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# Validation and Installation of the Narrow Belt Conveyor to Cater the High Throughput of FMCG Industries in India.

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**Abstract:-** Roller conveyors are conventionally used to convey/transport cartons, FMCG goods. The conventional roller conveyor was either toothed belt driven or PU cord driven. The roller and the conventional belt conveyors have a speed limiting value of 45 metres/minute. In the current day industrial scenario, looking at the increasing demands of the end customer, the speed limit of 45 metres/minute had to be overcome and increased to a higher level. For this purpose a narrow belt driven live roller conveyor has been designed to deliver goods at a speed of 90-110 metres per minute. In this drive mechanism, a narrow belt is running continuously below the rollers, tangentially driving them. A special 3 layered belt with acrylonitrile- butadiene-rubber as the rough surface on both sides of the belt and polyester (PET) fabric as the traction layer material is used. Special crowned nylon material plastic pulleys have been injection moulded for self-tracking and to guide the belt throughout the 5 metre long conveyor. Several experiments like: load test, slippage test, pull test, current overloading test, temperature test, lower speeds test have been performed to study the behaviour of the belt under various conditions. On the basis of the experimental results, further modifications have been done in the conveyor design. The final results show that this conveyor can convey 35 kgs of unit load per metre at a speed of 90-110 metres per minute within a permissible slippage range of 1-1.5 %. The higher the load, the higher the slippage is and lesser is the belt life. The system was also kept under simulation run for continuous 6 months with a load of 60 kgs per metre at a speed of 85 metres per minute to study the behaviour of the belt life under worse conditions. It was noticed that alignment and tensioning of the belt are 2 important criteria on which the belt life is mainly dependent upon.

**Keywords:-** Narrow belt conveyor; Belt driven live roller conveyor; Conventional belt conveyor; fastest roller conveyor; Narrow belt.

## I. INTRODUCTION

Roller Conveyor by definition are conveyor systems which comprise of a roller tube supported by a roller shaft with bearing caps at both the ends and driven by various drive mechanisms like timing belt, chain driven or O-ring driven. Conventional roller conveyors are often belt driven either by a plurality of intermediate O-ring belts associated with each of the respective rollers or chain or timing belt driven or a single continuous closed loop direct drive belt which extends over a discrete length of the conveyor section.

There were various because of which the existing drive mechanisms failed at a high speed or were not a feasible solution for the end customer. Nguyen [1] studied the reason for the failure of the O-rings to drive the roller conveyors at a higher speed. In his study he has claimed that these round belts are limited in length. So, the conveyor length is dictated by the length of the belt. Furthermore due to their round shape, they may twist which over time may cause the ring to break. Moreover due to the conventional configurations of these systems, replacement of these belts require partial disassembly of the conveyor which results in longer break down of the entire system. According to him, the belt driven roller conveyor is a conveyor comprising of a support frame; a plurality of rollers rotating and supported by the said support frame, a closed loop belt and a plurality of pulleys for supporting and guiding the said belt around a closed path on the said conveyor. The objective was to provide a belt driven system for a roller conveyor and a belt which is relatively simple to service or replace and which exhibits an increased life expectancy without the increased noise associated with the conventional link belts. Thus, even though the O-rings could be driven at a high speed, the maintenance downtime made them not suitable for this application.

Charles Jerome Glaser et al [2] relates a belt driven conveyor as a conveyor track comprising of a frame in which rotatable rollers are arranged one behind the other with their centre axes substantially transverse to the direction of the track, as well as circulating flat drive belt which extends in the direction of the track. The drive belt has a friction surface which engage on the rollers in order to cause them to rotate, the conveyor track furthermore having guide rollers which are arranged with their centre axes substantially transverse to the direction of the belt. A known problem with the conveyor tracks of these types is that the transverse force causes a lateral displacement of the drive belt, which may cause it to run off the guide rollers. One solution to eliminate this problem is to use a V-shaped drive belt to drive the roller. However, the transverse forces result in wear and tear of the belt to a very large extent and thus the drive belt has to be replaced frequently.

