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Savings Of Total Energy Consumption By Using Sequencing Rule-Based System

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Abstract--- Implementation of energy assessment and energy performance in any manufacturing enterprises has become key factor and this key factor also helped the manufacturer to improve both their economic and environmental performance. As the energy cost also gets incurred in the product. Thus, the rising energy cost is associated with the rise in the production cost for any manufacturing facilities. The decision-makers gets encouraged with this problem and thus always wants to tackle this problem in different way. Economic growth directly depends on the energy consumption. The energy awareness has been focused for last few years due to the drastic environmental impact and increasing energy cost. It is very much difficult to identify that aspect of the energy demanding manufacturing processes which one can energetically improve. This paper proposes a mathematical model to compute total energy consumption of the operation of different parts by considering only the direct source of energy. Each part has different operation. Further, the total energy consumption is computed by sequencing rule-based system.

Keywords-, Energy consumption, rule-based system, batch type production, sequencing.

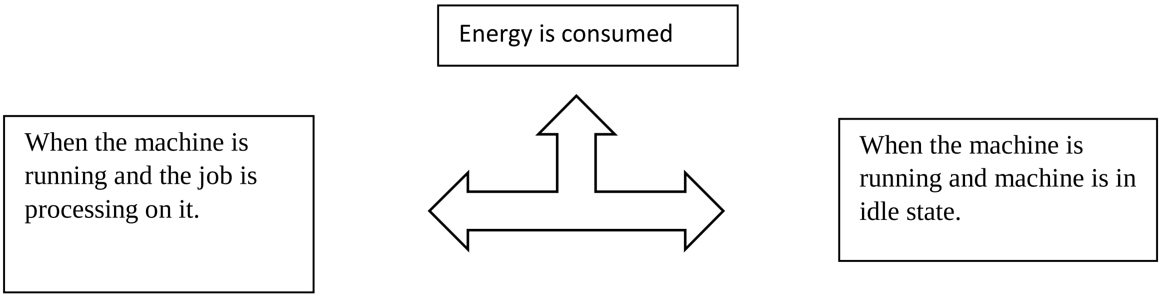
I. INTRODUCTION

Energy has been considered as an astronomically most important input for economic growth and human development. There is always a bridge between economic development and energy consumption. With the speed of globalization and quick and the pace in the development of the developing countries has resulted inan intense competition on energy resources and it also had a disastrous impact on the energy resources around the world. Due to an elevation in the energy prices, the manufacturing industry is facing more difficulties in maintaining their profit by fulfilling citizen's demand as well. Globally, 60 percent of the total energy needs are met by commercial energy resources, remaining 40 percent is comprised of non-conventional fuels and renewable resources of energy. For advanced manufacturing which basically focuses on the multi-disciplinary coordination that includes energy efficient method has attracted many researcher and industrialist. It is very much essential and thus it is necessary to upgrade the competitiveness of a manufacturing industry.

The energy consumption in machining processes can be divided into two types, firstly the energy consumed by a machine when the machine is in processing mode this type of energy is called direct Energy and secondly, the energy consumption by a machine when the machine is in idle mode and later one is called indirect form of energy.

Direct energy sources like of the operations that directly participate in the product manufacturing like machining, painting, etc. are optimized. In the direct energy sources there may be two types of energy consumption. Firstly, energy consumption when the machine is in processing mode and secondly, energy consumption of the machine with the machine is in idle mode.

Selection of the good manufacturing processes can also lead to a systematically lower energy input. There are many researchers are done on energy efficiency optimization for single machine, or on a single workpiece on a shop floor. Methods for overall energy consumption reduction in machine and plant planning and control are really missing. In India, industry sector accounts for almost 70% of the Total energy consumption whether it is processing industries thermal power plant, etc. And most of the sector covered a manufacturing sector.



