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Combinatorial Green Optimization of Individual Quick Freezer for Energy Savings through Linear Programming and Decision Theory of Shrimp Processing Industry : A Mathematical Approach

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ABSTRACT

The nature is becoming more and more a catholic marketplace and this environment is forcing companies to take almost everything into consideration at the same time as well as low cost with high quality production. Increase flexibility is needed to remain competitive and respond to rapidly changing markets. An effective machine optimization process is very important to the success of any organization. Machine selection and optimization represents one of the most important decisions in a company to remain competitive, in this context, we try to solve the machine optimization for energy savings and machine selection for better efficiency and production. Machining optimization and selection represents one of the most important functions to be performed by the production department. The machine optimization is a multicriterion problem which includes both qualitative and quantitative factors (criteria). In order to select the best IQF (individual quick freezer), it is necessary to make a tradeoff between these tangible and intangible factors some of which may conflict. This report deals with machine-job allocation through linier programming model and machine selection through decision theory.

Keywords : Assignment Method, MCDM, Individual Quick Freezer, Energy Savings, Material Selection, Sensitivity Analysis, Entropy, SAW

I. INTRODUCTION

In shrimp food processing industry, IQF is an important machine for production. Various size of shrimp with various glazing process done in production section. Optimizations of machining process and strategic sourcing have been one of the fastest growing areas of mathematics, particularly over the last decade. In sea food processing industry, the various types of jobs done by IQF. Machine allocation for particular job and machine selection for better production is an important task of this type of industry. Energy savings is necessary for the minimization of production cost. Not only the energy saving, for machining optimization, we will reduced the machining cost and other factors i.e. water consumption, engine oil consumption, diesel consumption etc. For machining optimization, we used Hungarian assignment problem machine-job allocation and proper machine selection by MCDM method for minimize the factory cost. An area of a current research focuses on the optimization of IQF for better machining process.

1.1 Assignment problem is a special type of linear programming model which deals with the allocation of the various resources to the various activities on one to one basis. It does it in such a way that the cost or time involved in the process is minimum and profit or sale is maximum. This paper focuses on three

IQF and four type of job that solve by Hungarian assignment.

1.2 The second phase of this paper included machine selection by MCDM method. Multi criteria decision making (MCDM) is the process of selecting the best alternative from a set of feasible alternatives considering multiple conflicting criteria. In precise terms criteria are considered to be 'strictly' conflicting if the increase in satisfaction of one result in a decrease in satisfaction of the other. An MCDM process always contains at least two alternatives and two conflicting criteria (Bhattacharya et al., 2003). MCDM are divided two broad categories: Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM).

Several useful tools for solving of MCDM problems are

- Simple Additive Weighting method (SAW)
- Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
- Multi Objective Optimization Ratio Analysis (MOORA)
- Analytical Hierarchy Method (AHP)
- Analytical Network Method ANP etc.

In this research, we used SAW method by MATLAB.

1.3 Entropy was originally a thermodynamic concept, first introduced into information theory by Shannon (see Shannon, 1948 [21]). It has been widely used in the engineering, socioeconomic and other fields. According to the basic principles of information theory, information is a measure of system's ordered degree, and the entropy is a measure of system's disorder degree. Using this theory we got unbiased result.

1.4 . Sensitivity analysis in actual situation decision-making is rather dynamic process not static. It varies in the continuous changing environment. In reality the value of decision-making attitude depends upon decision maker's personal choice. Under such circumstances decision making attitude behaves as a variable that may yield different results. Keeping it in mind, the proposed model for the selection of magnesium alloy has been enhanced by sensitivity analysis [Fig:2] to provide a readymade solution of the current problem under variable decision-making attitude. The governing equation of the material measure (AM) is given by

$$AMi = \alpha(OFMi - SFMi) + SFMi \quad \ldots\ldots\ldots\ldots\ldots (11)$$

Where, i = 1, 2…m.

OFMi = Objective factor measure for the alternative i

SFMi = Subjective factor measure for the alternative i

α = Objective factor decision weight

II. PROBLEM FORMULATION

According to one day data of production report, total raw material is 17,121kg.There are four type of shrimp glazing process is carried out by dipping or spraying the product with chill water (which is most common, but also salt-sugar solutions are used) to apply a thin layer of ice, done by three IQF i.e. 10% glazing on 13,387kg,20% glazing on 784 kg,25% glazing on 668 kg and 35% glazing on 2282 kg. The machine capacity (Table:1) ,the proper machine-job allocation and machine selection problem matrix is formulated below (Table:2). IQF-1 is having double glazer and double re-freezer while IQF-2 and IQF-3 are having single glazer and single re-freezer.