Edwin T. Lorrig [3] analysed that the conventional roller conveyors of belt driven type require side guides to prevent objects passing there over from falling off the conveyor and also get damaged due to their contact with the guides. These conveyors are often made much wider than the width of the objects. Another issue that he noticed was that the belt does not track properly when the conveyor is reversible. His objective was to create a belt driven roller conveyor which can be reversible and which can keep objects centred thereon without the use of side guides. He claims that a belt driven roller conveyor comprises of a plurality of load supporting self-centring rolls arranged in alignment with their axes substantially parallel with one another, an endless belt adapted to contact the lower portion of the said rolls, narrow bodied head and tail pulleys for supporting the said belt having a substantially less width than the belt so that the belt can overhang the said belt supporting surface. A plurality of snubbing rolls arranged between the upper and lower runs of the said belt between the load supporting rolls with their upper portion being above the lower tangent to the load supporting rolls and a plurality of spaced apart self-centring rolls bearing against the lower run of the said belt.

H. L. Lutes et al [4] analysed that tracking of the belt is a critical issue which can lead to a complete system failure. For this purpose he has claimed that at least one of the guide rollers is substantially cylindrical and has end sections with gradually increasing diameter so that when the drive belt tries to shift with reference to the guide rollers from the central position in the transverse direction, it runs up against one of the end sections of the guide roller and is forced back towards the central position by the end section. According to his claim the conveyor track now has a self-correcting capability with regards to the position of the drive belt. He claims when the drive belt will run up against the end section on one side, on the other side the drive belt will run off from the end section. Thus, the guide belt is subjected to an increased reaction force of the roller on one side and decreased reaction force on the other side. Consequently the drive roller will force the drive belt to the central portion.

Most of the past studies on belt driven roller conveyor show that a narrow belt has to be driven tangentially below the idler rollers and are pressed in between the rollers with the help of self-centring pulleys. These studies made no mention about how to optimize the design to the extent by which we can convert the narrow belt driven roller conveyor into a conveyor which can convey goods at a speed of around 90-110 metres per minute. For practical achieving this target, a design which was capable to achieve high speeds with a long run life considering various factors like: crowned self centring tensioning pulleys, alignment and belt tracking mechanism, tensioning of the belt, quick changeover mechanisms had to be done. A deep study in the selection of the belt, study and experimentation for the conveying parameters of the conveyor also had to be studied and finalised. Optimization of process, machining, design and manufacturing parameters are important to achieve the high speed, good quality and a very competitive price. The objective of this study/practical implementation is to demonstrate and install a conveyor for the end customer in order to achieve a throughput of around 80 boxes per minute which was out of the scope of the conventional belt conveyors or the timing belt/PU cord/chain driven roller conveyor.

## II. WORK METHODOLOGY

Figure 1. shows the methodology used for the development of the narrow belt conveyor to cater the high throughput rates of the end customer. The first stage was to define the basic product features and specifications to keep them as a target for the final outcome. A market survey and study of the past improvements made in this type of conveyor was mandatory to initialise the concept. Based on the claims of various studies made, a prototype design was made along with few changes incorporated to make it a high speed conveyor from a normal narrow belt conveyor.

After the concept of the product is finalized, strategic and competitive benchmarking is carried to check out the market leaders for this current product. What features the competitors are providing and what are the pros and cons of the product with the current edition of the product. And what value has to be added in the existing product and give the customer a product of better quality at a lower price.

A 3-D design of the product was done and a prototype of the conveyor was assembled to perform trials and study the effect. After the assembly, the prototype underwent a variety of experiments and a simulation run was also carried out with the requirements of the customer. The list of experiments are: current test at each stage, Maximum load and speed to transfer the load, Slippage test, Tests at lower speed, Motor selection test, Temperature test, Sound, vibration test, Pull load test, etc. Based on the experimental data, modifications in the design are performed to meet the practical application. After the finalization of the features, any issues to be addressed are taken into consideration; the prototype is made to undergo a simulation run for life for a period of at least 6 months and then was handed over to the customer for installation.

