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Application of Ranked Position Weighted and Kilbridge and Wester Method at Radiator Assembly Plant - A Case Study

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Abstract: Line-Balancing is distribution of total work load among various stations evenly as to achieve the production target. The problem is to minimize the difference between maximum station time and individual station time subject to element time constraint, precedence relationship constraint.
The assembly line as planned and installed based on the production rate required; any change in demand value, product design requires change in assembly line.
The case study involves Kilbridge and Wester (KBW) method and Ranked Position Weighted (RPW) method line balancing Heuristic Algorithm to balance the manual assembly line. Result is selected as best of two method and proposed arrangement for distribution of workload among various stations is made for the radiator assembling plant considering line-efficiency(E) and smoothness index(SI) as performance criterion.
Keywords: Line-Balancing, Kil-Bridge and wester method, Ranked Position Weighted method, line-efficiency, smoothness-index

I. INTRODUCTION

Manual Assembly lines consists of sequence of workstation where assembly tasks are performed manually by Human worker to assemble the product as they move along the line The Productivity of the Assembly line generally depends on balancing performance[1]. Prerequisites for proper line balance involves following things[2]:-

A. Production Volume
B. List of operations and sequence
C. Operation time and elemental time

In this case study Operation time is developed with help of Maynard Operation Sequence Technique(MOST). Production volume has been set by the Production Planning and control section, existing production rate is 500units/shift. Operation sequence for assembling the radiator has been set by the Process planning section of the firm.
Assembly tasks are broken down into elements, where each elemental taskis allocated to the workstation considering precedence relationship such that it does not exceed maximum station time. Authors found that considering present and future production volume it is required to increase the plant capacity, and propose distribution of elemental time among work station with minimum the idle time. This influence need for line-balancing.

II. LITERATURE REVIEW

Heuristic procedures for line balancing involves:-

A. Largest Candidate Rule method
B. Kilbridge and Wester(KBW) method
C. Ranked-Position Weight(RPW) method

KBW and RPW method allocates work element based on their elemental cycle time and precedence relationship unlike LCR method which allocates the work element based on maximum cycle time and irrespective of precedence relationship. As a result this study does not include LCR method for line-balancing.

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III. METHODOLOGY

Assembly line balancing problem are of two categories:

1) Assume fixed cycle time and find optimum number of workstations.
2) Assume fixed number of workstations and minimize the cycle-time to minimize the total delay time.

This case study uses first category of line-balancing problem.

A. Terminology used

1) *Task element(Te):* It is the minimum divisible element in the assembling process.
2) *Total work content (Twc):* It is the sum of all elemental task times, where iis individual task times.

Twc = $\sum_{i=1}^{n} Tei$

3) *Workstation process time(Ts):* It is the sum of elemental task time performed at jth work station.

Ts= $\sum_{j=1}^{n} Tej$

4) *Total time available for completion(TACT) time:* It is the speed with which production should proceed in order to meet customer demand.

Tact time = $\frac{\text{Available time for completion per shift}}{\text{Average demand per shift}}$

5) *Production Rate (R_P):* It is the ratio of amount of units to be produced to the avsilable time. It is measured in unit / sec.

$R_P = \frac{\text{Demand}}{Available\ time}$

6) *Balance Efficiency (E):* It is the measure of how good a given line balancing solution is. However it is not possible to balance a line 100% perfect. Here, 'n' is no. Of workstations.

E = $(T_{WC})/(n^* T_C)$

7) *Balance delay (d):* It indicates loss of time due to uneven work distributions at each station. It is opposite to balance efficiency.

d = 1-E

8) *Smoothing Index (SI):* This index indicates relative smoothness of a given assembly line balance.

SI= $\sqrt{(\sum[Tc - Ts^2])}$

Fig.1 shows the flowchart for the present research work.

