the learner to work easily with optimum efficiency.

Keywords: *industrial design, lifting device, acceptability, design, innovative*

INTRODUCTION

In any workplace, safety is a concept that includes all measures and practices undertaken to preserve life, health, and bodily integrity of individuals. There is no precise formula for safety. They can be practical and hands-on, need to know facts and relevant safety regulations. Ensuring the safety of workers is both necessary and beneficial for any organization in addition to avoiding costly fines, it ensures productivity, better morale and fewer lost work days.

Safety in training is one of the most important components of any laboratory activity. It is an antecedent to trainee's behavior, thus to some degree influences trainee behaviors. Therefore, it seems appropriate to measure and adopt effectiveness of safe training through test of skills development. (Bikner et al. 1999)

Schools are not exempted from observing safety while student trainees are at work. Use of safety equipment and devices are resources directly aligned to learning competencies defined by school in particular and in the industry general. Practicing safety modify personal protection thereby avoiding injury not only to the worker, other worker but also to the work as well.

For many years crane have been designed for lifting heavy objects with different capacity in different work sites. Portable cranes are one of the types of cranes designed for lifting objects which are beyond the capacity of human being. There is a need for using portable crane to lift up objects beyond the capacity and difficulty of human power. (Mulugeta Tadesse, et al 2017)

Modern technological period can't be imagined without various handling material or handling equipment. Cranes are amongst one of the material handling equipment which finds wide applications in different fields of engineering. This equipment are industrial machines that are mainly used for material movements in construction sites, production halls, assembly lines, storage areas, power stations and similar areas. (Naresh Chauhan and P.M. Bhatt/Procedia Engineering 38, 2012 pp 837-842)

In school, engine crane is a common repair tool and safety equipment used to remove or install gasoline or diesel engines in small or crowded vehicle engine compartments. It is also used when servicing transmission and the likes. It uses a heavy cantilevered support structure to hold the engine in mid-air so that the mechanic can carefully connect or disconnect fragile hoses and wires on the engine to the frame of the vehicle. Engine cranes are typically mounted on large casters so that an engine can be lifted straight up out the engine compartment and then rolled away from the immobile frame. The engine crane is commonly used with the engine stand so that the removed engine can be rotated to provide access to underside surfaces of the engine.

Sad to say, nowadays, the cost of imported equipment like shop cranes is so expensive that individuals and even schools seldom afford to produce. The scarcity of safety equipment are felt by both mentors and administrator. Safety of the trainees are at stake amidst attainment of desired learning outcomes through instruction and training.

Teacher should make the necessary innovations to make teaching effective. They should learn to devise their instructional materials to be consistently effective and efficient in delivering both simple and complicated concepts (Earthman, 2002). It is now the responsibility of automotive technology instructor to introduce and develop safety devices that would make working activities in automotive laboratory safe. Applying inventiveness and resourcefulness as instrument in preparing teaching device in his classes is a necessity. A need to innovate a movable, efficient and portable type of cranes that can be utilized for instruction activities will improve student's knowledge and productivity.

High-technology equipment remains as indispensable device yet to be produced on government run laboratory schools but we can fabricate devices without sacrificing the quality cranes that can be addressed through improvisation, thus study was conceptualized.

OBJECTIVES OF THE STUDY

The present study endeavors to accomplish the following objectives:1.specify the technical features of the lifting device; 2. fabricate and produce a portable movable automotive workshop crane out of locally available materials; 3. perform try-out and revision of the automotive workshop crane as industrial design for lifting vehicle components safely; 4. evaluate the acceptability of the device in terms of functionality and usefulness as safety and teaching device, and 5. compute analytically the net shearing force , stress and centroidal axis including weld applied to identified load bearing part of the lifting device.

METHODS

The Research & Development (R&D) method of research utilizing theories of resourcefulness is followed in this study. The fabrication and testing of the device were conducted in the industrial technology shop by the researchers involving Bachelor of Automotive Technology (BAT)2A students. Performance test, observations and documentary analysis were also used to supplement data gathering in the study and undertook different stages in the construction of the device.

The proponents distributed survey questionnaire to thirty (30) BAT 2A students, automotive experts and instructors of Partido State University (ParSU) campuses offering automotive technology as respondents. The design and main structure of the project is analyzed as to the shearing force and stress. The result was tabulated and analyzed and statistically treated to determine findings and conclusion as to the functionality, effectiveness and acceptability of the project.