II. LITERATURE REVIEW

Different selection approach was discussed and the best way of selection any dispatching rule was suggested that was analytical network process(ANP). Higher the thickness the better is the energy efficiency. For performing any task good manufacturing processes are selected which can significantly systematically minimize the energy input.[1] considered a dynamic scheduling problem and has selected dual objective function i.e. the sum of energy cost, and tardiness penalty by considering uncertainties of power consumption. The integrated and framework which consisted of augmented discrete event simulation control (ADEC) and max-throughput min-energy reactive scheduling model (MMTE) was proposed. Many researchers are made considering two or more objective like Total energy consumption, total completion time, workload balance, utilization. [2] Gave us research on minimization of energy consumption and workload balance of flexible job shop scheduling, later on, shuffled frog leaping algorithm was proposed. For verifying this model extensive experiment where carried out. [3] considered and peak power load and carbon footprint as an objective function and the model was verified using the case study. Same research was made by [4] Using the genetic simulated annealing algorithm by considering makespan and total energy consumption as their objective function and the trade-off was made between the two. Different Optimization technique was carried out and the improved algorithm was used later on, for example, improve Swarm Optimization technique was used for energy optimization in the flexible flow shop by the dynamically scheduled method, this was proposed by [5]. In manufacturing industries designer as well as manufacturer both play a vital role in the energy efficiency designer need to consider the stages of manufacturing stage in the Ecodesign effort to make it energy efficient this was observed by [6]. Energy consumption can be direct as well as indirect, this was noticed by [7] And the total embodied product energy is a sum of direct and indirect energy for manufacturing industries.

Minimizing the average energy consumption and maintenance of the finished job was the two-objective function which was given by [8]. The problem was formulated based on a single machine scheduling with the sequence-dependent setup times as the scheduling problem is dynamic in nature does to cope up this problem to energy-efficient dispatching rule-based algorithm were considered. Improved level of the mathematical algorithm we made later on efficient gene expression programming algorithm also called as EGEP was given by [9], the author further proposed the On/off decision-making technique for flexible job shop with machine selection and job Sequencing for optimizing the lower bound of energy. The experimental result shows that often decision efficiently reduce the total energy consumption and the discovered rules were calculated by GAMS /CPLEX in a small problem. multiobjective genetic scheduling method which efficiently reduces energy consumption was given by [10]. They considered Total energy consumption and total better tardiness as their to the objective function. A case study of 4 x 4 job shop was presented verify the effectiveness of the algorithm used, the proposed algorithm was a Genetic algorithm. Another multi-objective genetic algorithm was incorporated by [11] they considered job shop scheduling problem based on machine scaling. They also used to objective functions as their basic parameters they were total better tonight and Total energy consumption. To verify the effectiveness of the proposed solution comprehensive computational experiment we are carried out. An extensive case study of 10 x10 jobs shop was taken by [12] For this case, a multi-objective scheduling method was developed and minimizing the energy consumption was only their objective function.

III. PROBLEM FORMULATION

For establishing the corresponding mathematical model, the following assumption are made-

1. ***Each machine can process at most one operation at a time,***
2. ***No jobs may be processed on more than one machine at a time,***
3. ***Operations cannot be interrupted,***
4. ***Set-up times and remove times are treated as auxiliary time and is included in processing times***
5. ***Jobs are independent and have equal priority.***
6. ***After a job is processed on a machine, it is transported to the next machine immediately and the mean transportation time is fixed.***
7. ***Determine the value of total energy energy consumption***

E_{tot}can be represented as →

$$E_{t} = \sum E_z = \sum (E\ _z + E\ _z)$$

EM_z→it is the energy consumption by machine $m_z$during processing/machining.

EI_z→ It is the energy consumption by the machine during idle time.

To establish the corresponding mathematical model, the consideration of n jobs and m machines is taken.

- There are 5 different parts taken to be manufactured.
- Each parts has different number of operations.
- Each operation takes different processing(p_t)
- Processing time differs according to the machine features like starting power(p^{st})