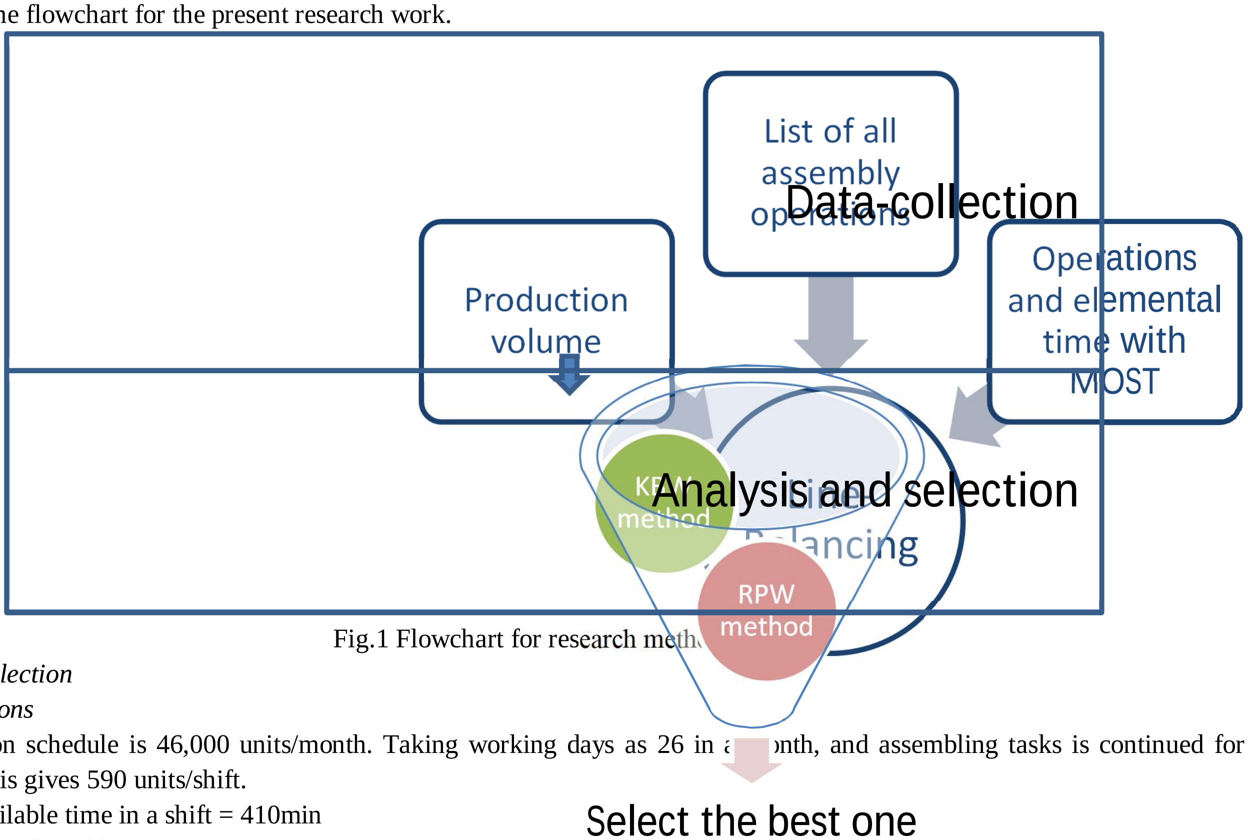

Fig.1 Flowchart for research meth

B. Data-Collection

1) *Assumptions*

a) Production schedule is 46,000 units/month. Taking working days as 26 in a month, and assembling tasks is continued for 3 shifts. This gives 590 units/shift.
b) Total available time in a shift = 410min
c) Maximum allowable station time equals to TACT time = 41.70 secs/unit

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d) Precedence relationship is as shown in Fig.2

