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DESIGN OF AUTOMATED MASS FLOW BUFFER CONVEYOR SYSTEM

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Abstract: *In many factory settings, the performance modeling and optimization of individual workstations (machines) which are interconnected with material handling systems (sometimes called Hard Link Up) is a complex problem. The buffer conveyor is one which makes the continuous flow transport from infeed section of Maker machine with the expectation/requirement of out-feed sections of Packers machines in handling high volume manufacturing transport. This paper discusses the productivity improvement by using buffer conveyor system in tobacco industries. A comprehensive overview of design of mass flow conveyors has been implemented and an endless chain conveyor is provided to advance the articles of the mass flow which can be used as a variable-capacity with first-in first-out reservoir for rod-shaped articles. The buffer capacity is made for 10 minutes run and electrical logic is built for system. The packing machine lines continue to run for some time when the maker machine stops and cigarettes are fed from the buffer.*

It focuses on specific research problems in design and control of closed loop conveyors. It provides an improved method of material handling with the aid of technical support as well as emerging technologies worldwide. Re scope to do further complex situations with emerging flow of two or more maker machines and feed them to two or more packer machines and quick changeover of conveyor systems for different products.

Keywords: *Hard Link Up, Buffer Capacity, Maker machine, Packer machine, Infeed module, Outfeed module.*

I. INTRODUCTION

Accumulation is the process of collecting products for temporary storage. ***Buffering*** is the ability to collect products that can be delivered at a different rate than it is received. Both conveyors and accumulators can be designed with buffering capability. ***Throughput*** refers to the production volume of the entire line from maker machine to packer machine. Buffer conveyor systems keep product flowing to machines, reducing number of machine stops and maximize the throughput of the line.

A mass-flow conveyor system conveys oriented product in the form of a continuous mass build up with uniform flow rate which includes a online buffer conveyor having an in feed section, an intermediate section called HLU (Hard Link Up) and an out feed section and the average speed of both in feed and out feed sections is the same. The intermediate section of the conveyor is driven at a non-uniform speed that is slower than, but proportional to, the speed of the in feed section.

The purpose of reservoirs is to avoid frequent stoppages of the entire production line, e.g., due to failure of the cigarette making machine to supply the packing machine with a requisite quantity of cigarettes per unit of time. In other words, the purpose of the reservoirs is to compensate for occasional failure of adjacent machines and apparatus to deliver products to the next-following machines or to supply requisite quantities of such products. The reservoirs supply the products during idling of the preceding machine(s) as well as when the output of the preceding machine(s).

Literature Survey

Peter golz [1] at. al have done the investigation on apparatus for transporting articles between two stations. A new design has been implemented which comprises two co-axial upright helical tracks one of which extends from the first station and the other which extends from and is at least close to the second station. This technique enhances the smooth movement without affecting the articles between the stations.

Leszek sikora [2] designed an apparatus for storing cigarettes supplied from a production machine and transferring cigarettes to a receiving machine. This storage was used for compensating the differences between the work speeds of those two cooperating machines.

Semi-automated systems were developed for handling cigarettes in the shop-floor. This involves automatically filling cigarettes into a plastic tray, which then gets loaded onto the packer manually with varying speed normally represented in table 1.1.

Making machine	Capacity in cpm	Packing machine	Capacity in ppm
Loga 2D	6000 cpm	Focke 349	300 ppm
Loga 3D85	9000 cpm	Focke 350	400 ppm
		Focke 700	600 ppm

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Table 1.1 Shows Capacity of Semi-automated machines

Where, cpm indicates cigarettes per minute

ppm indicates packers per minute

With further increase in machine speeds, complete automation of cigarette handling became inevitable. Table 1.2 shows the capacity of complete automation systems which was observed in ITC Limited, Bangalore. They have some standard buffer conveyor systems which were produced by some reputed international companies viz. flex link in Sweden, ITM (International Tobacco machinery) in Poland, GD in Italy and Hauni in Germany. They build HLUs for the following high speed Makers and Packers machines.