Experimental method and control group was adapted to compare functionality and effectiveness of the lifting device.

T-test and weighted mean was also used to validate the project study.

RESULTS AND DISCUSSION

MATERIAL SELECTION

Transportation of heavy machine parts and equipment within and outside the workshop has been a source of concerns and urgent attention because of the hazard it exhibit. Selecting materials for the project must be given preferential attention since it is the most difficult problem for the project at a minimum cost. The necessity for weight reduction to save energy will require the use of different materials. (Okolie, P. C. et al., Department of mechanical engineering, Nnambi asikiwe university, P.M.B 5025 Awka, anambra state, Nigeria, 2015.)

Since the project is a lifting device that will be used to back up students while working in a vehicle, welding and connection design. The use of the shielded metal arc welding where applicability of low hydrogen electrodes was utilized in the fabrication. The complete joint groove (CJP) was applied in some load carrying parts of the assembly (figures 1a and 1b) to ensure the full strength of the attached material is developed, There is no design calculation required when specifying CJP groove weld in the statically loaded structure. Other parts of the assembly uses fillet welds that are considered environment friendly weld since depositing less metal saves energy too. (Stockman, M., et.al, Steelwise 2008.

The following parts of the device are necessary in the project such as strength, machinability, hardness an ductility of each component as a lifting device, to wit:

a. Vertical column with high compressive stress.
b. Retractable base legs with wheels to make it portable and movable
c. Lifting boom is being telescopic adapted to retract to a predetermined height.
d. Chain block for the final lift of the work.
e. Pins/bolts subjected to shearing stress.

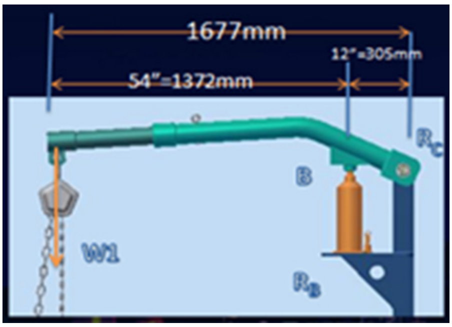

Figure 1a. *The figure shows the retractable boom is free to rotate around an axis and when a torque or load is applied changed its angular momentum.*

Computation is shown below.

Where:

$W_1 = 1015$ kg (9.81m/s2)

= 9957 Newton

($\sum Mc = 0$)

9957 (1677) – RB (305) =0

R_B= 54747N

W_2 =1/2 (54747 + 98)

= 27422 N

$\sum L = 100 + 405 + 305$

$\sum L\dot{x} = 100(50) + 405\ (102.5)$

= 36,512.5

$\dot{x}$= -45mm

$\sum L\dot{y} = 100(315) + 405\ (305) + 305\ (152.5)$

= 201,537.5

$\dot{y}$ = 249mm

Based on figure 1, the shearing force is computed:

Fd = P/∑L = 27422/810 = 34N/mm and the moment of load is

M =W2 (160) = 27422(160) = 4,387,520 N/mm.

Table 1. Computed Moment of Inertia

	Angular momentum (L)	x^2	y^2	Moment of Inertia
J_{ab}	100mm³	95mm³	66mm³	1,421,433mm³
J_{cd}	405mm³	58mm³	56mm³	8,168,344mm³
J_{ef}	305mm³	45mm³	97mm³	5,851,755mm³
			Total	15,441,532mm³

By locating the x and y axis of the lifting device where weld was applied, the total computed moment of inertia is 15,441,532mm^3.

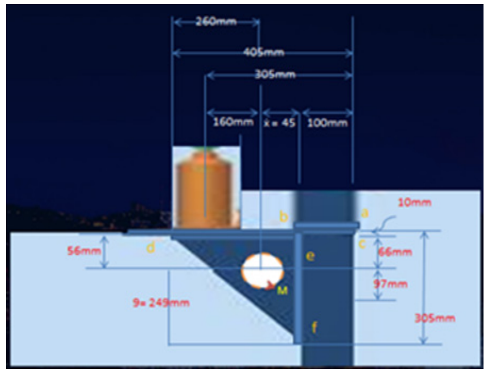

Figure 1b. *Identified load bearing point in the lifting device where appropriate weld is applied*

Table 2. Computed Centroidal Axis

Joint/s	f_d	f_{tx}	f_{ty}	F_{ty}-F_d
@joint a	34	19	41	20N/mm
@joint b	13	19	13	28N/mm
@joint c	34	16	41	17N/mm
@ joint d	34	16	108	109N/mm
@joint f	34	71	13	74N/mm

Table 2 are results that shows where large amount of loads and bending are taking place on parts and joints of the lifting device to make sure it will hold the load. Axial loads are applied along the longitudinal or centroidal axis of the structural member.