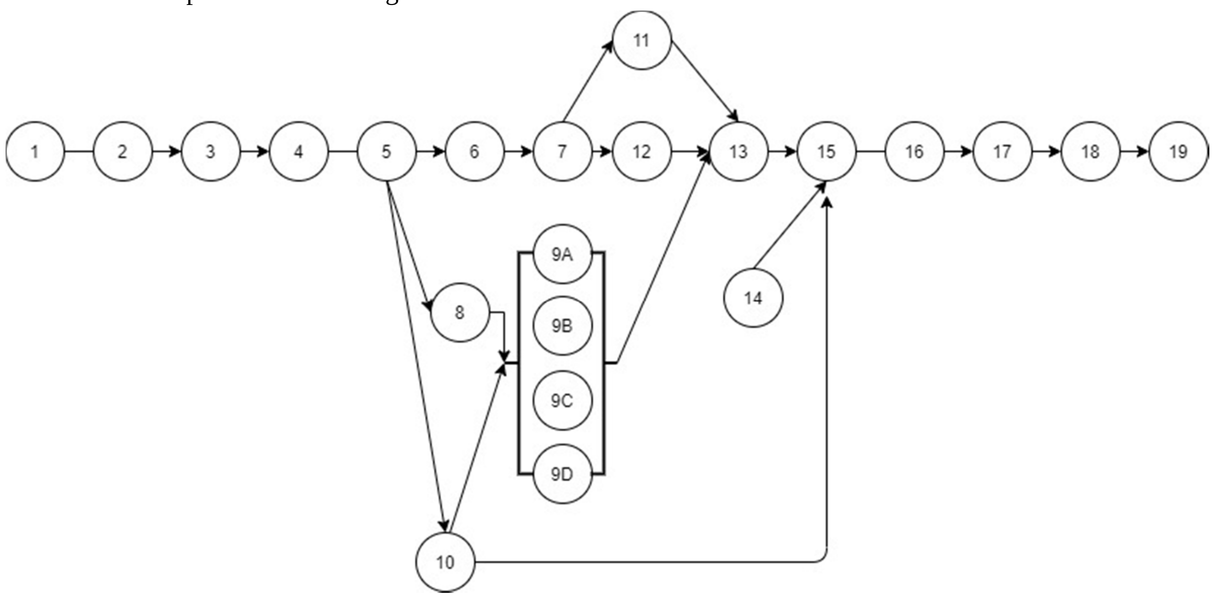

Fig.2 Precedence diagram for radiator assembly.

2) Operation time as per 'MOST' method:-

Fig.3 shows the flow process for assembling the radiator in the manual assembly line.

