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Optimization of Overall Equipment Effectiveness in A Manufacturing System

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ABSTRACT — Recent developments in engineering optimization allow choosing the best input values thereby enhancing the effectiveness of any equipment. Overall Equipment Effectiveness (OEE) is a performance measure which employs factors such as availability rate, performance rate and quality rate to determine the efficiency of a manufacturing system. In this paper, Overall Equipment Effectiveness (OEE) is optimized using Genetic Algorithm to achieve the best utilization of the plant resources. The availability rate of the machine, performance rate of the machine and quality rate of the products are considered as parameters while maximizing the Overall Equipment Effectiveness (OEE) of a manufacturing system. It is found that the lagging in performance rate contributes more than availability rate and quality rate that deficiency of effectiveness in the system. It is concluded that maintaining the performance rate above 95% will result in effective utilization of the considered manufacturing system.

KEY WORDS — Optimization, OEE, MTBF, MTTR, etc.

I. INTRODUCTION

Efficiency and effectiveness are buzzwords in today's competitive market. Greater the efficiency and effectiveness, more productive is the organization. Overall equipment effectiveness is such a performance measure, which indicates current status of production with least calculations. It also helps to measure losses and corrective actions can be taken to reduce it. Effective utilization of Man, Machines, Material and Methods will result into higher productivity.

Overall Equipment Effectiveness (OEE) is a product of three important parameters, Availability (A), Performance Rate (PR) and Quality Rate (QR). When higher productivity is expected the machine tool which are converting raw state of the product into finish goods, must be reliable. Reliability includes availability of the machines with least down time. If mean time between failures (MTBF) is more, it indicates machines are available for its desired performance. Attempt must be made to reduce mean time to repair (MTTR) and improve MTBF. It requires failure data analysis and root cause analysis. The failure data collected will help us to calculate availability (A) of equipment.

OEE = A * PR * QR

MTBF = Total breakdown time / Number of occurrence
MTTR = Total repair time / Number of occurrences

Availability = MTBF / (MTBF + MTTR)
Performance Rate = (e * t_s) / Actual operating time
Quality Rate = (Output - Rejected) / Output

Nomenclature
A – Availability
PR – Performance
QR – Quality Rate

OEE is a measure of machine capability. It indicates where scope of improvement. Statistical data collected from tyre manufacturing process results into useful information for improvement area.

Nakajima (1988) introduces OEE in Total Productive Maintenance. Researchers have noted that this definition varies with different processes. A.J. de Ron and J.E. Roda modified OEE by introducing operational efficiency (OE) and rate efficiency (RE) in performance rate. [2] Tom Pomorski[8] of semiconductor industry, USA defines OEE in terms consistent with SEMI E-10-96. OEE as one element of which measures the performance of equipment, but can OEE measures the performance of the entire manufacturing process. The productive metric standard proposal defines variations of OEE as production OEE, demand OEE, simple OEE and cluster tool OEE. P. Muchiri and L. Pintelon[3] evolve OEE as tool to track

improvement and enlarge this tool with different terminologies. Such as at equipment level production equipment effectiveness (PEE) and total equipment effectiveness performance (TEEP) at factory level, overall factory effectiveness (OFE) and overall plant effectiveness (OPE).[2][3]

II. METHODOLOGY USED

It is observed that various parameters of OEE, contribute to overall OEE in a different manner has significant effect on improving the performance. In this paper, Regression modeling of the parameter is done to find the significant contributor. Based on these results, Genetic Algorithm is employed to optimize the Overall Equipment Effectiveness (OEE) of a manufacturing system.

Literature review in the field of overall equipment effectiveness shows that there is strong need of performance measurement system. It indicates to reduce down time losses, speed losses for performance improvement.