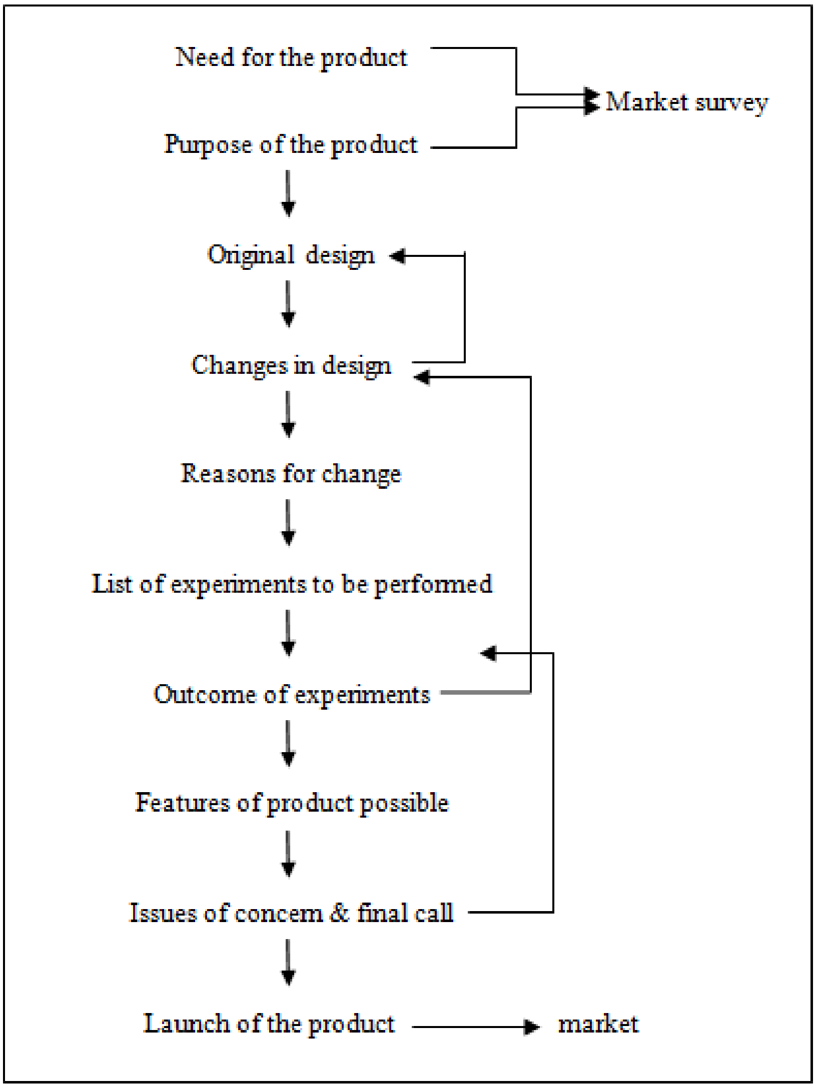


**Fig. 1** Work methodology flow chart.

## III. EXPERIMENTAL WORK

Various experiments have been performed to come to various conclusions on the selection of the right belt, the maximum load the conveyor can convey, the maximum speed at which the goods can be conveyed etc. For this purpose the experiments performed were current at each phase for various incremental loads, load test to rotate the rollers and to calculate the friction value, the maximum load the conveyor can convey, the maximum speed at which the goods can be conveyed, the slippage test, slippage test at low speeds and temperature test.

The various apparatus equipment used in the following experiments was: Spring balance, clamp-meter, tachometer, thermometer, decibel meter, weights (increment of 10kg), ac motor (180 w), and gear-box (5.53 ratio)

The experimental details are as follows:

The 1$^{st}$ experiment that was essential was to calculate the pull load required to start the rotation of the rollers at various conditions (no load and increments of 10 kgs up to 100 kg).

After the pull load it was essential to find out the current drawn by the motor at each stage. Current information is required for the selection of motor and if 180W as a standard practice can convey goods up to 100 kgs for a 5

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meter long module length. The current rating has a direct relationship with the pull load. The experiment had to be performed to check if the motor was getting over rated or not. The observations were as follows:

