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WASTE ANALYSIS AND OPTIMIZATION IN ENERGY AND FIBER OBTIC CABLE MANUFACTURING

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INTRODUCTION

Energy and communication cables have an important place in construction and energy sectors. Cables play a role in delivering the energy produced to the end-user and in providing the flow of information while creating internet infrastructures. It is also used in circuit designs and energy flow of electrical appliances. Cables used in different industries must meet different standards. Otherwise, cables can cause many disasters, especially fire. Therefore, cables are not produced to the required standards can endanger human life. Companies operating in the cable manufacturing industry want to keep the production process under constant control so that the cables produced can meet the required standards. Due to the effective and stable quality product production policy, the companies ignore the scrap generated in the production processes.

In this project, scrap analysis and optimization in production was studied with HES Kablo, a leading company in the sector of energy and communication cables. A field analysis has been made about the scraps that may arise during the cable production phase and the cost to the company as well as the reduction of the scraps that may arise. Rescheduling for manufacturing was prepared using a mathematical model to reduce scrap.

COMPANY PROFILE

HES Kablo was established in 1974 in Hacılar/Kayseri. It produces copper or aluminium energy cable, fibre optic cable, enamelled coil wire, and solar cable. HES Kablo can produce in accordance with many different quality standards. It aims to appeal to every customer by developing products suitable for special customer specifications and requests.

PROBLEM DEFINITION

The main aim of the company is customer satisfaction. Therefore, HES Kablo has adopted the principle of delivering orders from customers in the best quality and in the shortest time possible. It produces cables in 3 different conductors (Copper, Aluminium, Natural Fiberglass), 4 different isolation raw materials (PVC, XLPE, HFFR, PBT) to meet customers' demands. In the cable isolation process, the outer wall of the conductor is covered by using one of 4 different insulation raw materials. HES Kablo can produce cables in 7 different colours for PVC, 8 for XLPE, 8 for HFFR, and 12 for PBT.

In the current system, since the company could reprocess copper and aluminium scraps, work has been done to reduce insulation raw materials. In the cable isolation process, the outer wall of the conductor is covered by using one of 4 different isolation raw materials. The cable isolation process is carried out in different machines for each different isolation raw material, since the production plan is made according to the customer's order, the company could change the colour many times in the same machine. Since the colour inside the machine cannot be discharged while the colour is being changed, some mixed colour is formed until a new colour of suitable quality is formed. Thus, production cannot be made with mixed colours and the raw material processed during this period is given as waste.

In January 2020, the company lost 19 tons of PVC, 13 tons of HFFR, 8 tons of XLPE, 7 tons of PBT. The cost of scrap generated for January 2020 alone is approximately 850,000 TL to the company. On the other hand, customers also desire cables in different molds. At present, 19 different diameters for energy cables and 14 different diameters for fiber optic cables can be produced in the factory. To produce cables of different thicknesses for energy cables, the molds might be changed. However, mold change is not necessary for fiber optic cables. Re-installation and detailed adjustment are required for energy cable isolation machines. This process is a preparation process and causes a waiting in production.