Machine	Actual Capacity	Working Capacity
IQF - 1	1000kg/Hour	800kg/Hour
IQF - 2	750kg/Hour	600kg/Hour
IQF - 3	1000kg/Hour	800kg/Hour

Table : 1

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)
Individual Quick Freezer(IQF)-1	16.7 Hours	0.98 Hours	0.84 Hours	5.7 Hours
Individual Quick Freezer(IQF)-2	22.3 Hours	2.6 Hours	2.2 Hours	11.4 Hours
Individual Quick Freezer(IQF)-3	16.7 Hours	1.96 Hours	1.67 Hours	8.5 Hours

Table: 2

III. Result and Discussion

4.1. Machine optimization by assignment method

Problem matrix

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)
Individual Quick Freezer(IQF)-1	16.7 Hours	0.98 Hours	0.84 Hours	5.7 Hours
Individual Quick Freezer(IQF)-2	22.3 Hours	2.6 Hours	2.2 Hours	11.4 Hours
Individual Quick Freezer(IQF)-3	16.7 Hours	1.96 Hours	1.67 Hours	8.5 Hours

Table: 3

Step -1 (The following matrix is non square matrix. For calculation it will must be the square matrix. So dummy row is used for this problem)

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)
Individual Quick Freezer(IQF)-1	16.7 Hours	0.98 Hours	0.84 Hours	5.7 Hours
Individual Quick Freezer(IQF)-2	22.3 Hours	2.6 Hours	2.2 Hours	11.4 Hours
Individual Quick Freezer(IQF)-3	16.7 Hours	1.96 Hours	1.67 Hours	8.5 Hours
Dummy	0 Hours	0 Hours	0 Hours	0 Hours

Table: 4

Step -2 (row and column reduction)

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)

Individual Quick Freezer(IQF)-1	15.86 Hours	0.14 Hours	0 Hours	4.86 Hours
Individual Quick Freezer(IQF)-2	20.1 Hours	0.40 Hours	0 Hours	9.20 Hours
Individual Quick Freezer(IQF)-3	15.03 Hours	0.29 Hours	0 Hours	6.83 Hours
Dummy	0 Hours	0 Hours	0 Hours	0 Hours

Table: 5

Step -3 (All zeros are covered by three line i.e. column 2 & 3 and row 4. After that the calculation is following below)

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)
Individual Quick Freezer(IQF)-1	15.72 Hours	0 Hours	0 Hours	4.72 Hours
Individual Quick Freezer(IQF)-2	19.96 Hours	0.26 Hours	0 Hours	9.06 Hours
Individual Quick Freezer(IQF)-3	14.89 Hours	0.15 Hours	0 Hours	6.69 Hours
Dummy	0 Hours	0 Hours	0.14 Hours	0 Hours

Table: 6

Step -4 (All zeros are covered by three line i.e. column 3 and row one and four. After that the calculation is following below)

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)
Individual Quick Freezer(IQF)-1	11 Hours	0 Hours	0 Hours	0 Hours
Individual Quick Freezer(IQF)-2	15.24 Hours	0.26 Hours	0 Hours	4.34 Hours
Individual Quick Freezer(IQF)-3	10.17 Hours	0.15 Hours	0 Hours	1.97 Hours
Dummy	0 Hours	4.72 Hours	4.86 Hours	0 Hours

Table: 7

Step -5 (All zeros are covered by four line i.e. column 2&3 and row one and four. After that the calculation is following below)

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)
Individual Quick Freezer(IQF)-1	11 Hours	0 Hours	0.15 Hours	0 Hours
Individual Quick Freezer(IQF)-2	15.09 Hours	0.11 Hours	0 Hours	4.19 Hours
Individual Quick Freezer(IQF)-3	10.02 Hours	0 Hours	0 Hours	1.82 Hours
Dummy	0 Hours	4.72 Hours	5.01 Hours	0 Hours

Table: 8

Step -6 (Machine-job allocation done by final matrix. After that the calculation is following below)

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)
Individual Quick Freezer(IQF)-1	11 Hours	1.82 Hours	1.97 Hours	0 Hours
Individual Quick Freezer(IQF)-2	13.27 Hours	0.11 Hours	0 Hours	2.37 Hours
Individual Quick Freezer(IQF)-3	8.20 Hours	0 Hours	0 Hours	0 Hours
Dummy	0 Hours	6.54 Hours	6.83 Hours	0 Hours

Table: 9

Machine – Job allocation:

Machine	**Jobs**
Individual Quick Freezer(IQF)-1	Job -4
Individual Quick Freezer(IQF)-2	Job -3
Individual Quick Freezer(IQF)-3	Job -2
Dummy	Job -1

Table: 10

Step -7 : Calculating the minimum possible time of three jobs.