**Table 1:** Pull load test and Current test readings.

| Condition | Pull load-kg | Current-R-term | Current-Y-term | Current-B term | Average-current (A) |
|---|---|---|---|---|---|
| Only motor | - | 0.26 | 0.28 | 0.26 | 0.27 |
| Motor with gear box and pulley | - | 0.46 | 0.48 | 0.46 | 0.47 |
| Motor and gear box-no load | 1.74 | 0.62 | 0.64 | 0.61 | 0.62 |
| Motor and gear box with load: | | | | | |
| 10kg | 2.65 | 0.62 | 0.64 | 0.61 | 0.62 |
| 20kg | 3.25 | 0.62 | 0.64 | 0.61 | 0.62 |
| 30kg | 3.45 | 0.61 | 0.59 | 0.59 | 0.61 |
| 40kg | 3.75 | 0.66 | 0.64 | 0.64 | 0.66 |
| 50kg | 4.1 | 0.71 | 0.69 | 0.69 | 0.71 |
| 60kg | 4.21 | 0.76 | 0.74 | 0.74 | 0.76 |
| 70kg | 4.35 | 0.81 | 0.79 | 0.79 | 0.81 |
| 80kg | 4.75 | 0.86 | 0.84 | 0.84 | 0.86 |
| 90kg | 5.25 | 0.91 | 0.89 | 0.89 | 0.91 |
| 100kg | 5.75 | 0.96 | 0.94 | 0.94 | 0.96 |

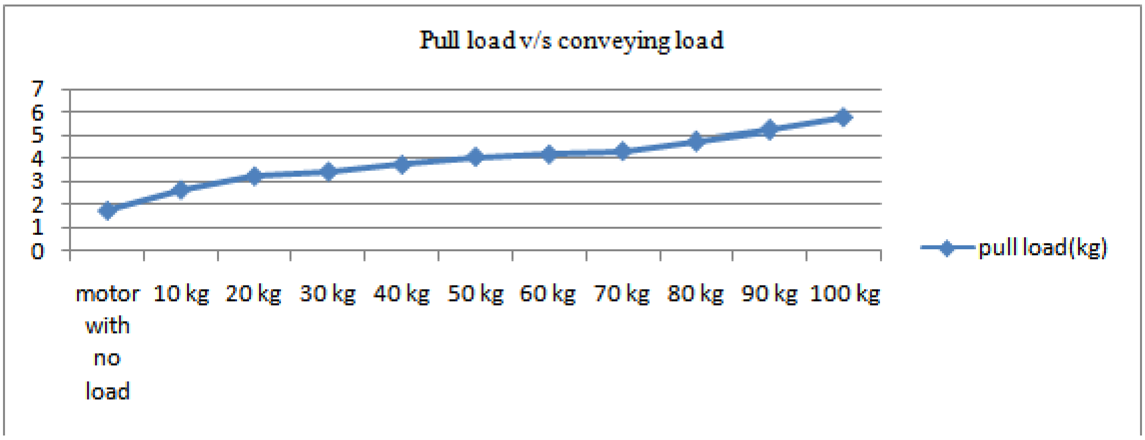


**Fig. 2** Pull load v/s conveying load graph.

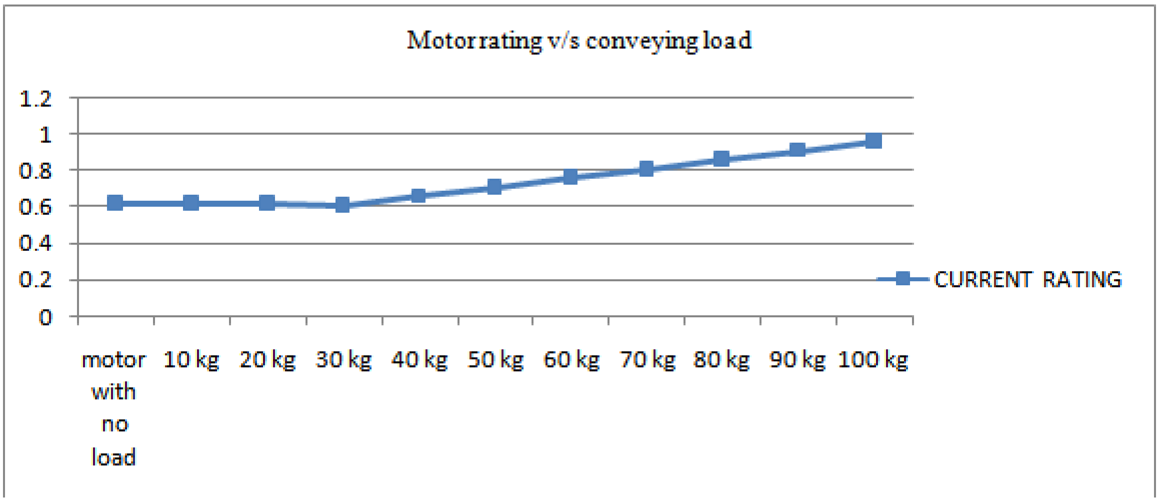


**Fig. 3** Motor current rating v/s conveying load graph

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In the 2nd experiment we had to calculate the maximum load the conveyor can convey at a speed of -60-110 m/min.
- The purpose of this experiment was to check the maximum load the conveyor can sustain to convey goods in the speed range of 60 to 110 meters per minute. This will be the deciding factor while selecting the right motor and gear box for the application.