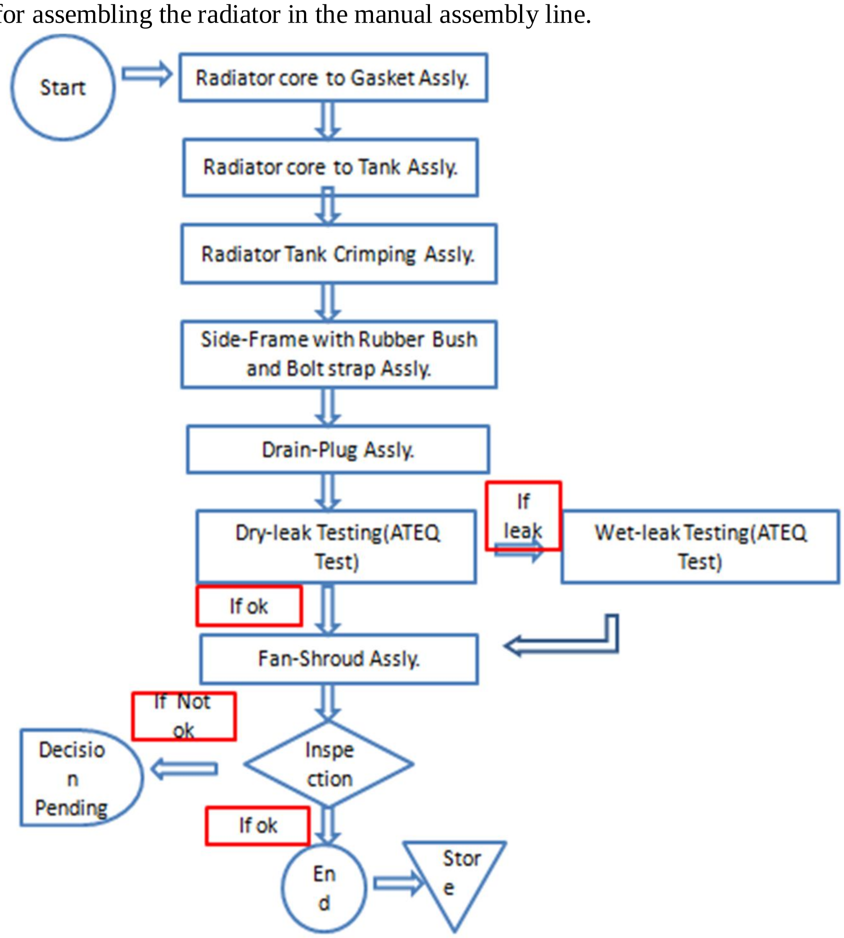

Fig.3 Flowchart for operation of Assembling radiator

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Table 1 shows the operation cycle time of each operation as developed by Maynard Operation Sequence Technique(MOST).

TABLE 1
CYCLE TIME FOR ASSEMBLY OPERATION WITH MOST

St.No.	A					B				
Activities	Top-tank Fitting	Get the core	Put gasket	Get tank	Fit tank	Top-tank Crimping	Get radiator	load into machine	Machine time	
Time(sec)	20.52	7.92	1.44	6.48	4.68	21.08	3.6	2.52	11	
St.No.		C					D			
Activities	Unload radiator	Bottom-tankFitting	Get radiator	Put gasket	Get tank	Fit tank	Bottom-tank Crimping	Get radiator	load into machine	Machine time
Time(sec)	3.96	16.2	3.6	1.44	6.48	4.68	21.08	3.6	2.52	11
St.No.		E					F			
Activities	Unload radiator	Side Crimping	Get radiator	Perform crimping with foot-pedal machine	Unload radiator	Marking	Side-frame pre-assy.	Get radiator	Loose fitting of left side frame	
Time(sec)	3.96	20.88	5.76	6.12	2.88	6.12	37.08	6.12	11.88	
St.No.				G				H		
Activities	Loose fitting of right side frame	Unload radiator	Marking	side-frame final assy.	Get radiator	Use guage and power tool for torque apply	Unload radiator	Drain cork and manual lug tightening		
Time(sec)	11.88	2.16	5.04	34.56	3.24	28.08	3.24	20.52		
St.No.				I						
Activities	Get drain-cork	Use power tool for torque apply	Lug tighten with wrench	Ateq leak test**(4 Parallel stations)**	Get radiator	load into machine	Machine time	Unload radiator		
Time(sec)	1.8	6.12	12.6	34.41	7.92	1.8	120	7.92		
St.No.	J					K				
Activities	Inlet pipe fitt.	Take pipe	Fit bolts loosely	Use power tool for torque apply	Marking	Greasing	Get and apply grease	Get and apply sticker		
Time(sec)	39.24	1.44	11.88	21.24	4.68	14.76	14.76	12.24		
St.No.	M			N						
Activities	Visual Inspection	Reach radiator and check marking	stick ok tag	Hey-guard assembly	Get radiator	Get and place guard	Loosely fit screws	Unload radiator	Get radiator	
Time(sec)	19.44	17.28	2.16	62.64	2.16	3.24	19.08	2.16	2.16	
St.No.				O						
Activities	Use power tool for torque apply	Marking	Unload radiator	Shroud pre-assy.	Get radiator	Put shroud	Loosely fit screws	Marking	Unload radiator	
Time(sec)	23.4	8.28	2.16	36	3.24	2.16	19.08	8.28	3.24	
St.No.	P				Q					