Maker machine	**Capacity in cpm**	**Packer Machine**	**Capacity in ppm**
D121	12000 cpm	GD X2 NU	420 ppm
Protos	12000 cpm	GD X6	600 ppm

Table 1.2 Shows Capacity of automated machines

General Description of Buffer Conveyor Systems

Principal of Operation

Cigarettes are delivered to the machine via in feed module, which transports them to the feeding dispenser unit, where the flow intensity of Cigarettes is recognised and the speed of the machine's transporting chain is adjusted to temporary changes of intensity (of Cigarettes flow) to maintain a constant layer height of cigarettes along the chain in transporting section. Shown in fig a. after automatic loading onto the endless transporting chain the cigarettes along the chain in the transporting chain the cigarettes are in the area of the variable- capacity buffer. This area is divided into two sections:

- Transporting section - which transfers cigarettes from Infeed module to the Outfeed module, cigarettes main buffer.
- Compensating section - where the part of the transporting chain, which is currently not taking part in transporting/storing filter cigarettes is moving.

When the capacity of the transporting section increases (e.g. the machine which receives the cigarettes does not work or works slower than the producing machine), the transporting chain is taken from the compensating section. When the capacity of the transporting section decreases (the producing machine does not work or works slower than the machine which receives the cigarettes), the chain surplus is stored in the compensating section is Shown in fig.1.

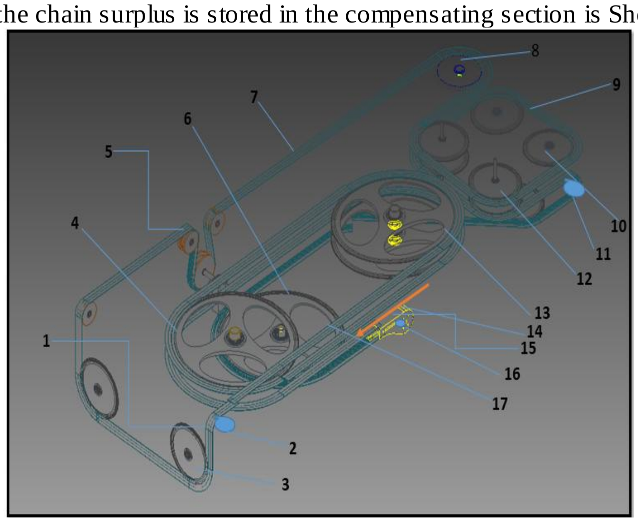

Fig. 1 shows Scheme of variable capacity buffer system(HLU)

Where,

1. Out feed hopper/ filter outlet
2. Out feed motor or emptying motor
3. Vertical pulleys
4. Tensioning control
5. Horizontal compensation wheel
6. Transporting Section
7. Endless chain
8. Horizontal pulley
9. Compensation section
10. Stationary Pulley Unit
11. In feed motor or filling motor
12. Sliding pulley unit
13. Sliding wheel unit

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14. Infeed hopper or cigarette inlet
15. Flow direction
16. Additional in feed motor

Wheels' inclination angle of Buffer system

Each wheel in the transporting section is inclined at an angle 3.60° from the horizontal as shown in fig.2. These values make the transporting chain with cigarettes come up gently to the higher level in the transporting section.

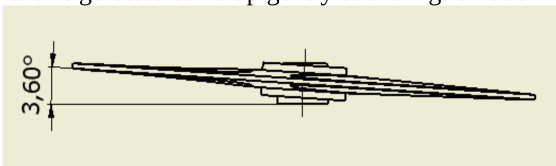

Fig.2 Shows inclination of transporting section wheels

Wheeled units in the machine change the direction of the transporting chain as well as bring the chain to an upper buffer level.