To calculate the maximum speed at which the conveyor can convey a load of 100 kg.
-100kg on a roller conveyor is usually considered as the maximum condition in the FMCG division. So a trial for this maximum load had to be taken to check the maximum speed.
Along with that it was also important to calculate the slippage at various incremental loads. The main purpose of this experiment is to check out the maximum unit load the belt conveyor (narrow belt and v-belt) can convey within the permissible slippage limits. If the slippage value exceeds the permissible limit, it will lead to excessive wear and tear of the belt and it will eventually break.
The experiment was performed for the v-belt as well as the narrow belt for the selection for the right belt to tangentially drive the rollers.

The observations were as follows:

**Table 2:** Cumulative slippage readings for narrow belt.

| Condition | Current (A) | Roller RPM | Linear speed of the roller (m/min) | % slippage | Linear speed of the pulley (m/min) | Motor slowdown % | Cumulative slippage |
|---|---|---|---|---|---|---|---|
| Motor + gear box+ roller-no load | 0.6 | 1100 | 110 | 5.91 | 116.9 | 0 | 5.91 |
| Motor + gear box +roller +load: | | | | | | | |
| 10kg | 0.63 | 1069 | 107 | 6.15 | 114 | 2.49 | 8.64 |
| 20kg | 0.66 | 1042 | 104 | 7.72 | 112.7 | 3.6 | 11.32 |
| 30kg | 0.68 | 1019 | 101 | 8.44 | 110.3 | 5.65 | 14.09 |
| 40kg | 0.69 | 994 | 98.5 | 9.64 | 109 | 6.76 | 16.4 |
| 50kg | 0.72 | 990 | 98.1 | 9.34 | 108.2 | 7.45 | 16.79 |
| 60kg | 0.73 | 969 | 96.5 | 9.22 | 106.3 | 9.07 | 18.29 |
| 70kg | 0.75 | 954 | 94.5 | 11.02 | 106.2 | 9.16 | 20.18 |
| 80kg | 0.75 | 935 | 94.1 | 10.81 | 105.5 | 9.76 | 20.57 |
| 90kg | 0.76 | 902 | 92.7 | 11.89 | 105.2 | 10.01 | 21.9 |
| 100kg | 0.77 | 885 | 92 | 11.88 | 104.4 | 10.7 | 22.58 |

**Table 3:** Cumulative slippage readings for V-belt.

| Condition | Current(A) | Linear speed of roller (m/min) | % slippage | Linear speed of pulley (m/min) | Motor slowdown % | Cum. Slippage |
|---|---|---|---|---|---|---|
| Motor + gear box+ roller-no load | 0.71 | 104 | 4.5 | 109 | 0 | 5.91 |
| Motor + gear box +roller +load: | | | | | | |
| 10kg | 0.76 | 97 | 6.74 | 104 | 11.04 | 17.78 |
| 20kg | 0.78 | 92 | 9.81 | 102 | 12.75 | 22.56 |
| 30kg | 0.8 | 88 | 10.21 | 98 | 16.17 | 26.38 |
| 40kg | 0.84 | 83 | 13.55 | 96 | 17.88 | 31.43 |
| 50kg | 0.86 | 81 | 14.74 | 95 | 18.74 | 33.48 |
| 60kg | 0.9 | 79 | 16.41 | 94.5 | 19.17 | 35.58 |
| 70kg | 0.92 | 78 | 16.13 | 93 | 20.45 | 36.58 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 80kg | 0.94 | 77 | 15.39 | 91 | 22.16 | 37.55 |
| 90kg | 0.94 | 75 | 16.39 | 89.7 | 23.27 | 39.66 |
| 100kg | 0.95 | 73 | 17.05 | 88 | 24.73 | 41.78 |