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Activities	Shroud final assy.	Getradiator	Use guage and power tool for torque apply	Unload radiator	NLT assy.	place tank	Loosely fit screws	Use power tool for torque apply	Use of pliers wire twist
Time(sec)	32.04	3.24	25.56	3.24	36.36	5.76	8.64	13.68	4.32
St.No.		R		S					
Activities	Use power tool for torque apply	Cap fitting	Take and fit cap	Q.A. Passing	Inspect	Write code	Apply Barcode		
Time(sec)	3.96	10.08	10.08	20.16	7.2	10.8	2.16		

C. Use of line-balancing Method

1) *Kil-bridge and Wester method:* Kilbridge and Wester method was introduced in 1961 makes much use of precedence diagram as tool of balancing. This method allows total distribution of work elements essentially on positional and fixed facility restrictions on operating line[4]. In order to achieve optimum balance permutability within columns and lateral transferability are exploited. Following are the steps for using this method:-

a) *Step-1:* Prepare Precedence diagram
b) *Step-2:* As per the position of elements in the precedence diagram, organise them into columns.
c) *Step-3:* Organise work-elements into list of columns, starting with first column.
d) *Step-4:* Assign work-elements to the station such that it does not exceed the TACT time
e) *Step-5:* Repeat step-4 until all elements are allocated to the workstation.

Table 2 shows column wise distribution of elements. Precedence diagram is as shown in Fig.2.

TABLE 2. Coloumn-Wise Distribution Of Work Elements

Work Elements	Column	Te(sec)	Preceded by
1	i	20.52	-
2	ii	21.08	1
3	iii	16.2	2
4	iv	21.08	3
5	v	20.88	4
6	vi	37.08	5
7	vii	34.56	6
8	vi	20.52	5
9	vii	34.41	8
10	vi,vii,viii	39.24	5
11	viii	14.76	7
12	viii	12.24	7
13	ix	19.44	9,10,11,12
14	ix	36	-
15	x	36	14
16	xi	32.04	15
17	xii	36.36	16
18	xiii	10.08	17
19	xiv	20.16	18

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Table-3 shows allocation of work-elements to the station such that it satisfies precedence relation and each station-time does not exceed TACT time.

TABLE 3
Allocation Elements To Station With Kbw Method

Station	Work Elements	Column	Te (sec)	Station-time (sec)
1	1	i	20.52	41.6
	2	ii	21.08	
2	3	iii	16.2	37.3
	4	iv	21.08	
3	5	v	20.88	41.4
	8	vi	20.52	
4	6	vi	37.08	37.1
5	7	vii	34.56	34.6
6	9	vii,viii	34.41	34.4
7	10	vi	39.24	39.2
8	11	viii	14.76	27
	12	viii	12.24	
9	13	ix	19.44	19.4
10	14	ix	36	36
11	15	x	36	36
12	16	xi	32.04	32
13	17	xii	36.36	36.4
14	18	xiii	10.08	30.2
	19	xiv	20.16	

$E = (T_{WC})/(n * T_C)$
Total work content(Twc) is found as 482.65sec. With KBW method n = 14 workstations, Tc = 41.6sec.
Thus, E = 82.87% and SI = 34.07

2) *Ranked-Position Weight(RPW) method:* Helgeson and Birnie developed the ranked-position weight method in 1961[5]. Following are the steps for using this method:-

a) *Step-1:* Prepare Precedence diagram
b) *Step-2:* Positional weight for 'i'th element is calculated by summing Te values of all the elements that follow 'i'th element in diagram with the Tei itself.
c) *Step-3:* Arrange the elements as per descending order of their positional weights.
d) *Step-4:* Allocate element to the station such that station time does not exceed TACT time.

Table 4 shows the positional weights calculated for each elements with help of precedence diagram.