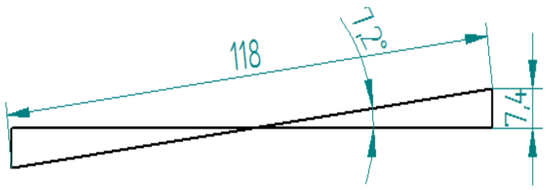

Fig.3 shows the calculation of wheel angle

The angle of inclination in the wheel is calculated by,
Distance between levels of buffer= 14.8 cm
Wheel diameter = 118 cm
Then, Sin Θ= 14.8/118, Θ=7.2°
The inclination with quarter of wheel, Θ=3.60°
Wheeled assembly unit consists of set of wheels and rotating on their own axis individually.

Pulleys' Inclination angle of buffer system

Each pulley in compensating section, the inclination angle at 2.40° shown in fig.4. Where in transporting section, chain moves gently to the higher level and where as in compensating section chain will come down without cigarettes to the lower level because the cigarettes are moved through the outfeed hopper.

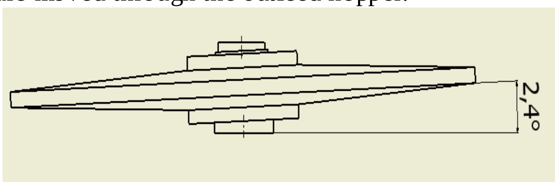

Fig.4 shows inclination angle of compensating section pulleys

Pulley unit consists of set of pulley and each pulley rotates around its own axis and it brings down the chain from upper level to lower level of compensating section.

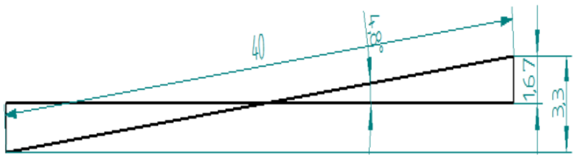

Fig.5 Shows calculation of Pulley angle

The number of pulley units required in compensating section from higher level to lower level= 4
The distance between each pulley one section to another section of 140mm height buffer level= 33mm
The angle of inclination in the pulley is calculated by,
Pulley diameter =400mm
Then, Sin Θ = 33/400, Θ=4.8°
The inclination with quarter of pulley, Θ =2.40°
During the minimum filling of the buffer, sliding pulley unit of the compensating section i.e., assembled with carriage is maximum from the stationary pulley unit.
At maximum filling of the HLU buffer with cigarettes the sliding wheeled unit of transporting section and sliding pulley units moves closer to the fixed pulley unit or away from the stationary wheel unit of HLU.

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Maximum Position of the buffer system

The transporting chain moves between the stationary wheeled unit and sliding wheeled unit along horizontal guides of the chain (fig. buffer levels). The guides are fixed to the frame of HLU.

Behind each drive a compensator has been installed whose task is to compensate for the difference of real and theoretical length of transporting chain, a compensator has been installed behind each drive. This difference is a function of actual position of the carriage and chain's load, which occurs due to non-zero extension of the chain. The chain's load is a sum of loads resulting from:

- Friction between the chain and the guides.
- Inertia of the entire system.
- Resistance of movement of all elements moving in connection with the chain's movement.

Compensator positions are the reflection of these differences.
The functions of compensators as follows,

- The compensators of the chain flow in the zone of its lowered tension.
- Control of the proper length of the chain.
- Recognition of chain overload.
- Cigarettes will leave the HLU via the out feed module.

Operational positions of the HLU buffer

The sliding wheel unit and pulley units of the transporting and compensating sections are attached to carriage which can be in one of the three positions:

- Zero Buffer position.
- Maximum Buffer position.
- Operational position.

Zero Buffer position

If the distance between sliding wheel unit and Stationary wheel unit of transporting sections is very less, then it is said to be in zero buffer position. This distance is in relation with time of a product and this is an extreme position of HLU operating in the emptying mode (No cigarettes in Buffer).