A. System Layout.

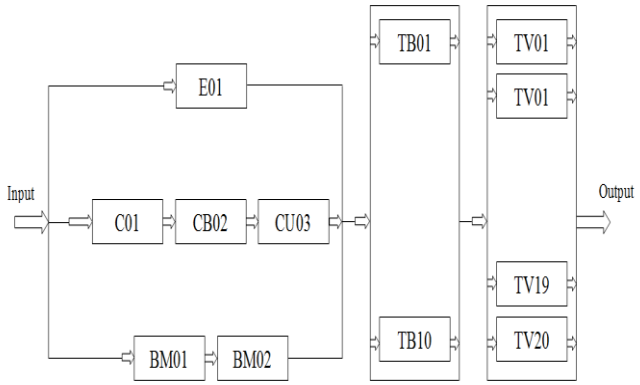

Fig. 1 Machine arrangement of tyre manufacturing process

Where

E0	- Extruder machine
C01	- Calendar machine
CB 02	- Bias cutting machine
CB 03	- UT calendaring machine
BM 01	- Bead winding machine
BM 02	- Bead wrapping machine
TB 01-10	- Tyre building machine
TV 01-20	-Tyre vulcanizing machine

III. DATA COLLECTION

Process taken into consideration: Tyre manufacturing

Size of the tyre : 3.50inch X 10inch
Weight of the tyre : 3.650 kg

Scrap (Trimmed flash) : 0.060 kg
Production/day (3.50X10) : 8000 Nos.
Production/day (All sizes) : 25000 Nos.

Input Material:

Compound	= 85%	{Rubber	- 50%
		Chemical	- 05%
		Carbon	- 35%
		Oil	- 10%}
Fabric	= 10%		
Bead wire	= 05%		

IV. CALCULATION OF OEE & OEE FACTOR

A. Availability Rate Calculations.

TABLE I
AVAILABILITY CALCULATION

Process	Machine	Total Breakdown Time (Min.)	Total Repair Time (Min.)	Number of occurrences	MTBF (Min.)	MTTR (Min.)	Availability	
Extruding	E-01	120	20	4	30	5	0.857142857	
Calendaring	C-01	120	5	2	60	2.5	0.96	0.85411665
	CB-02	90	7	2	45	3.5	0.9278	
	CU-03	140	6	3	47	2	0.9589	
Bead Making	BM-01	150	15	4	38	3.8	0.9090	0.844155844
	BM-02	130	10	3	43	3.3	0.9285	

B. Performance Rate Calculations.

In performance rate, from processing time of machines, the bottleneck machine has been found to be E-01 (Extruder machine).

Here, the actual operating time accounts per day

Actual operating time = 8*60*3 = 1440 Minutes

Where, 8 mention the number of hours per shift
60 mention the number of minutes per hour
3 mention the number of shifts

C. Quality Rate Calculations.

Quality Rate = (Output - Rejected) / Output
= (8010 – 7946) / 8010
= 0.9920
Quality Rate = 99.2%

TABLE II
AVAILABILITY CALCULATION IN PARALLEL MACHINES

Process	Machine	Processing Rate/Min. Uj	Probability that machine is working Pwj	Probability that machine is down Pdj	Failure rate/Min. λj	Equivalent Machine				
						λeq	μeq	MTBFe	MTTReq	Aeq
Tyre Builder	1	24	0.98	0.02	0.014	0.1964	74.6148	0.5111	0.0134	0.9744
	2	26	0.97	0.03	0.02					
	3	22	0.99	0.01	0.025					
	4	25	0.96	0.04	0.022					
	5	24	0.98	0.02	0.021					
	6	27	0.97	0.03	0.019					
	7	22	0.99	0.01	0.018					
	8	25	0.97	0.03	0.019					
	9	26	0.96	0.04	0.018					
	10	24	0.98	0.02	0.025					
Vulcanizing	1	14	0.98	0.02	0.028	10.4058	345.515	0.09609	0.002894	0.971
	2	16	0.97	0.03	0.026					
	3	16	0.96	0.04	0.027					
	4	14	0.98	0.02	0.029					
	5	13	0.99	0.01	0.028					
	6	16	0.98	0.02	0.026					
	7	15	0.97	0.03	0.027					
	8	16	0.98	0.02	0.026					
	9	13	0.98	0.02	0.027					
	10	12	0.97	0.03	0.028					
	11	12	0.96	0.04	0.026					
	12	14	0.96	0.04	0.025					
	13	17	0.99	0.01	0.029					
	14	16	0.98	0.02	0.028					
	15	15	0.97	0.03	0.027					
	16	12	0.96	0.04	0.024					
	17	11	0.95	0.05	0.029					
	18	16	0.97	0.03	0.023					
	19	17	0.94	0.06	0.026					
	20	14	0.97	0.03	0.027					