TABLE 4
POSITIONAL WEIGHTFOR EACH WORK ELEMENT

Work Elements	1	2	3	4	5	6	7	8	9	10
RPW	482.65	462.13	441.05	424.85	404	240	202.6	209.01	188.49	193.32
Work Elements	11	12	13	14	15	16	17	18	19	
RPW	168.84	166.32	154.08	165.96	135	98.6	66.6	30.24	20.16	

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Table-5 shows arrangement of elements as per descending order of their positional weights.

TABLE 5
Allocation Elements To Station With Rpw Method

Station	Work Elements	RPW	Te(sec)	Station-time(sec)
	1	482.65	20.52	
1	2	462.13	21.08	41.6
	3	441.05	16.2	
2	4	424.85	21.08	37.28
3	5	403.77	20.88	20.88
4	6	239.68	37.08	37.08
5	7	209.01	34.56	34.56
6	8	202.6	20.52	20.52
7	10	193.32	39.24	39.24
8	9	188.49	34.41	34.41
	11	168.84	14.76	
9	12	166.32	12.24	27
10	14	165.96	36	36
11	13	154.08	19.44	19.44
12	15	134.64	36	36
13	16	98.64	32.04	32.04
14	17	66.6	36.36	36.36
15	18	30.24	10.08	30.24
	19	20.16	20.16	

Elements are allocated to the station such that station time does not exceed the maximum station time (here, TACT time value).Total work content(Twc) is found as 482.65sec. With RPW method n = 15workstations, Tc = 41.6sec.
Thus, E = 77.34% and SI = 45.10

IV. RESULT AND CONCLUSIONS

Table 3 and Table 5 show allotment of elements to the work-station with KPW method and RPW method respectively. Performance criterion used is Line-efficiency(E) and Smoothness-index(SI). Line with higher balancing efficiency means more productive line. Hence here, allotments with KBW method is proposed. Fig.4 shows revised precedence relationship with work-stations. Also, by applying KBW line balancing method production rate have increased from500units/shift to 590 units/shift. Higher value of line-efficiency and lower value of smoothness-index suggests that line is smooth.

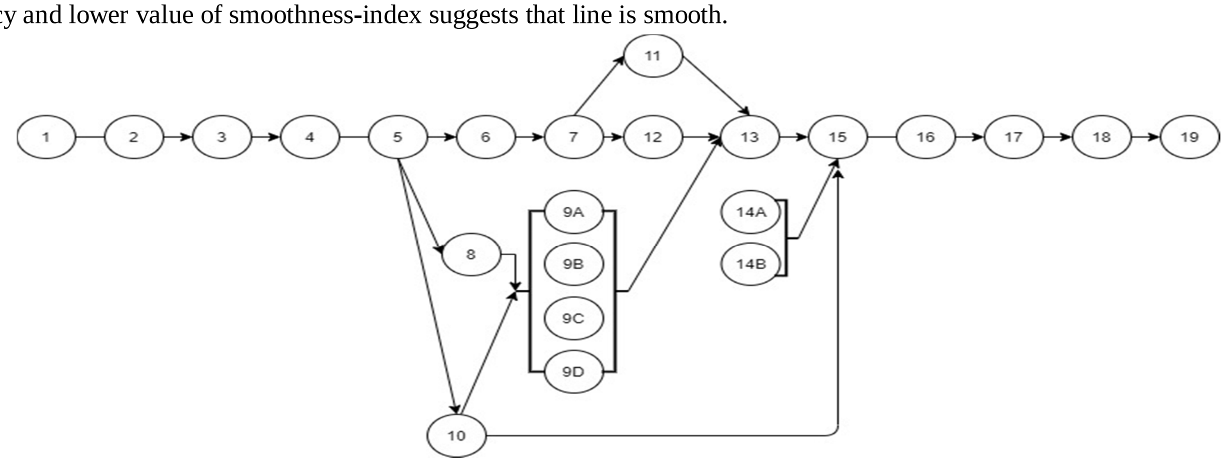

Fig.4 Revised Precedence diagram for radiator assembly.