Maximum Buffer position

If the distance between sliding wheel unit and Stationary wheel unit of transporting sections is extreme, so that the sliding wheel unit of transporting section and pulley unit of compensation section is very much closer to the stationary pulley unit then it is said to be in maximum buffer position. This is an extreme position of HLU operating in the initial feeding mode.

Operational buffer position

If the distance between sliding wheel unit and Stationary wheel unit of transporting sections is between zero and maximum position of carriage then it is said to be Operational position mode. The operational position makes it possible to perform the basic operational function of the machine.

Capacity of HLU

The function of this machine is to store Cigarettes. The capacity of HLU is determined by number of cigarettes that can be stored in the machine which is variable as per the need. The machine's capacity is directly influenced by the length of the transporting chain present is in the transporting section.
The buffer capacity is determined by three values:

- Passive capacity
- Active capacity
- Total capacity

Passive capacity Buffer

The passive capacity is determined by the number of filter cigarettes which is left in the machine (between the feeding dispenser and the out-feed dispenser) after it has reached the zero position.
The machines passive capacity is given by,

$$P_P = I_{pm} \cdot 10{,}270 \cdot W_{ww}$$

Where:

P_P - Passive capacity;
I_{pm} - Number of buffer levels;
10,989 - Number of cigarettes at one buffer level (for diameter of filter $\varphi = 8$ [mm]
And layer height 100 [mm]);
W_{ww} - Coefficient of height of cigarettes layer on the chain;
The value of W_{ww} is,
1.0 For layer 100 mm

0.9 For layer 90 mm
0.8 For layer 80 mm, Etc.

Active capacity of Buffer

The active capacity is determined by the number of cigarettes which are fed into the machine while it turns from zero position to maximum position. The machine's active capacity is given by,

$P_A=2 \cdot I_{pm} \cdot S \cdot 1{,}650 \cdot W_{ww}$

Where:
I_{pm} – No of buffer levels
W_{WW} - Coefficient of height of cigarettes layer on the chain;
P_A - Active capacity;
1,650 - Number of cigarettes at one buffer level at the length of 1m
(For diameter of filter φ = 8 [mm] and layer height 100 [mm]);
S - Stroke length (maximum length the sliding wheel unit distance from the stationary wheel unit).

Total capacity

The total capacity of the machine is the sum of the passive and the active capacity:

$P_T=P_A+P_P$

Where:
P_T - Total capacity.

Transporting chain speed

The linear speed of the transporting chain will be different in different points of the machine.

The chain speed at the entry to the machine depends on the number of cigarettes delivered from the production machine. The chain speed at the exit end of the machine depends on the number of cigarettes received by the transferring machine.

The speed of chain in buffer area will be different at different buffer levels. The chain speed in the buffer area depends on the above mentioned speeds. The chain speed in this area can be different at each buffer level. This concept is explained in Fig. 6.

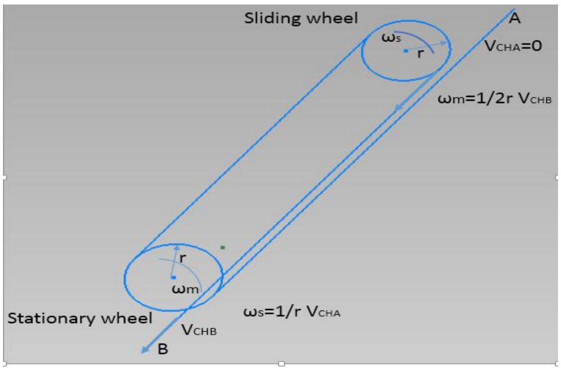

Fig.6 Shows Chain speed difference at each buffer level

w_s - Angle speed of stationary wheel
V_{CHB} - Chain speed at point B
w_m - Angle speed of sliding wheel
V_{CHA} - Immobilized chain speed

The conveyor speed of the machine depends on the speed of maker machine, diameter of cigarette and carpet height.

$$linear\ speed\ of\ conveyor\ \left(\frac{m}{\min}\right) = \frac{speed\ of\ maker\ machine\ (cpm) \times Diameter\ of\ cigarettes}{\frac{carpet\ \ height}{Diameter\ of\ cigarettes} \times 1000}$$