These are the 5 jobs which are to be machined-

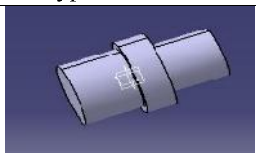
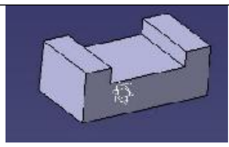
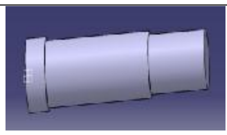
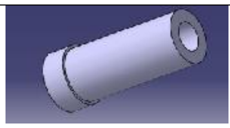
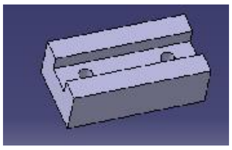
Job	Operations	Job type
A	1. Step turning 1 2. Step turning 2	
B	1. Face milling 2. pocketing	
C	1. Rough turning 2. Step turning 1 3. Step turning 2	
D	1. Rough turning 2. Step turning 3. Drilling	
E	1. Face milling 2. Milling(pocketing) 3. Drilling	

TABLE I. Total energy consumption and total processing time conceded

Part no	Total processing time(sec)	Machining time(sec)	Auxiliary time(sec)	$E\ _z$(J)	EI_z(J)	E_{tot}(J)
A	204.1	131.86	72.24	2.302×10^6	794.64×10^3	3.09×10^6
B	250.68	200.54	50.14	11.141×10^6	18.07×10^3	11.16×10^6
C	386.95	286.75	100.2	4.369×10^6	569.16×10^3	4.94×10^6
D	538.1	436.9	101.2	6.09×10^6	1.11×10^6	7.2×10^6
E	305.36	250.09	55.27	2.43×10^6	20.01×10^3	2.45×10^6
	Total energy consumption for corresponding 5 parts $\sum(\boldsymbol{E_{t}}\ ) = \mathbf{2\ .8\ \times 1\ ^6}\boldsymbol{J}$					

Total energy consumption for corresponding 5 parts, is $\sum(E_{t}\ ) = 28.84 \times 10^6$J and this can be optimized using rule-based system.Taking this data as standard the objective will be to optimize the total processing time and total energy consumption using different approaches. Different approaches may include rule-based system.

Table II. Summary of data using sequencing rule approach

Sl no	Sequencing rules	Part sequence	Completion time	Total idle time	EM_Z	EI_Z	E_{tot}
1	FIFO	A-B-C-D-E	1434.51 sec	1183.83 sec	8.15×10^6J	3.67×10^6J	11.82×10^6J
2	SPT	A-B-E-C-D	1129.15 sec	573.11 sec	6.414×10^6J	206.61×10^3J	6.62×10^6J
3	EDD	C-B-A-E-D	1129.15 sec	666.27 sec	6.414×10^6J	240.19×10^3J	6.65×10^6J
4	CR	C-B-D-E-A	1230.41 sec	876.89 sec	6.99×10^6J	1.39×10^6J	8.38×10^6J
5	LS	C-B-A-D-E	1434.51 sec	1183.83 sec	8.15×10^6J	3.67×10^6J	11.82×10^6J

IV. RESULT & DISCUSSION

The total energy consumption(TEC) gets optimized after using different sequencing rule. Previously, TEC was 28.84×10^6J which is much more than the TEC calculated using sequencing rule approach. And by SPT calculated TEC is 6.62×10^6 J.

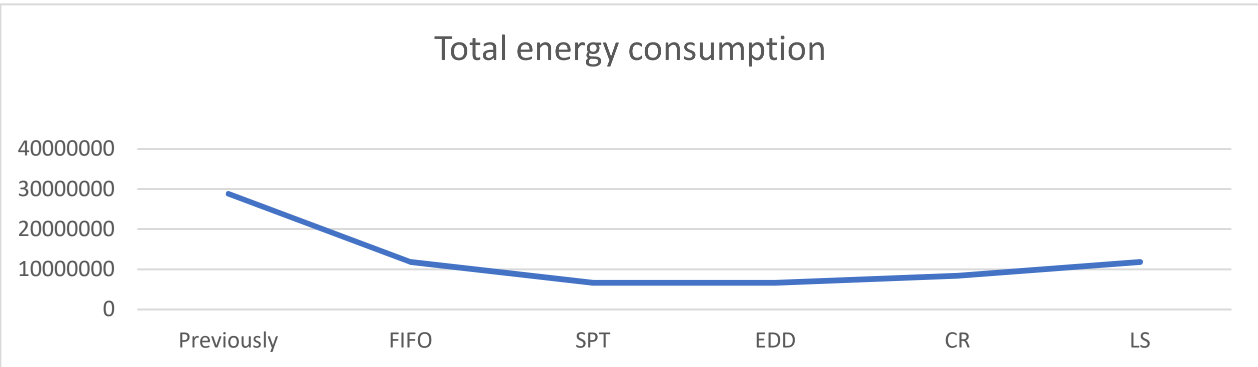


Fig 1- Graph showing TEC using sequencing rule

Fig 1 shows TEC for SPT sequencing rule is minimum, idle time also gets optimized using SPT sequencing rule which is shown by fig 2