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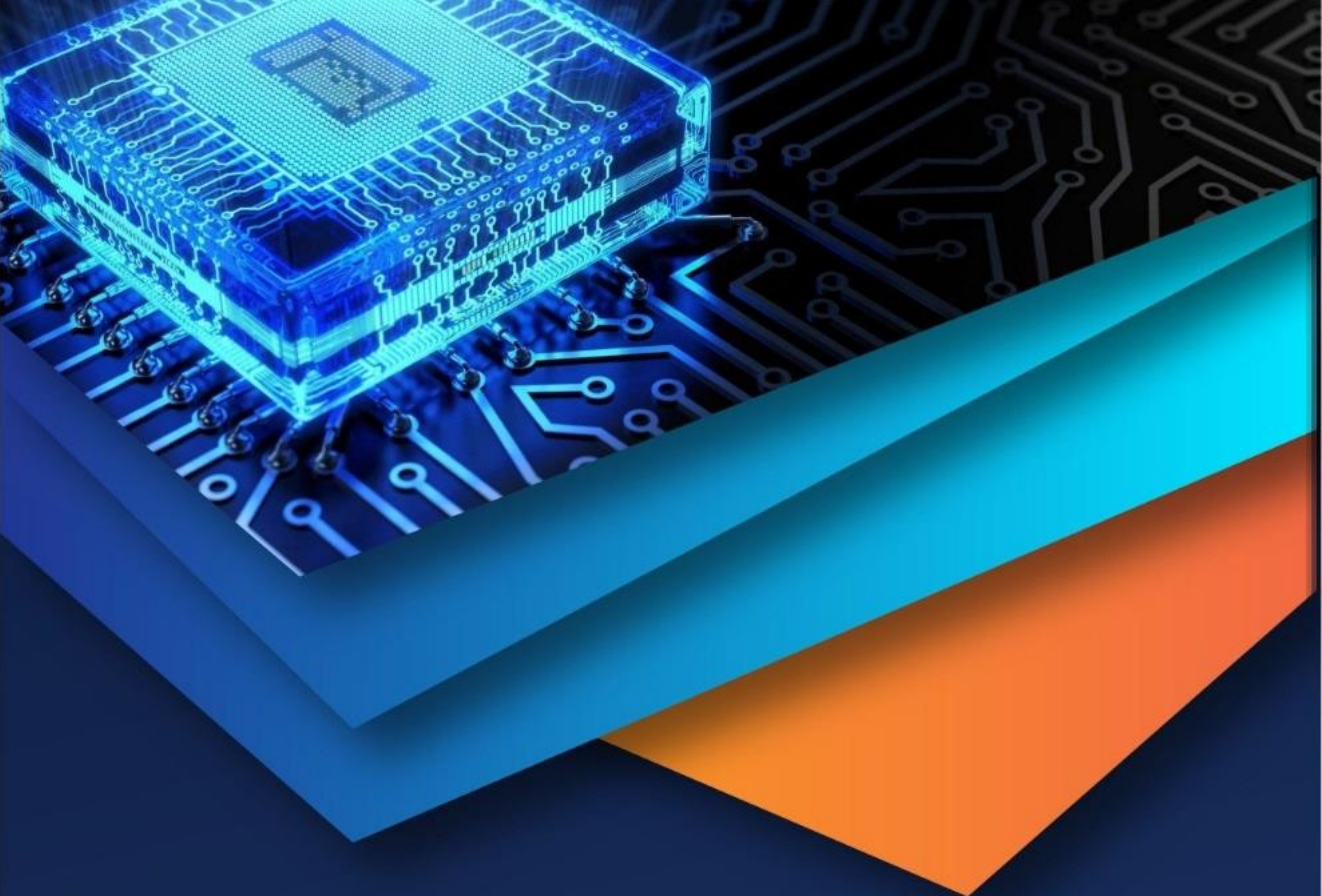

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