SYSTEM UNDER CONSIDERATION

HES-1 ENERGY CABLES PRODUCTION FACILITY

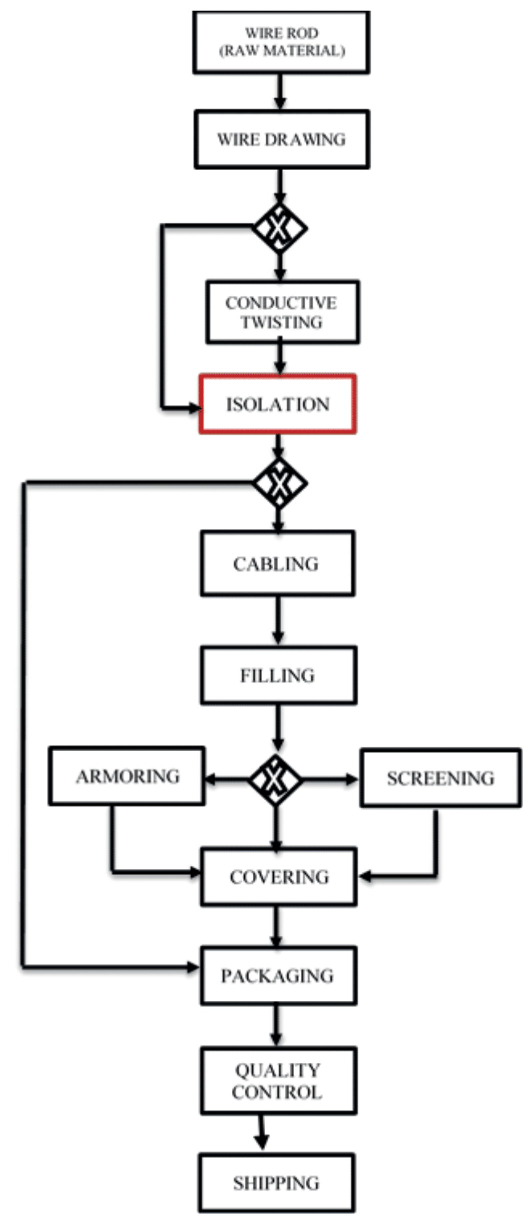

Figure 1. Process Chart for HES-1

HES-2 FIBER OPTIC CABLES PRODUCTION FACILITY

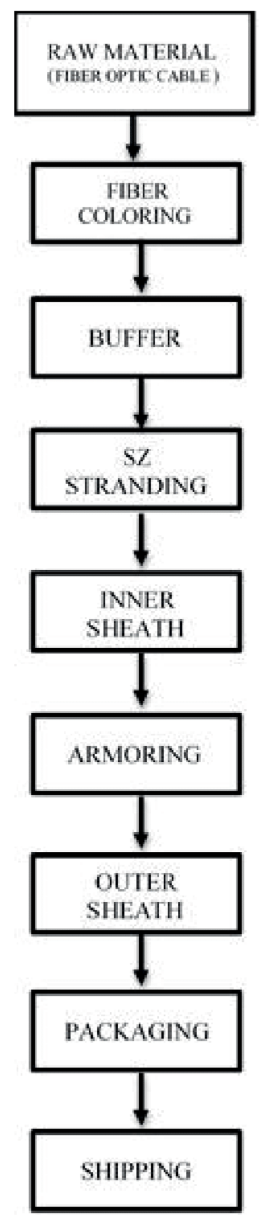

Figure 2. Process Chart for HES-2

ROOT COUSE ANALYSIS

Table 1. Process Based Scrap Analysis

Process	Input	Output	Waste In Process
Wire Rod	Wire rod	Wire	Copper/Aluminum
Wire Drawing	Wire	Twisted Wire	Wire, Twisted Wire
Isolation	Twisted Wire / Single-core Cable	Insulated Cable	PVC, HFFR, XLPE, Twisted Wire / Single-core Cable
Copper Twisting	Single-core Cable	Twisted Single-core Insulated Cable	Single-core Cable
Filling	Twisted Single-core Insulated Cable	Filled Semi-Finished Products	PVC, HFFR, XLPE, Single-core Cable
Screening / Armoring	Twisted Single-core Insulated Cable, Filled Semi-Finished Products	Screened & Armored Semi-Finished Product	PVC, HFFR, XLPE, Twisted Single-core Insulated Cable
Covering	Screened & Armored Semi-Finished Product, Filled Semi-Finished Products	Product	PVC, HFFR, XLPE, Single-core Cable, Screened & Armored Semi-Finished Product, Filled Semi-Finished Products
Natural Fiber Coloring	Natural Fiber	Dyed Fiber	Dyed Fiber, Fiber Dye
Buffering	Dyed Fiber	Buffer	PBT, Dyed Fiber, Jelly
SZ Twisting	Buffer	Twisted Fiber Kablo	Twisted Fiber Cable, Buffer
Inner Isolation	Twisted Fiber Cable	Inner Isolated Fiber Cable	Twisted Fiber Cable, Inner Isolated Fiber Cable
Armoring	Inner Isolated Fiber Cable, Buffer	Armored Fiber Cable	Armored Fiber Cable, Inner Isolated Fiber Cable, Buffer
Outer Isolation	Armored Fiber Cable, Twisted Fiber Cable	Fiber Cable	Armored Fiber Cable, Twisted Fiber Cable

COLOUR TRANSITION

The isolation process is the coating of a certain amount of colour pigment and isolation raw material in the desired Diameter around the conductor wire by kneading in the extruder at a certain temperature. In this process, colour change is inevitable as the wire is coated with different colours in line with customer orders. For instance, in the production of fiber optic cable with 12 buffer tubes, buffer tubes in different colours will be produced in a single machine and at least 11 colour changes will take place as per order. For the next process, twisting line, to continue production, the specified buffer tube of 12 different colours could be produced uninterruptedly. When the colour change process is analysed, there is a transition from the current produced colour to a different colour, some mixed colour occurs in the extruder. Furthermore, the coloured raw material which is in the extruder chamber and the new colour pigment added are mixed. The mixed colour in the extruder must be discharged until a new colour is formed. The mixed colour formed in this process does not meet the production standard and is called "scrap". The mixed colour in the process was measured in different amounts for all colour transitions, with the analyses made for each insulation raw material and machine, and the scrap amounts were recorded as a table to be used in the mathematical model.