The American Institute of Steel Construction (AISC) allowable requirement for shearing stress using E60 electrodes is 93.8mpa and for E70 electrodes is 108.9mpa. The capacity of weld made in the lifting device use the maximum value of Reaction (R) which is 109 N/mm. Therefore the shearing force should be equal to the shearing area multiplied to the shearing stress:

For E60 Electrodes

$$109\text{N/mm} = (0.707t)\ (0.30Fu)$$

OR

$$109\text{N/mm} = (0.0707t)\ (93.8)$$

$$t = 1.64\text{mm}$$

For E70 Electrodes

$$109\text{N/mm} = (0.707t)\ (108.9)$$

$$t = 1.42\text{mm}$$

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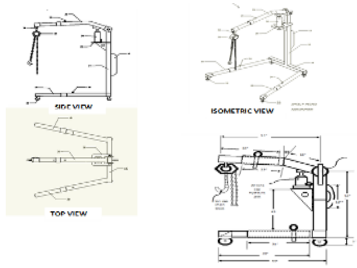

Figure 2. *The working drawing of the combined hydraulic and mechanical automotive workshop crane*

The improved workshop crane consists the main frame and the combined hydraulic-mechanical assembly. The base is made of angle bar that can withstand the weight of the object being worked on and the swivel and ball caster is attached thereof. The extension boom has a maximum length of 71 inches where chain block is installed. The center post is made of a combined angle bar and pipe measuring 54 inches. The maximum load capacity of 500 to 1000 kilogram –easily foldable and adjustable. The boom and it's base legs extends from 42 to 62 inches. The shearing force and shearing stress of each joints and correct weld specification conforms to the American Institute of Steel Construction (AISC) requirements in the fabrication of the lifting device.

STAGES IN THE FABRICATION

The proponents performed the following stages in fabrication:

1. Conceptualization of design and plan-The working drawing of the "combined hydraulic-mechanical automotive workshop crane was carefully planned with aim to maintain accuracy of the proposed project.
2. Preparation-The supplies and materials, tools and equipment needed for the study were estimated, purchased and utilized;
3. Construction and Assembly of Parts- A.

Construction procedures

a. Construction of the Frame-

a.1 Read and interpret the working drawing of the hydraulic-mechanical automotive workshop crane.

a.2 Prepare and cut the angle bar for the frame according to the design of the improved workshop crane. Adjustable & relative parts, length required and it's correct specifications should be followed according to working plan;

a.3 Assemble each part of the frame using arc welding;

a.4 Check accuracy and straightness of the main frame including the brace intended for the chain block;

a.5 Install the hydraulic jack in it's base though a bolt and see to it that it lifts the boom to an approximate height;

a.6 Check that extension boom and leg base are adjustable. Fixed these parts with bolts or nuts; and,

a.7 Properly install relative parts to ensure functionality of the device.

4. Finishing

a. Grind rough surfaces using a grinder;

b. Apply metal primer;

c. Test for the functionality and effectiveness of the device.

Figure 3. *Fabrication of the lifting device using gas,arc welding and electrically operated angle grinder.*

One hundred eighty two (182) hours was allotted for the following task: construction of the main frame; movable & fixed beam; painting; try-out & revisions; and, evaluation.

The total cost of the lifting device amounted to Php17,000.00. Included in the computation is forty percent (40%) labor cost, total cost for supplies and materials and additional ten percent (10%) overhead cost considering the power consumption and machine depreciation of the estimated cost of supplies, materials and labor.

