Computer Aided Modelling of the Impact of Irregular Power Supply on Machining Foundry Products

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Abstract- Computer aided models, such as Dynamic, Quadratic and Integer programming, have been developed to solve production challenges relating to manpower, inventory and maintenance assuming constant and regular power supply, which is a hard condition to meet in a developing country like Nigeria where power supply is irregular. This paper developed a Computer aided model to address this challenge using Integer programming, by considering profit as a function of cost and revenue of a machined foundry product. Software was developed to serve as database and the same time analysed complex mixed model system where parallel workstation, shift or batch production is allowed. The software was designed to have graphic user interface (GUI), which enable the user to input data like values of product code (identification number for each product), capacity of machine, established unit cost of production, production cycle time, selling cost and the unit cost of production to determine the impact when electricity power from national grid is used, as opposed to fuelling a diesel-engine generator, for machining foundry products. Costs and production capacity data were collected from Ruthade Foundry Engineering Services, Akure, Ondo State, to validate the model. The results revealed that output per unit time is higher when power from national grid is holistically utilized than when power from generator was used for machining foundry product. The results serve as genuine guiding tool for foundry operators in selecting a particular course of action on electricity utilization during production and enhance sustainability of production industry.

Keywords- Constraint, cycle time, integer programming, Microsoft Visual Basic, model, optimal number

1 INTRODUCTION

The unreliable electricity supply and high tariffs has a negative effect on quantity and quality of products from small scale industries, and leads to low profitability. Owa et al. (2020) reported that many industries in developing country are not functioning properly and some of them have closed down because of their inability to meet minimum operation standards to support their sustainability. Those operating on standby electric power generating plant are running at loss, due to additional cost of fuel (diesel) to power the generator; and this comes with noise pollution and Bolaji et al., (2018) reported that prolong exposure to sound/noise pressure level in excess of the threshold of pain can cause physical damage, potentially leading to hearing impairment.

Adekunle et al. (2016) opined that the influence of globalization on business forced most industries to become innovative and implementing newer approaches to maintain market leadership and growth with the anticipated profitability. Generating electric power from sources of energy is known as electricity generation (Ipadeola et al., 2014). Electromechanical generators are used to generate electricity at a power station, driven by heat engines usually fuelled by nuclear fission/chemical combustion; it can also be fuelled by kinetic energy from wind, vapour and flowing water (Angeli, 2010). Literature affirmed that some researchers developed models in various sector of human activities. For example, Felix et al., (2013) researched on farm activities and developed a linear programming model that reflects choices of selection that is feasible given a set of fixed form constraints and maximize income while achieving other goals such as food security. The result from the model is more superior than that obtained by traditional methods.

Jaber and Ajib, (2011) developed linear model to conserve energy in buildings and Das et al., (2017) developed electrical energy conservation model using linear programming which aimed on optimising profit margin for production industry, the work reported that best way of utilising resources is an important factor to achieve maximum profit margin in every organization. This was corroborated by Ibitoye et al. (2015) in a research that examined the impact of linear programming in entrepreneur decision making process as an optimization technique for maximizing profits with the available resources. The result shows that there should be discontinuity of two products of the company used as case study and concentrate on one in order to maximize profit.

Oladejo et al. (2019a) solved the challenge of classroom space allocation by developing a linear programming model to examined optimization principle and its application in solving the problem of over-allocation and under-allocation of the classroom space in Landmark University, and Oladejo et al., (2019b) determined the optimal profit of Landmark University bakery product, using linear programming model. The work shows that trial-and-error method are used by most enterprises, which make it difficult in assigning rare resources in a way that guarantee profit maximization and/ or minimization. Ezellora and Obiafudo, (2015) showed that excess waste that incurs in production cost of developing country’s production industries can be mitigated; through research on the optimal production cost of raw materials to its production output using linear programming model, while Adebiyi et al. (2014) researched on linear optimization for achieving product-mix optimization in terms of the product identification using a paint industry in developing economy (Nigeria) as a case study. The result showed that the company is making profit on only two out of five products produced. As computers became more inexpensive, the application areas have progressively increased. Computer software is used in many businesses.
and organizations around the world (Adejuyigbe, 2002; Andersen, 1997).

Recently, some researchers developed computer aided models to solve some industrial challenges. Olorunfemi et al. (2018) researched on management of grain silos in Nigeria and developed a computer aided model to minimize post-harvest losses at storage level in Nigeria, the work reported that application of the software would save time by 66% (two-thirds of manual operation) and it is more accurate and energy saving. Also, Adekunle and Adejuyigbe (2012), researched on gas welding process and developed computer aided model using Microsoft Visual Basic 6.0 for mild steel welding, they reported that robotic welding is uniformly, error free and faster. Consequently, a need arises for development of computer software to aid in modelling the effect of irregular power supply on the profits of machining foundry products in developing economy.

