ESTIMATION OF STANDARD TIME AND ERGONOMIC ANALYSIS OF ENGINE ASSEMBLY USING SIMULATED MODEL

G. DEENADAYALAN¹ & VIJAY P²

¹Professor, Department of Mechanical Engineering, Vel Tech Rangarajan Dr Sagunthala
Institute of Science and Technology, Avadi, Chennai, Tamil Nadu, India

²Research Scholar, Department of Mechanical Engineering, Vel Tech Rangarajan Dr Sagunthala
Institute of Science and Technology, Avadi, Chennai, Tamil Nadu, India

ABSTRACT

Considering the prevalence of simulation modeling in production design, integrating ergonomic safety considerations into models can help production planners identify and prevent ergonomic risks before workers encounter unsafe conditions, in addition to productivity improvements. This study integrates ergonomic analysis into simulation modeling by developing a modeling template that enables simultaneous estimation of the standard duration of manual activities, as well as biomechanical risk factors involved in the production design. As a case study, the proposed methodology is implemented in an engine assembly operation and the results confirm the validity of the approach in identifying ergonomic risks associated with a production design.

KEYWORDS: Ergonomic Analysis, Simulation Modeling & Bio-Mechanical Risk

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INTRODUCTION

Simulation modeling is an effective tool for design and planning of assembly operations. A digitalized model representing a physical system allows prediction of the system performance in a real-world application, as well as an understanding of the system behavior under various conditions. In engine assembly, advances in simulation modeling techniques have been made to estimate the duration of projects and the productivity of different operational systems. However, it still remains challenging to analyze manual operations due to the uncertainties in modeling human movements and estimating the cycle time of manual tasks. The impact of the workplace design and workflow on human capacity (e.g., durations and frequencies of physical tasks) for ergonomic safety analysis has not been thoroughly considered.

So integrating ergonomic considerations into simulation models can help in identifying and preventing ergonomic risk factors affecting human movements before the workers encounter the unsafe conditions as well as help in understanding the impact of production systems on human behavior. This study proposes integrating ergonomic analysis into micro-motion-level simulation modeling. A simulation template is developed which enable simultaneous estimation of the standard duration of manual activities and biomechanical risk factors in the production design.

The concept of a Predetermined Motion Time System (PMTS) is adopted to model human movements and estimate cycle time of manual tasks based on the unit cycle time of each movement. The human postures and motions involved in the manual operations are evaluated from an ergonomic perspective, using an ergonomic assessment tool.

As a result, the simulation model not only provides information regarding the standard duration of the production but also reports on the level of ergonomic risk associated with the design. Thus the proposed simulation model enables modifying the workplace design in order to achieve both ergonomically safe and productive system.

Figure 1: Workcell

METHODOLOGY

The basic human operations in engine assembly include Grasp, Position, Handstart and Rundown. The methodology is to select an assembly station in the engine assembly process that covers basic motions of the operator.

This study uses PMTS and ergonomic assessment in order to develop an integrated micro-motion-level simulation modeling environment using the Process Simulation platform.

VALIDATION

Validating the simulation using the case study involves two steps:

- Comparing the MODAPTS duration calculated by the model with actual time data collected from the job site, and
- Investigating the reliability of the ergonomic assessment provided by the simulation model.

The MODAPTS code and duration are also calculated manually to ensure that the simulation model is calculating the durations accurately, and the results are consistent with the duration calculated by the simulation model.

In order to investigate the reliability of the ergonomic assessment results from the developed simulation, for each instance of the task, the level of ergonomic risks associated with the instance is analyzed using the Rapid Upper Limb Assessment (RULA) (McAtamney and Corlett 1993) method which is embedded within Process Simulate software.

The result of a RULA analysis is a total score between 1 and 7, with 1 and 2 indicating acceptable posture, 3 and 4 indicating that changes may be needed, 5 and 6 indicating that changes are required soon,

Figure 2: Rula Employee Assessment Worksheet

CASE STUDY

Assembly Line Data

- Capacity of the line : 120 JPH
- Takt time for the line : 28 seconds
- Work load % of operator = (Total operation time/Takt time)*100
- Exhaust Manifold spacers and nuts Install – Load percentage 108.2%

Time Study Analysis of Workstation

The engine assembly operations are studied to identify the benchmark station suitable for the case study. Based on the time study data and the assembly process the Exhaust Manifold Nuts and Spacer install operation is selected as the benchmark station.

Figure 3: Actual Engine Assembly Process

Table 1: Time Study of operation

Station Description	Operation details	Actual time data in sec
Exhaust Manifold Spacers and Nuts Install	P/U (8) spacers from line side dunnage (4 per hand)	3.7
	Install (8) spacers onto studs (simo using both hands)	9.6
	Pick up (8) exhaust manifold nuts (4 per hand)	4.3
	Hand start (8) exhaust manifold nuts	12.7
	Total Cycle time	30.3

Identification of Bottleneck Operation

Bottle neck station

WORKCELL BUILD UP AND SIMULATION OF THE ASSEMBLY PROCESS

Work cell Build up

Building the work cell includes the following tasks,

- 3D CAD parts collection
- Splitting workstation parts wherever movable joints are available
- Importing parts into the simulation environment
- Placing parts in position

Kinematics to Station Components and Human Jack

- The station components and the Human are rigid
- Hence to make the components movable constrained kinematic movement is assigned to joints based on the usage of the joint
- The Human Jack model is made to simulate the station activities.
- The station process includes stepping to the nuts bin and grasping the nuts and spacers, stepping back to the engine area and position the spacers, then position the nuts and hand start the nuts.
- The human Jack is simulated to perform these processes in the defined sequence for further study.