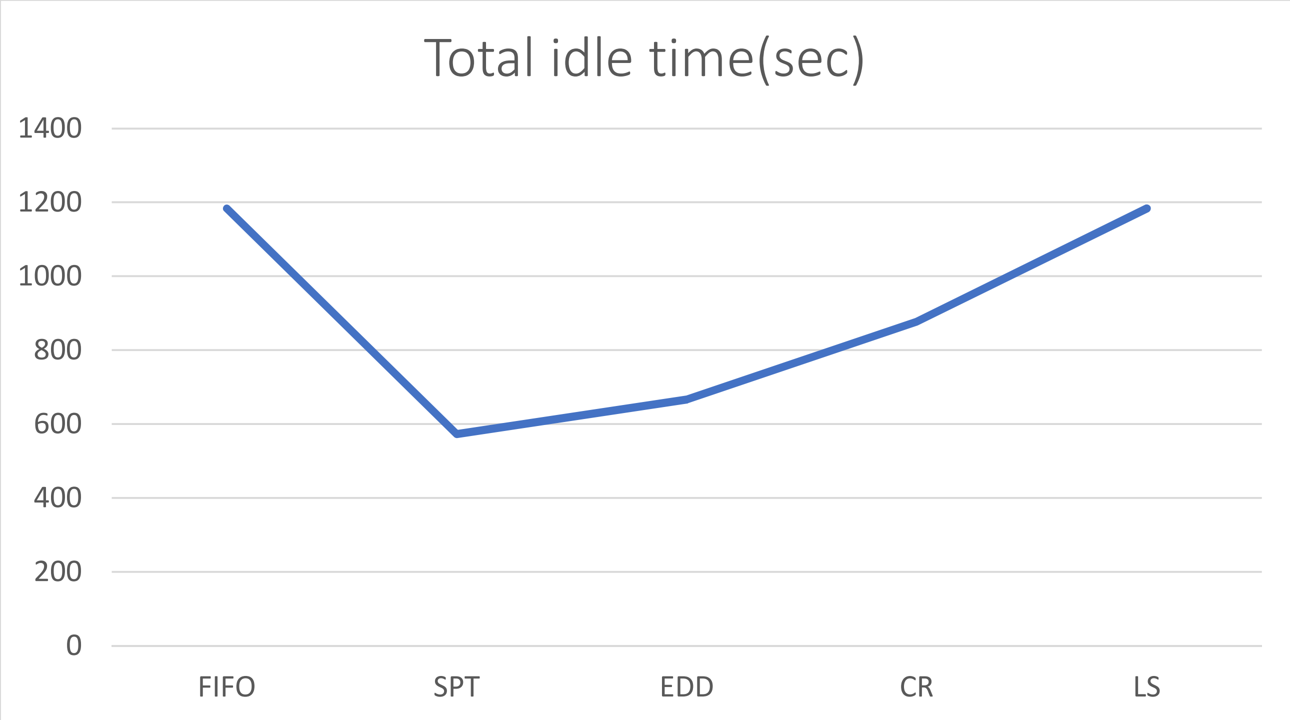


Fig 2- Graph showing Idle time also gets optimized in SPT(Shortest Processing time)

V. CONCLUSION

The Total energy consumption process is a complex, so it is necessary analyzed by more simplified and practical method in machining system. Firstly, the energy consumption of 5 different parts is analyzed and further by using different approach i.e. Sequencing rule Optimization.

Further research could look into focusing on optimizing energy consumption by considering various machining parameters. Future scope of work may include factory level optimization of energy consumption by considering uncertainties and indirect source of energy.

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