2 METHODOLOGY

The Integer programming model used for this work was developed by Owa et al., (2020); based on the relationship between revenue, cost and profit of any product. The objective function $Z$ is stated in equation 1.

$$z = \sum_{i=1}^{m} \sum_{k=1}^{n} (t_{ik} \cdot c_{ik} \cdot p_{ik} - t_{ik} \cdot c_{ik} \cdot p_{ik}) \quad (1)$$

Where $P_{ik}$, $P_{ik} \in P_{ik}$, $t_{ik}$ = Product cycle time for i number of product and k number of shifts of production

$C_{ik}$ = Established unit cost of production output (Naira) for i number of product and k number of shifts of production.

$P_{ik}$ = Production capacity of machinery (units) per unit time (hr) for i number of product and k number of shifts of production.

$C_{ik}$ = Selling price per unit item produced (Naira) for i number of product and k number of shifts of production.

Equation (1) evaluates the profit obtained when batch, shift, or parallel production scheduling system (k) is utilized for the production of product(s) (i). Formulation of constraint equations were based on four conditions, as stated in equations (2) – (6):

(i) Throughout production cycle, it was presumed that public electricity was utilized.

$$t_{ik} \cdot P_{ic} \leq t_{ik} \cdot P_{ia} \quad (2)$$

(ii) throughout the production cycle, alternate electricity was used

$$t_{ik} \cdot P_{ia} \leq t_{ik} \cdot P_{ia} \quad (3)$$

Equation (3) is the corresponding equation for alternative (generator) electricity.

(iii) production started with public electricity and ended with (generator) alternate electricity.

$$t_{ik} \cdot P_{ic} + t_{ik} \cdot P_{ia} \leq t_{ik} \cdot P_{ia} \quad (4)$$

(iv) production started with alternate (generator) electricity and ended with public electricity.

$$t_{ik} \cdot P_{ia} + t_{ik} \cdot P_{ia} \leq t_{ik} \cdot P_{ia} \quad (5)$$

Non negativity conditions of Integer programming.

$P_{ia}, P_{ia} \geq 0$ and Integers

2.1 COMPUTER SOFTWARE DEVELOPMENT

Computer program was developed to enhance the model to accommodate large data of a mixed – model system where parallel workstation, shift or batch production is allowed. The software was developed in Microsoft Visual Basic 6.0 programming language, because of its user’s friendliness.

2.2 ALGORITHM

The program has the following modules: -

(i) Main module.

(ii) Production output ($P_{i}$) using public electricity and its profit module.

(iii) Production output ($P_{s}$) using alternate electricity and its profit module.

(iv) Production output during transition from public electricity to alternative electricity ($P_{i}$ to $P_{s}$) and vice versa, with its profit module.

(v) Cumulative profit module.

The software development flow chart is shown in Fig. 1. The algorithm is as follows:

(i) Start

(ii) Get unit costs of production using public electricity ($C_{i}$).

(iii) Get time of utilization of electricity ($t_{i}$).

(iv) Get production cycle time (hr.) per day ($t_{g}$).

(v) Get established unit cost of production output ($C_{g}$).

(vi) Get production capacity of the machinery per unit hr ($P_{g}$).

(vii) Get the selling price per unit item ($C_{s}$).

(viii) If ($C_{g} \& t_{g}$) > 0 Call production using public electricity

(ix) If ($C_{g} \& t_{g}$) > 0 Call production using alternate electricity (Generator)

(x) If ($C_{s} \& t_{s} \& C_{g} \& t_{g}$) > 0 Call production using transition

(xi) If not end of file Go to start

(xii) $Z_{i} = Z_{t} + Z_{s} + Z_{gs}$

(xiii) Else cumulative profit = cumulative profit + $Z_{i}$

(xiv) Stop.

Production using public electricity:

$$p_{i} = \frac{t_{i} \cdot c_{i}}{t_{i} \cdot g_{i}} \quad (8)$$

$$P_{i} = \text{ABS} (P_{i}) \quad (9)$$

$$Y = t_{i} \cdot c_{i} - t_{i} \cdot p_{i} \quad (10)$$

$$Z_{i} = Z_{s} + Y \quad (11)$$

Production using alternate electricity (Generator)

$$p_{g} = \frac{t_{g} \cdot c_{g}}{t_{g} \cdot g_{i}} \quad (12)$$

$$P_{g} = \text{ABS} (P_{g}) \quad (13)$$

$$Y = t_{g} \cdot c_{g} - t_{g} \cdot p_{g} \quad (14)$$

Production by transition:

$$p_{gs} = \frac{t_{g} \cdot c_{gs} - t_{g} \cdot p_{gs}}{2} \quad (15)$$

$$Y = t_{g} \cdot c_{gs} - t_{g} \cdot p_{gs} \quad (16)$$

$$Z_{gs} = Z_{s} + Y \quad (17)$$
The various costs involved in machining Foundry products were obtained from Ruthade Foundry Engineering services, Akure, Ondo State, (stated below) was used to validate the model.