ERGONOMIC ANALYSIS OF THE FINAL ASSEMBLY POSITION USING RULA

- The final assembly position of the operator where most of the assembly process is carried out has to be analyzed for ergonomics.
- Hence to validate the ergonomic condition of the operator in the assembly position RULA is considered.
- The position of the operator shown in the above image is considered for RULA since a majority of the task including positioning spacers, nuts and handstart of nuts is carried out
- The RULA score for the assembly position is '2' which shows the position is within an acceptable limit and does not incur any bio-mechanical stress to the operator in this assembly position.
- Hence the workstation model is said to be ergonomically designed and hence suitable for deriving the task duration standards.

Figure 4: Rigid Model and Simulated Model

Human Simulation of the Station Process

Figure 5: Simulation of Assembly Process

Figure 6: Final Assembly Position of Operator

Arm & Wrist Analysis		Neck, Trunk & Leg Analysis	
Step 1: Locate Upper Arm Position: 	Upper Arm: 2 Upper Arm Adjustment 0	Step 9: Locate Neck Position: 	Neck: 2 Neck Adjustment 0
Step 2: Locate Lower Arm Position: 	Lower Arm: 1 Lower Arm Adjustment 0	Step 10: Locate Trunk Position: 	Trunk: 2 Trunk Adjustment 0
Step 3: Locate Wrist Position: 	Wrist: 1 Add -1	Wrist Twist: 1	Legs: 1
Arm Muscle Use: 0	Force Load Score A: 0	Upper Body Muscle Use: 0	Force Load Score B: 0
Final Score 2			

FINAL SCORE: 1 or 2 = Acceptable; 3 or 4 Investigate further; 5 or 6 Investigate further and change soon; 7 Investigate and change immediately

Figure 7: RULA Score for the Position

RESULTS FROM THE CASE STUDY

Time Study of the Operation using MODAPTS

- Time study for a simulated process which is proved to be ergonomically safe is made using MODAPTS, where the time can be captured at every motion level. Total Cycle time: 26.832 s
- Takt time for the line : 28 s
- Work load % of operator = $(\text{Total operation time} / \text{Takt time}) * 100$
- Operator Workload : 95.8%

Also by simulating the process in virtual environment unwanted motions are identified and removed and the workload is brought down within the permissible limit.

Standard Task Duration

The handstart operation which involves three turns to secure the nut to the stud of an engine has been coded using MODAPTS in the ergonomically stable position.

- Handstart nuts/bolts to three turns – 0.903 secs

Similarly, the activity of positioning fasteners to the engine in the ergonomically stable position is also coded using MODAPTS.

- Position fasteners to assembly considering standard ergonomically designed work cell – 2.193 secs

Result for Case Study

- Standard MODS for hand starting fasteners for 3 turns is M1P0 2(M1G1 M1P0) which is 0.903 s
- Standard MODS for positioning fasteners is M3P5 J2 M2P5 which is 2.193 s.

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Work Element	Sub steps	MODAPTS code	MODS	Time in secs
Pickup (8) spacers from box	Walk (1) step	W5	5	0.645
	Grasp (8) spacers using both hands	M3G3 3(M1G1)	12	1.548
Position (8) spacers to block and handstart	Walk (1) step to engine	W5	5	0.645
	Position (2) spacers using both hands	M3P5 J2 M2P5	17	2.193
	Position (2) spacers using both hands	M3P5 J2 M2P5	17	2.193
	Position (2) spacers using both hands	M3P5 J2 M2P5	17	2.193
	Position (2) spacers using both hands	M3P5 J2 M2P5	17	2.193
Pickup (8) nuts from box	Walk (1) step	W5	5	0.645
	Grasp (8) nuts using both hands	M3G3 3(M1G1)	12	1.548
	Walk (1) step to engine	W5	5	0.645
	Position (2) nuts using both hands	M3P5 J2 M2P5	17	2.193
	Handstart (2) nuts simo	M1P0 2(M1G1 M1P0)	7	0.903
Position (8) nuts to studs on block and handstart	Position (2) nuts using both hands	M3P5 J2 M2P5	17	2.193
	Handstart (2) nuts simo	M1P0 2(M1G1 M1P0)	7	0.903
	Position (2) nuts using both hands	M3P5 J2 M2P5	17	2.193
	Handstart (2) nuts simo	M1P0 2(M1G1 M1P0)	7	0.903
	Position (2) nuts using both hands	M3P5 J2 M2P5	17	2.193
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	Position (2) nuts using both hands	M3P5 J2 M2P5	17	2.193
	Handstart (2) nuts simo	M1P0 2(M1G1 M1P0)	7	0.903
	Position (2) nuts using both hands	M3P5 J2 M2P5	17	2.193
Total Cycle time				26.832

Table 2: Timestudy of Operation

Task	MODAPTS code	MODS	Time in secs
Handstart (2) nuts simo	M1P0 2(M1G1 M1P0)	7	0.903

Task	MODAPTS code	MODS	Time in secs
Position (2) nuts using both hands	M3P5 J2 M2P5	17	2.193

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