TABLE III
PERFORMANCE RATE CALCULATION

Process	Machine	Processing Time (Min.)	Actual Output of Machines	Performance Rate
Extruding	E-01	0.1572	8190	0.894075
Calendaring	CA-(01-03)	0.0752	8190	0.4277
Bead Making	BM-(01-02)	0.0804	8190	0.457275
Tyre Building	TB-(01-10)	0.0893	8190	0.50789375
Vulcanizing	TV-(01-20)	0.0728	8190	0.41405

D. Overall Equipment Effectiveness Calculations.

TABLE IV
OEE CALCULATION

Process	Machine	Availability	Performance	Quality	OEE
Extruding	E-01	0.85714	0.8941	0.992	0.76024
Calendaring	CA-(01-03)	0.85412	0.4277		0.36238
Bead Making	BM-(01-02)	0.84416	0.427275		0.3578
Tyre Building	TB-(01-10)	0.9744	0.507893		0.49093
Vulcanizing	TV-(01-20)	0.971	0.41405		0.39883

From above OEE calculation, performance rate of all the machines are poor except Extruding machine. That is below 95%. Above 95% is considering as a better performance of a machine.

V. Problem Identification

From above OEE calculation, performance rate of all the machines are poor except Extruding machine. That is below 95%. Above 95% is considering as a better performance of a machine.

Here we need to increase the performance rate for each machine. Genetic algorithm is used to optimize the performance rate for each machine. Solve XL an excel Add-Ins for Genetic Algorithm is used to optimize the OEE values.

The following are the expected values for each OEE factors

Availability	≥ 90 %
Performance Rate	≥ 95 %
Quality Rate	≥ 99.9 %

VI. Solution

A. Genetic Algorithm.

An algorithm is a set of instructions that is repeated to solve a problem. A genetic algorithm conceptually follows steps inspired by the biological processes of evolution. Genetic Algorithms follow the idea of SURVIVAL OF THE FITTEST- Better and better solutions evolve from previous generations until a near optimal solution is obtained. Also known as evolutionary algorithms, genetic algorithms demonstrate self-organization and adaptation similar to the way that the fittest biological organism survive and reproduce. A genetic algorithm is an iterative procedure that represents its candidate solutions as strings of genes called chromosomes. The basic schematic of Genetic Algorithm is shown in the below flow chart.

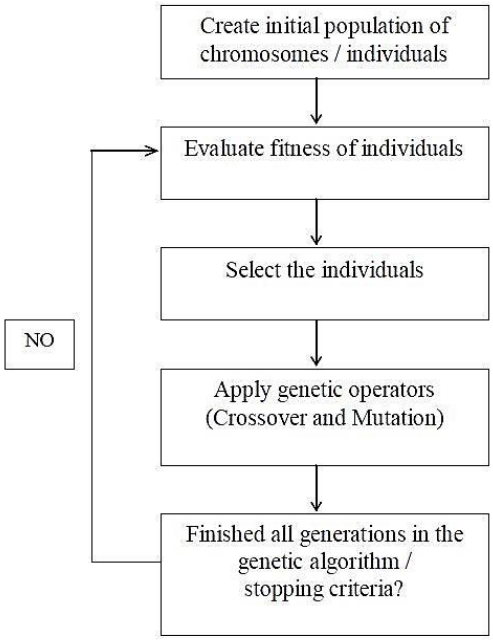

Fig. 2 Flow chart of a Genetic Algorithm

The solutions are given below for the better performance of an each machine. While optimizing the Overall Equipment Effectiveness (OEE), the calculated values are considered as a minimum value and expected values are considered as a maximum value of OEE. The below table shows the optimized values of OEE. It is done by Solve XL. To optimize the value of OEE, the Genetic Algorithm is used and optimized values are merged in an Excel sheet for each machine.