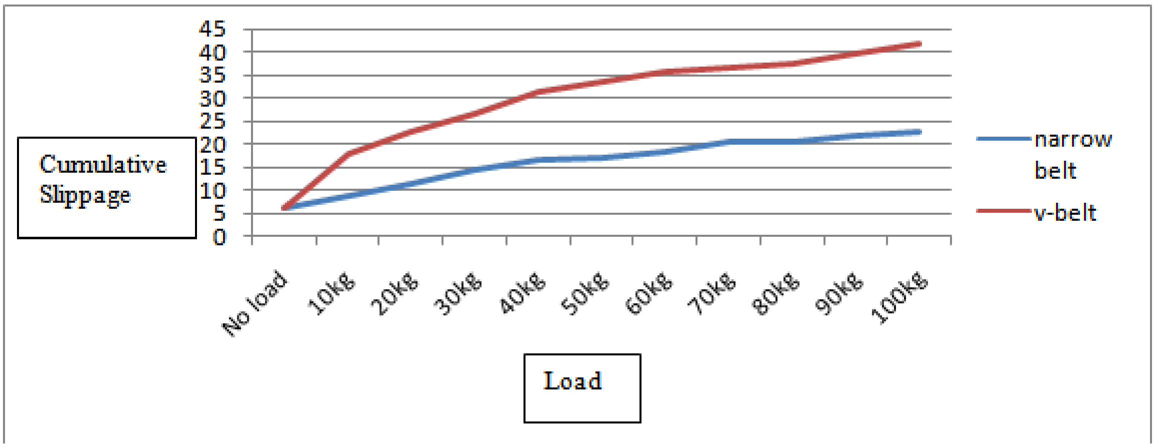


**Fig. 4** Cumulative slippage v/s load comparison for V-belt and narrow belt.

Considering the fact that the narrow belt conveyor is designed to serve as a high speed conveyor, it was essential that a trial needs to be taken also at the slow speeds and not restrict the application of this product and should not fail by any means of excessive slippage, wear and tear, etc. For this purpose an experiment was performed to take trials of the conveyor at slow speeds and also to calculate the % slippage at lower speeds at various constant linear speed of the drive pulleys.The drive pulley is kept at constant linear speed. For various incremental loads, the linear speed of the roller is noted down and the corresponding slippage is calculated. The observations were as follows:

**Table 4:** Cumulative slippage readings for Narrow belt at slow speeds.

| linear speed of pulley-20m/min | | |
|---|---|---|
| Weight | Linear speed of roller | % Slippage |
| 50 | 18.95 | 5.25 |
| 100 | 18.55 | 7.25 |
| 150 | 18.42 | 7.9 |
| 200 | 18.21 | 8.95 |

| linear speed of pulley-41.6m/min | | |
|---|---|---|
| Weight | Linear speed of roller | % Slippage |
| 50 | 39.06 | 4.74 |
| 100 | 38.3 | 6.59 |
| 150 | 38.25 | 6.71 |
| 200 | 36.5 | 10.98 |

| linear speed of pulley-60.36m/min | | |
|---|---|---|
| Weight | Linear speed of roller | % Slippage |
| 50 | 57.12 | 4.8 |
| 100 | 55.93 | 6.79 |
| 150 | 53.2 | 11.34 |
| 200 | 50 | 16.67 |

| linear speed of pulley-78.5m/min | | |
|---|---|---|
| Weight | Linear speed of roller | % Slippage |
| 50 | 72 | 7.5 |
| 100 | 69 | 11.25 |
| 150 | 67 | 13.75 |
| 200 | 64 | 17.5 |

In the next experiment it was mandatory to perform the temperature, vibrations and sound test for the v-belt and narrow belt before the product is successfully launched in the market.
The main purpose of this experiment is to study the behavior of the belt from temperature and heating point of view and what impact it can have on the belt life. The conveyor is made to run for a long duration and a comparison between the original temperature of the motor and belt along with the ambient room temperature with the value after the conveyor was kept running for a long duration is made. Also other factors like noise, vibrations etc. are also required to be noted down.
The observations were as follows:

For the narrow belt:
Ambient room temperature= 29 deg
Temperature of the belt at the start of operation= 27.5 deg
Temperature of the motor at the start of operation= 31 deg