Consider,

$$\frac{Carpet\ hieght}{Diameter\ of\ Cigarette} = 12.5$$

Angle speed of stationary wheel,

$W_s = 1/r\ (V_{CHA})$

Angle speed of sliding wheel,

$W_m = 1/2r\ (V_{CHB})$

For example,
If speed of maker machine (cpm) = 12000cpm

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Carpet height/Diameter of cigarette = 12.5
Diameter of cigarette = 7.8mm
Linear Speed of conveyor
$= 12000 \times 7.8 / (12.5 \times 1000)$
$= 7.488$ m/min.

Proposed conceptual Design Features and Specification

- Online buffer with FIFO (First In First Out).
- Low power requirement.
- Simple design for maintenance and operation.
- Simpler and reliable Method of chain tensioning.
- Method of chain length compensation.
- Optimum Space utilization.
- Unique Flexibility of both active and passive capacity of buffer.
- Building control logics for buffer position.
- Easy installation procedure.
- Aesthetically good looking.
- Rejected Cigarette disposal unit at inlet or outlet section.

Technical Specifications of the Indigenous Design

The system has online buffer to support the line in case of short time stoppages. The typical line taken up for study comprises one maker machine and two Packing machines through HLU. It receives cigarettes from maker and feed to packer machines without affecting the quality of cigarettes. It acts as reservoir with online storage capacity of up to 12000 (i.e., Cigarettes) ×10 (min) cigarettes, which supports the system for specified time during machine stoppages.

1. Storage capacity of Cigarettes at 100mm carpet height = 1650 cigarettes per meter.
2. Diameter and Circumference of the Buffer coveyor wheel = 1.18 m and 3.71m.
3. Cigarettes accumulated in wheel circumference = 3.71x1650=6117 cigarettes.
4. Center distance between wheels (at maximum position) = 7.3 m.
5. Center distance between wheels (at minimum position) = 1.48 m.
6. Cigarettes accumulated between two wheels at max. position = Center distance between wheels (at maximum position)× Storage capacity at 100 mm carpet height × two sides
   $= 7.3 \times 1650 \times 2$
   =24090 cigarettes.
7. Total cigarettes at one level in max position
   = Cigarettes accumulated in wheel circumference + Cigarettes accumulated between two wheels at max. position
   =6117+24090
   =30207 cigarettes.
8. Passive capacity at one level=
   (Cigarettes accumulated in wheel circumference+ 2(Minimum distance between wheels)× Storage capacity at 100 mm carpet height
   $= (3.71+1.48+1.48) \times 1650$
   = 11005cigarettes.
9. Active buffer for one level = Total cigarettes at one level in max position- Passive capacity at one level
   = (30207- 11005)= 19202 cigarettes.
10. Total cigarette capacity of the buffer for 6 levels = Total cigarettes at one level in max position × Number of levels
    $= (30207 \times 6)$
    = 181245 cigarettes.
11. Passive capacity of the buffer for 6 levels
    = Passive capacity at one level × Number of levels
    = 66030 cigarettes.
12. Active capacity of the buffer for 6 levels
    = Total cigarette capacity – Passive Capacity
    = 115215 cigarettes.

Fuctional Description Of HLU

Function of the HLU Infeed hopper is aimed at.

- Receiving of incoming product and recognition of the flow rate.
- Forming continuous product stream of suitable height of the product layer.
- Detection of emptying device.
- Rejection of damaged cigarettes from the Infeed module.
- Transport of product in horizontal direction.