Established unit cost of production output = ₦23
Unit cost of production using public electricity = ₦20
Unit cost of production using Generator = ₦30
Selling price per unit item produced = ₦30
Production capacity of machinery (units) / unit time (hour) = 4

3 RESULTS AND DISCUSSION
The following shows the sequence of calculating the profit of machining the foundry products obtained from this computer aided model. Figure 2 shows the welcome page; it shows the start button at the bottom right corner, clicking it will display the login menu.

Figure 3 shows the login menu; this is the interface where the user can input user name, password and click OK button at the bottom left corner, to proceed to Data entry form interface, provided the information supplied are correct and Cancel button at the bottom left corner, if otherwise.

Figure 4 shows the data entry form; this is the interface where the user can input values of product code (identification number for each product), capacity of machine, established unit cost of production, production cycle time, selling cost and the unit cost of production when electricity power from national grid or generator are use and save button is clicked to proceed. However other buttons like edit for editing entries, new for creating new entry, delete for deleting wrong entry and exit, are present.
Figure 5 shows transaction form, this is the next interface after data entry form. Process data button is clicked to proceed to the next interface. Figure 6 shows the process form; this is the interface to process the entered entries, by clicking on the button process.

Figure 7 shows the output of the processed data; it displays the various profit margins that can be made from each product and the quantity that can be produced to maximize profit. Also, the overall profit that can be made, if more than one product is to be produced. From Fig. 7, considering 4 hrs production cycle; it was observed that when power from National grid was holistically utilized for machining foundry parts, the accrued profit (Z) is ₦112, as shown by product with code 001. Even with gradual increase in the cost/tariff of public electricity (Ce) from ₦20 to ₦23, the profit remains the same, as shown by product with codes 002-004.

A decline of production output/hr, from 4 units to 3 units was observed, when there was a shift from national grid’s power to generator which resulted to 25 % reduction in accrued profit (₦ 84), as shown by product with code 005. This was attributed to idle time of the machine, during change over, thus production output/hr was affected which lead to profit reduction; since non integer number can’t be accommodated. It was also observed that, utilization of power from generator throughout the machining operation, reduced the accrued profit to ₦84, because the off time has reduced the output/hr to 3 units and off time effects on the accrued profit, as shown by product with code 006. Gradual increase of cost of power from generator (Ce) from ₦26 to ₦30, still keep the profit at ₦84, as shown by products with codes 007 – 010.

Considering 6 hours cycle time, it was observed that ₦168 was recorded as profit (code 011), when power from national grid was utilized; profit of ₦126 (code 015) and holistic utilization of power from generator; with gradual increase of cost of power from generator (Ce) from ₦27 - ₦30, recorded ₦126 as profit (codes 016 – 020). The same trend was observed when 8 hours cycle time was considered.

Generally, it can be deduced that the higher the cycle time, the higher the accrued profit, irrespective of the source of the power used. However, the utilization of power from national grid boost the profit the more, thereby improving the chance of hedging against competition. Profitability increased to about 100%, when full time of 8 hours was used for production instead of lesser hours, which is common in developing country; where off time is created for personal activities such as breakfast, lunch and visitor’s attention. It was shown that cycle time has a significant effect on the productivity and profit accruable, as the cycle time increases quantity of product produced increases, thereby increases the accrued profit.

Figure 8 shows the report dialogue box, where the result can be accepted by clicking ok button, reject it by clicking cancel button and the printer can be set up to choose the type of printer to be used for printing. Clicking printer set up button at the bottom left corner to proceed to print interface. Figure 9 shows printer page, this is the interface where the user can select the printer to be used and print the output result.
CONCLUSION
The bulk of power requirement in foundry product production are utilized in machining operation. Computer software was developed using Microsoft visual 6.0 which was successfully used to compute the profits accrued from machining more than one foundry products in a large data of a mixed-model system where parallel workstation, shift or batch production is allowed. Reference to the results, the following conclusions were drawn:

- Output per unit time is higher using power from national grid than when power from generator is utilized for machining operation.
- 33% improvement in profitability was achieved with utilization of power from national grid for the full period of production cycles.
- Production cycle time had positive effect on the overall output of the products, thereby increasing the total profit expected.

It is recommended that adoption of the computer aided model will curtail the colossal loss recorded by production industries and help the foundry operators to make decisions faster and easier.

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