Jobs	**Time**
Job-2	1.96 Hours
Job-3	2.20 Hours
Job-4	5.70 Hours

Table : 11

Total minimum possible time = 9.86 hours

There are four jobs but three machines, so rest of one job is allocated after the machine selection by MCDM.

4.2. Machine selection by MCDM method

JOBS / MACHINES	10% glaze (job-1)	20% glaze (job-2)	25% glaze (job-3)	35% glaze (job-4)	Machine Capacity(kg/hour)
Individual Quick Freezer(IQF)-1	16.7 Hours	0.98 Hours	0.84 Hours	5.7 Hours	800
Individual Quick Freezer(IQF)-2	22.3 Hours	2.6 Hours	2.2 Hours	11.4 Hours	600
Individual Quick Freezer(IQF)-3	16.7 Hours	1.96 Hours	1.67 Hours	8.5 Hours	800

Table: 12

The weighted values got from entropy method, values are:

0.1857	0.2233	0.2203	0.2068	0.1638

Table: 13

STEP1: Determination of normalized decision matrix

0.7489	1.0000	1.0000	1.0000	0.7500
1.0000	0.3769	0.3818	0.5000	1.0000
0.7489	0.5000	0.5030	0.6706	0.7500

Table: 14

STEP 2: Determination of weighted normalized decision matrix

0.1391	0.2233	0.2203	0.2068	0.1229
0.1857	0.0842	0.0841	0.1034	0.1638
0.1391	0.1117	0.1108	0.1387	0.1229

Table: 15

STEP 3: Computation of composite score s......by sum of all weighted normalized rows The values of (s) are:

0.9124	0.6213	0.6231

Table: 16

STEP 4:

Arranging the final value (s) in descending order :--------->>> IQF-1 >IQF-3 >IQF-2 ....in SAW method

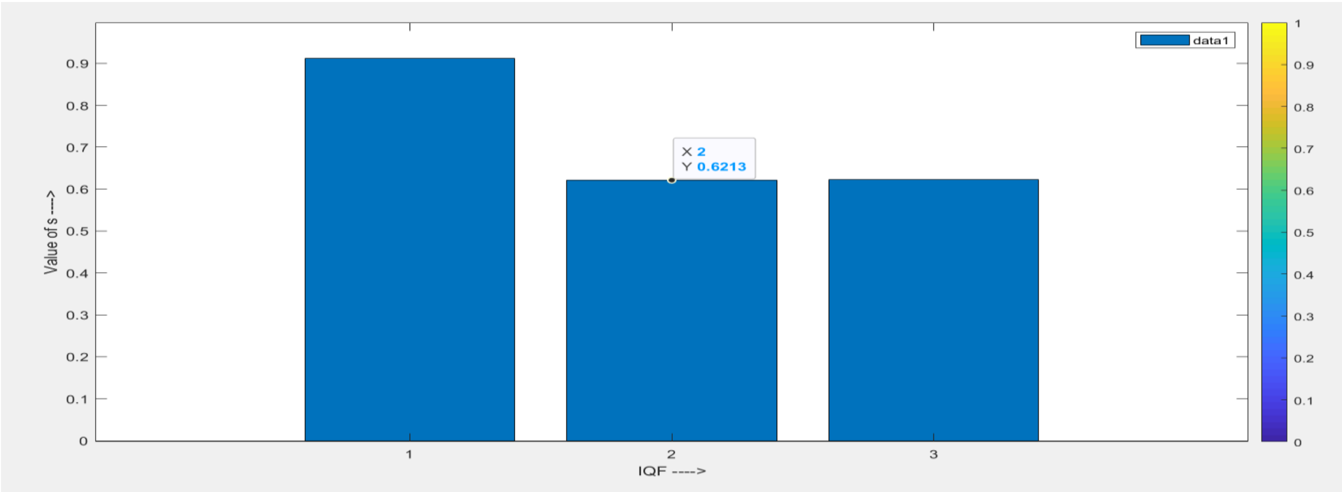

Fig: 01

In machine selection, the MCDM method shows that (Fig: 01) IQF -1 is the best machine among the following criteria. So, after job-4 is done, the IQF-1 involved with job-1.