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The Capacity of machine is defined by number of cigarettes stored in the machine and it is variable. HLU filling and emptying process depends on speed of co-operating machines i.e., maker machine and Packer Machines. Magazine control system receives signals from co-operating machines about their speeds, Position and product volume in hopper.
Depending on speed of Maker Machine (SM), as well as on volume of cigarettes in Infeed hopper, chain speed within the area of product Infeed is changed via change of speed of the Infeed motor. Depending on the Packer machines speed (SP) as well as on volume of cigarettes/filters in the out-feed hopper, chain speed within the area of product receiving is changed via change of the out-feed motor speed.
The Position of magazine carriage, speed and its direction, depend on current speeds of Maker machine (SM) and Packer machine (SP),

- If Speed of Maker machine(SM) = Speed of Packer Machine(SP) – The carriage does not change its position;
- If SM > SP - carriage is moved towards filling of 100%;
- If SM < SP - carriage is moved towards filling of 0%.

Magazine carriage reaches one of its critical positions in a case when different capacities of Making and Packing machine occur. The critical operating conditions of HLU are,

a. If Maker machine speed is Higher (SM > SP).

If Carriage reaches filling position up to 100%, and signal from proximity sensor S_8 stops operation of Infeed motor M_1 operation and then supplying machine. In case of sensor S8 damage, the carriage continues its movement, and sensor of critical maximal position S_9 is enabled. It will cause immediate stop of the motor M_1. Message informing about sensor S_8 is displayed on the panel.

b. If Packer machine speed is Higher (SM < SP).

If Carriage reaches filling position up to 0%, and signal from proximity sensor S_6 will stop operation of the out-feed motor M_2, which results a reaching minimal level and stop the receiving machine. In case of sensor S_6 damage, carriage continues its movement, and sensor of critical position S_5 is enabled. It will cause immediate stop of motor M_2. Message informing about sensor S_6 damage is displayed on operator panel.

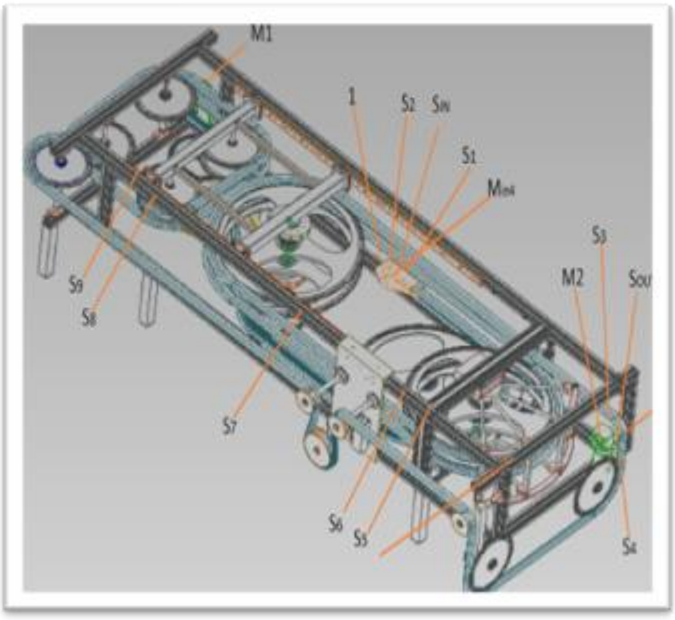

Fig.7 Scheme of HLU Multi-Capacity Buffer system

1 - Infeed hopper
2 - Out-feed hopper
S_{IN} - Sensor of lever angle position in the Infeed hopper
S_{OUT}- Sensor of lever angle position in the out-feed hopper
S_1-Sensor of detection of the reference link - at Infeed
S_2 - Sensor of sprocket wheel rotation - Infeed
S_3- Sensor of detection of the reference link - at out-feed
S_4 - Sensor of sprocket wheel rotation - out-feed
S_5- Detector of critical (minimal) carriage position
S_6 - Carriage position sensor - filling 0%
S_7 - Carriage position sensor - filling 50%

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S_8 - Carriage position sensor - filling 100%
S_9-Detector of critical (maximal) carriage position
M_1 - Infeed motor
M_2 - Out-feed motor
M_{IN} - Additional Infeed motor