Table 3. *Mean rating of the functionality, effectiveness and acceptability as perceived by students, experts and instructors*

ASSESSMENT VALIDATION	Total Points	Weighted Mean	DESCRIPTIVE INTERPRETATION
1. **FUNCTIONALITY USE OF THE AUTOMOTIVE WORKHOP CRANE** Using the device, it can lift works: engine, transmission and other heavy automotive materials.	113	3.76	Highly Functional
2. **EFFECTIVENESS AS TEACHING DEVICE** Effective as an approach to teaching: a. engine overhauling where mounting/ dismounting of work is a requirement b. installing transmission assembly, other automotive related works	127	4.23	Highly Effective
3. **ACCEPTABILITY**		4.0	Highly Acceptable

Shown above are the weighted mean that functionality of the safe lifting device has a weighted mean of 3.76 which means "Highly functional." A mean of 4.23 in terms of effectiveness of the device means "Highly Effective" and an over-all average mean of 4.0 in terms of that acceptability means "Highly Acceptable."

Figure 4. Students and mentor conducting test and assessment validation of the project.

Table 4. *Perceptions of the evaluator on the functionality, effectiveness and acceptability compared to when not using a back-up device while working with heavy automotive materials.*

N=30

Item for validation	t-computed value	t-tabulated value	Level of significance	df	description	Interpretation
Functionality	15	2.776	0.05	4	Significant	H.o.:rejected

Findings above showed that the lifting device performs better as compared to when not using a back-up lifting device.

The performance of the lifting device finds the following:

a. Functionality - the computed t-value on the functionality of the lifting device is 15 which is greater than the tabular value of 2.776 at 0.05 level of significance. Commercially available lifting devise in the market and the improved lifting device both can do the same function.

b. Effectiveness - the computed t-value is 0.7431 and less than the tabular value of 2.776 at 0.05 level of significance. The devise is close if not totally the same with commercially available one.

c. Acceptability - the computed t-value is 3.8 greater than the tabular value at 0.05 level of significance. This means that there is a significant difference in the perception of the respondents.

Table 5. *Defects found and revisions made*

DEFECTS	REVISIONS
Installation of Extension boom	Movable boom was repaired and welded to the frame to correctly install the relative parts.
Alignment of Hydraulic jack	Alignment was corrected

Minor defects were technically corrected to ensure operative mechanical movement of the parts as desired. Some defects were noted and corrected such as: imperfect alignment of wheel base where hydraulic jack is installed and corrected the limited movement of the pivoting part of the boom. Application of weld perfected the wheel base and the mounting of the hydraulic jack. Greasing and lubrication in the pivoting base remedied the limited movement of the improved workshop crane.

CONCLUSIONS

The project gains a dominant application in automotive workshops in carrying, holding, positioning, loading and unloading of heavy automotive parts and materials where there are no provision for overhead shopcranes. Students exposed to the improved training device attained better performance than students taught without the use of the trainer.

The instructor in any skill development is still the key factor in the classroom specially in the teaching-learning process is ensured. The use of the utility model served as back up in learning and ensure safety while at work and is perceived by respondents to be effective and an added strategy in accomplishing task in automotive.

The design of the combined mechanical and hydraulic automotive workshop crane was carried out successfully meeting the specified and required standard of a lifting device for automotive works. It is capable of lifting automotive materials of various load ranging from 50 to 100 kilograms that ascertains safety of student trainees.

The teaching device has provision for developing students for Automotive Servicing National Competency I, II and III (NC-I, II &III) in engine servicing, overhauling and relative chassis works.

RECOMMENDATIONS

It is recommended that the combined hydraulic and mechanical automotive workshop crane as instructional equipment be manufactured and be made available for automotive instruction.

The university administrator shall finance the production and commercialization of the automotive workshop crane. This will ensure safety of Bachelor of Automotive Technology(BAT) students while working with heavy automotive materials.

The industrial design can be introduced to other school as instructional model for teaching engine overhauling and underchassis work specially in the K12 program where safety equipment are noted to be scarce. More innovations can be made to enhance the instructional material.

Other researchers with similar study may follow the same processes and stages in modifying device like a trainer into a utility model.

TRANSLATIONAL AND IMPACT OF RESEARCH

The outcome of the research/patent works conducted had been translated into instructional materials utilized in automotive classes of Partido State University. Said instructional materials had effectively improved the efficiency of its learners in performing relevant tasks while undergoing training in the university.

The lifting device is patented with Registration No. 32014000037 compliant with the provisions of Republic Act (RA) No. 8293 and it's regulation thereby registered as Industrial Design." The device was claimed and meets required points in the "Normative Funding and SUC Leveling" of Partido State University, Philippines.

Likewise, considering the high cost of available equally worthy simulators and projects in the market, the authors project said device to be commercialized.

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