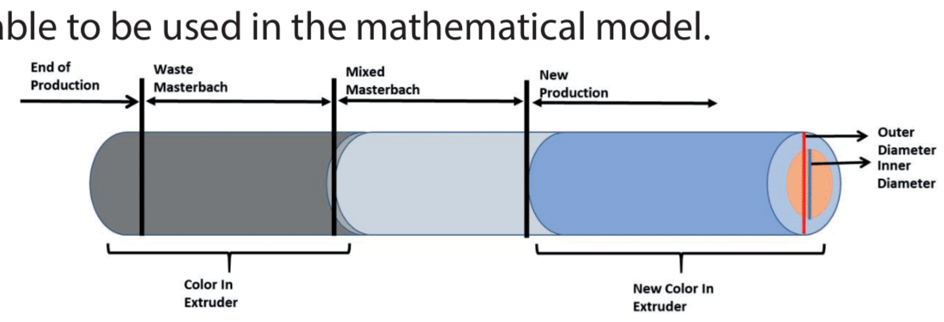

Figure 3. Sample of Colour Transition (Black --> Blue)

PROPOSED MODEL

Sets

i, j — *Cable Type*

Parameters

$Scrap_{ij}$ — *The amount of scrap generated when switching from the i^{th} cable type to the j^{th} cable type.*

$MoldChanging_{ij}$ — *1 If mold changing occurs, 0 otherwise.*

Decision Variables

X_{ij} — *1, if it has changed from the i^{th} cable type to the j^{th} cable type, 0 otherwise.*

u_i ve u_j — *Positive variables*

ε — *Total number of mold changes that can be made.*

Objective Function

$$z^* = \min Z = \sum_{i=1}^{n}\sum_{j=1}^{n} Scrap_{ij} * X_{ij} \quad (1)$$

Constraints

$$\sum_{i=1}^{n}\sum_{j=1}^{n} MoldChanging_{ij} * X_{ij} \le \varepsilon \quad (2)$$

$$\sum_{i=1}^{n} X_{ij} = 1 \quad \forall j \quad (3)$$

$$\sum_{j=1}^{n} X_{ij} = 1 \quad \forall ij \quad (4)$$

$$u_i - u_j + nX_{ij} \le n - 1 \qquad 1 \le i \ne j \quad (5)$$

$$X_{ij} \in \{0,1\} \quad (6)$$

Equation (1) is the objective function of the model. Calculates the amount of scrap raw material that occurs in colour transitions. Constraint (2) calculates the number of mold changes during colour change. The number of mold changes must be less than or equal to the given epsilon value. The number of Epsilons was ordered from the smallest number of pattern changes that could occur in the sample to the largest. Constraint (3) guarantees that each node can be visited only once, while Constraint (4) assures that the visited node exits. Constraint (5) is the constraint that used to prevent sub-tours that may occur. Constraint (6) is X binary (0 or 1).

RESULTS

Table 2. Current and Proposed System Comparison in Same Number of Mold Changes for PVC

	3.08.2020	4.08.2020	5.08.2020	6.08.2020	7.08.2020	8.08.2020	9.08.2020
Current System Number of Mold Changing	3	5	4	6	2	3	4
Current System Amount of Wastage (KG)	24,2	19	55,8	47,8	46,6	62,4	46,4
Proposed System Amount of Wastage (KG)	19	19	30,2	19	43,6	43,4	19
Percentage of Improvement of Wastage	21%	0%	46%	60%	6%	30%	59%

Table 3. Current and Proposed System Comparison in Same Number of Mold Changes for XLPE

	3.08.2020	4.08.2020	5.08.2020	6.08.2020	7.08.2020	8.08.2020	9.08.2020
Current System Number of Mold Changing	3	3	5	2	6	4	3
Current System Amount of Wastage (KG)	28,7	15	38,65	35,25	26,5	26,45	16,25
Proposed System Amount of Wastage (KG)	22,05	12,6	30,05	9	8,8	19,2	14,4
Percentage of Improvement of Wastage	23%	16%	22%	74%	67%	27%	11%

Table 4. Current and Proposed System Comparison in Same Number of Mold Changes for HFFR

	3.08.2020	4.08.2020	5.08.2020	6.08.2020	7.08.2020	8.08.2020	9.08.2020
Current System Number of Mold Changing	3	5	6	4	3	3	4
Current System Amount of Wastage (KG)	65,89	45,09	128,79	62,98	52,78	25,54	36,4
Proposed System Amount of Wastage (KG)	33,27	20,34	51,46	33,3	34,33	12,57	33,22
Percentage of Improvement of Wastage	50%	55%	60%	47%	35%	51%	9%

Table 5. Current and Proposed System Comparison for PBT

	3.08.2020	4.08.2020	5.08.2020	6.08.2020	7.08.2020	8.08.2020	9.08.2020
Current System Amount of Wastage (KG)	23,85	71,1	48,2	32,4	43,6	82,3	27,4
Proposed System Amount of Wastage (KG)	22,45	41,65	38,15	25,9	32,4	57,3	21,7
Percentage of Improvement of Wastage	6%	41%	21%	20%	26%	30%	21%

CONCLUSION

By analysing the data on a daily basis and using the current number of mold changes, the improvement average of the 7-day data was determined as 31.7% for PVC, 34% for XLPE, 47% for HFFR and 24% for PBT. Moreover, a decision support system was designed for production decision makers and the created model was integrated into the interface presented to the user. In this interface, the decision support system, which predicts how many mold changes and how much scrap for planned productions, is presented to the user.

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