Position of the HLU carriage is set by the machine control system, based on signals from sensors about chain wheel rotation at the Infeed (sensor S_2) and out-feed (sensor S_4). The sensors S_6, S_7 and S_8 as shown in figure gives the information about current magazine filling in the panel and are activated during carriage movement. This activation will sent to information to the machine control system, about carriage position adequate to magazine filling of 0%, 50% and 100%, respectively. Signals from these sensors are used to correct carriage position, based on signals from sensors S_2 and S_4. They are usually used during machine installation, or after replacement of transporting chain. Signals from sensors S_1 and S_3 are used in procedure of the transporting chain links counting.

C. Control of Packing and making machine speed

HLU machine controls the speed of Making and Packing machines in order to optimize the efficiency of Entire line. The Percentage filling of buffer controls speed of neighbouring machines. There are two speed hysteresis for maker machine and two other for packer machines.

Example (nominal machine setting);

- If percentage filling of the HLU machine reaches value of 80% ("Limit for upstream machine low speed 1"), maker machine speed is changed from nominal into middle-speed. Nominal speed takes place when percentage filling is reduced by about 5%. If the percentage filling reaches value of 90% ("Limit for upstream machine low speed 2"), supplying machine speed is changed from middle into low. Middle speed takes place if the percentage filling is reduced by about 5%.
- If percentage filling of the HLU machine reaches value of 15% ("Limit for downstream machine low speed 1"), packer machine changes its speed from nominal into middle. Nominal speed takes place when percentage filling is increased by about 5%. If the percentage filling reaches value of 10% ("Limit for downstream machine low speed 2"), packing machine changes its speed from middle into low. Middle speed takes place when the percentage filling is increased by about5%

Operational Procedure for different conditions

There are various types of Electrical logics built with different conditions,

S. No	**Maker Machine Operating condition**	**Packer Machine Operating condition**
1.	Maker machine with high speed	Both Packers runs with high speed
2.	Maker machine with high speed	1st Packer machine runs with high and 2nd packer machine stops.
3.	Maker machine with high speed	1st Packer machine stops and 2nd Packer machine runs with high speed.
4.	Maker machine stops	both packers runs with high speed
5.	Maker machine stops	1st Packer machine runs with high and 2nd packer machine stops.
6.	Maker machine stops	1st Packer machine stops and 2nd Packer machine runs with high speed.
7.	Maker machine runs with variable speed	Both packer machine runs with Variable speed.

CONCLUSION

An improved method of transporting cylindrical products like cigarettes with sufficient on-line buffer. A Production line often comprises a number of different machines, apparatus, reservoirs and/or other components which serve for the making, transporting, storage and/or processing of commodities. The imbalance in the machine speeds in the line is taken care by the buffer system to ensure minimum disruption to production and maximize throughput. The

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system works on First-in-First out (FIFO) principle which ensures product freshness where as in first in- Last out (FILO) and Last in First Out (LIFO) system some of the products stay in the conveyor systems for hours.

There are various critical areas in the design like method of chain length compensation, Reliable method of chain tensioning, Building electrical logic for buffer management etc. The design is being indigenous has its own advantages of overcoming any sort of problems and breakdowns related to the machine. Indigenous development would help us in getting good technical support for Maintenance, relocation of the system and adaptation to size changes of the product.

SCOPE FOR FUTURE WORK

Re scope to do further research in complex situations like to high line speed for 20K, with emerging of product flow of two or more makers and feeding them two or more packers, quick change over of conveyor systems for different cigarette length.

Further research can be done in this area to address the following challenging situations,

1. Buffer system to have quick changeover diverters to run with any maker and any Packer combination.
2. Quick size changeover (cigarette Length) to run different product.
3. Current system is designed for 12K line, advanced design can be worked out for high speed line like 16K and 20K.
4. Combining the output of two or more makers and feeding them to two or more packers.
5. Designing the buffer position to above Maker or Packer to save on the floor space requirement.

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