For 4 jobs, the three IQF take total time is = 9.86 + 16.7 = 26.56 Hours

In actual scenario, that day the three IQF total running time is = 46 hours

Actual Consumption	**Theoretical Consumption**
46 Hours	26.56 Hours

Above the following data, per day energy optimization is--------

46 Hours - 26.56 Hours = 19.44 Hours

Electrical load capacity of three machines are

Machines	Electrical Load Capacity
IQF-1	402 KWh
IQF-2	330 KWh
IQF-3	330 KWh

Table : 17

According to machine load capacity, the power consumption given below (actual running) ---------

Machine	Actual running hours	Actual power consumption
IQF-1	21 Hours	8442 KWh
IQF-2	12 Hours	3960 KWh
IQF-3	13 Hours	4290 KWh

Table : 18

Here, Total actual running hours = 46 Hours

And actual power consumption = 16,692 KWh

According to machine load capacity, the power consumption given below (theoretical running)

Machine	Theoretical running hours	Theoretical power consumption
IQF-1	22.4 Hours	9004.80 KWh
IQF-2	2.2 Hours	726 KWh
IQF-3	1.96 Hours	646.80 KWh

Table : 19

Here, Total theoretical running hours = 26.56 Hours

And theoretical power consumption = 10,377.60 KWh

Total savings = 16,692 - 10,377.60 = 6314.40 KWh

Total savings in Indian rupees = INR 63144

Where electrical unit charges is = INR 10 /KWh

IV. Discussion

In this paper, the above calculation shows that after machine optimization the energy was saved and the proper machine selection provide the best machine among the criteria for better productivity.

Through power savings we also saved diesel in case of using power from generator instead of grid power, saved water, reduced man power consumption as well as improvement of machining service life. Schedule maintenance of machine is easy for this optimization. This is one type of green based power optimization that used first time in KNC. AGRO LIMITED.

V. Conclusion

From a global outlook, considering the overutilization of the earth's natural resources, energy optimization is a promising area to be explored. As there is more and more focus on the environmental impacts from seafood processing industries, it is of increasing importance to ensure that technologies and practices implemented has to achieve a high level of environmental performance along with higher production efficiency.

An IQF system is defined as is an expressive term for freezing methods used in the food processing industry. The food is in individual pieces, and is frozen quickly.

Products commonly frozen with IQF technologies are typically smaller pieces of food, and can include berries, fruits and vegetables both diced or sliced, seafood such as shrimp and small fish, meat, poultry, pasta, cheese and grains. Products that have been subjected to IQF are referred to as individually quick frozen. One of the main advantages of this method of preparing frozen food is that the freezing process takes only a few minutes. The proper job allocation is saving the electricity, not only energy the water, engine oil and other factors are optimized simultaneously.

The use of SAW (Simple Additive Weighting) method is observed to be quite capable and computationally easy to evaluate and select the proper machine from a given set of alternatives. These methods use the measures of the considered criteria with their relative importance in order to arrive at the final ranking of the alternative machine. Thus, these popular MCDM methods can be successfully employed for solving any type of decision-making problems having any number of criteria and alternatives in the manufacturing domain. As a future scope, a fuzzy SAW based methodology may be developed to aid the decision makers to take decisions in presence of imprecise and incomplete data.

VI. REFERENCES

[1]. BIM. (2017). Ireland's seafood development agency, Resource Efficiency Guide for Seafood Processors.

[2]. Pillai V K (1973). Special publication. Marine Biological association of India.

[3]. FAO (2010) the state of world fisheries and aquaculture (2010). (PDF) FAO of the UN

[4]. P. R. Amulya, Energy Optimization in Seafood Processing Industries (2018), Indian Food Industry Mag Vol 37 No 6,

[5]. Perry S J (2007). Process optimization to minimize energy use in food processing, Food Processing, 59-89. Science, Technology and Nutrition, Handbook of Waste Management Co-Product Recovery in Food Processing, 59-89.

[6]. http://stellarfoodforthought.net/6-ways-tooptimize-your-facilitys-energy consumption

[7]. https://www.worldatlas.com/articles/leadingcountries-in-fishing-and-aquacultureoutput.html.

[8]. Bureau of Energy Efficiency (BEE). (2015). Manual on Energy Conservation Opportunities in Seafood processing industries in Kochi. BEE, New Delhi.

[9]. P. Jana, "Supplier selection under strategic decision environment," Independent Journal of Management & Production, vol. 11, no. 1, p. 065, Feb. 2020, doi: 10.14807/ijmp.v11i1.1018.

[10]. Operations Research by D. S. Hira and Prem Kumar Gupta.

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