B. Optimized values of OEE by GA.

TABLE V
OPTIMIZED OEE VALUES

Process	Machine	A	PR	QR	OEE	Fitness
Calendaring	CA - (01-03)	89	87	99	76.6557	76.6557
		90	85	99	75.735	75.735
		89	85	99	74.8935	74.8935
		90	79	99	70.389	70.389
		90	79	99	70.389	70.389
		89	75	99	66.0825	66.0825
		88	75	99	65.34	65.34
		88	73	99	63.5976	63.5976
		90	69	99	61.479	61.479
		90	47	99	41.877	41.877
		90	95	99	84.645	84.645
Bead Making	BM - (01-02)	90	79	99	70.389	70.389
		90	75	99	66.825	66.825
		90	75	99	66.825	66.825
		90	75	99	66.825	66.825
		90	75	99	66.825	66.825
		90	75	99	66.825	66.825
		90	73	99	65.043	65.043
		90	73	99	65.043	65.043
		90	65	99	57.915	57.915
		90	43	99	38.313	38.313
		90	95	99	84.645	84.645
Tyre Building	TB - (01-10)	90	91	99	81.081	81.081
		90	91	99	81.081	81.081
		90	91	99	81.081	81.081
		90	91	99	81.081	81.081
		90	91	99	81.081	81.081
		90	89	99	79.299	79.299
		90	89	99	79.299	79.299
		90	89	99	79.299	79.299
		90	89	99	79.299	79.299
		90	87	99	77.517	77.517
		90	95	99	84.645	84.645
Vulcanizing	TB - (01-20)	90	59	99	52.569	52.569
		90	58	99	51.678	51.678
		90	58	99	51.678	51.678
		89	58	99	51.1038	51.1038
		89	58	99	51.1038	51.1038
		90	57	99	50.787	50.787
		90	57	99	50.787	50.787
		89	57	99	50.2227	50.2227
		89	49	99	43.1739	43.1739
		90	48	99	42.768	42.768
		90	95	99	84.645	84.645

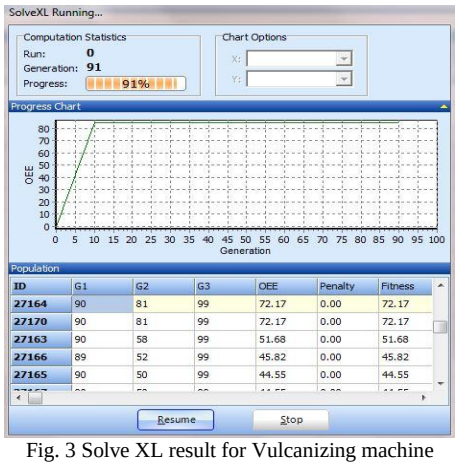

Fig. 3 Solve XL result for Vulcanizing machine

The above is results of Vulcanizing machine done by solve XL. G1, G2 and G3 are Availability rate, performance rate and quality rate.

VII. CONCLUSION

As OEE is an important performance measure for effectiveness of any equipment, careful analysis is required to know the effect of various components. A excel sheet can be used as simplest tool to measure and monitor true data collection. An attempt has been done in this study to optimize the OEE by using Genetic Algorithm (GA). This study indicates that OEE will be significantly improved if focus is given on performance rate improvement. To achieve the OEE of 84.645%, optimized values are Availability 90%, Performance Rate 95% and Quality Rate 99%. Simulated values of above scenario will add more valuable information to industry.

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