**Table 5:** Temperature readings for narrow belt.

| Condition | Temperature of motor | Temperature of the belt |
|---|---|---|
| Motor and gear box with roller-no load(AFTER 15 MINS) | 34 | 27.5 |
| Motor and gear box with roller-no load(AFTER 6 HOUR) | 40 | 28 |
| Motor and gear box with roller-no load(AFTER 24 HOUR) | 48 | 29.5 |

For V-belt:
Ambient room temperature= 26.2 deg
Temperature of the belt at the start of operation= 28 deg
Temperature of the motor at the start of operation= 32 deg

**Table 6:** Temperature readings for V-belt.

| Condition | Temperature of motor | Temperature of the belt |
|---|---|---|
| Motor and gear box with roller-no load(AFTER 15 MINS) | 34 | 27.5 |
| Motor and gear box with roller-no load(AFTER 6 HOUR) | 40 | 32 |
| Motor and gear box with roller-no load(AFTER 24 HOUR) | 48 | 38 |

## IV. EXPERIMENTAL RESULTS AND DISCUSSION:

As shown in table 1, the maximum current rating is 0.96 A when the NBC conveyor is conveying 100 kgs at a speed of 90 meters per minute. The maximum current carrying limit for a 0.18kW motor is approximately 1.23A for a SEW motor that was installed for trials. This shows that the current rating is well within the limits. The current rating has a direct proportion to the load pull test. Pull load indicates the resistance of the rollers to convey a specific load. The higher the pull load test, higher is the initial current rating.

The pull load test determines the load required to initiate the rolling action to convey the goods. Ideally the pull load should be the value of rolling friction. The rolling friction value is 0.3. As shown in table 1, the pull load was found to be 1.74 kg for the narrow belt for a 5 metre module ad 5.75 kg of pull load to convey 100kg.

As shown in observation table no 2, the conveyor can convey goods weighing 10 kg of unit load per meter at a speed of 107 meter per minute and a unit load of 100kg per metre could be conveyed at a speed of 92 meter per minute. A time-speed study was carried out to check if the carton box also was conveyed at the same speed or slippage was noticed. The carton box weighing 10 kg displayed no slippage and was getting conveyed at the same speed. However, cartons weighing more than 60 kgs, initially showed slippage and after gaining momentum, they were getting conveyed at the same speed.

As shown in observation table no 2 the friction value of the v-belt was very high because of which the linear speed obtained for conveying 100kg was 72m/min as compared to 92m/min for NBC. The slippage value of v-belt was 44 % as compared to 22 % of cumulative slippage for narrow belt. Thus, as seen from the data, there is power loss and speed loss when using v-belt. This will also lead to more wear and tear of the belt and eventually, the belt will break up. A cumulative slippage value of 20% is permissible for the narrow belt. However, the slippage can also be reduced by providing the appropriate tensioning to the belt. Usually a tensioning of 1.2-1.4% can be provided to the belt. But if we aim at conveying unit loads exceeding 50 kgs, we can increase the tensioning to 1.8-2.2% and thus reduce the cumulative slippage and protect the belt from getting damaged.

The v-belt gets heated up at a faster rate as compared to the narrow belt reaching a temperature of 38 deg. Due to this heating, the belt gets softened and wearing out of the belt starts taking place. Minute rubber particles were seen on the surface of the roller where the belt comes in contact which depicted that the belt is getting worn out and its life is reducing. However, for the narrow belt, the temperature was within limits and in the permissible range no minute particles were seen. No vibrations were noted down and the sound range for the working of the conveyor was 52 dB Also the narrow belt conveyor works completely fine and the calculated slippage value were well within the calculated limits for loads at slow speeds.

## V. CONCLUSIONS

### *A. DESIGN AND EXPERIMENTAL CONCLUSION:*

On the basis of the various experiments performed, the following conclusions can be made:

In comparison with the V-belt, the Habasit narrow belt TC-20 EF was selected to drive the rollers tangentially. The criteria helped in selecting the belt was the minimum pulley diameter (50 mm) that was required for the wrapping of the belt, the upper and lower NBR rubber coating which will generate enough friction to drive the rollers, the availability of the loop length required to drive the 5 metre/ 10 metre long conveyor, the working temperature of the belt and the cumulative slippage.

As compared to V-belt which had a cumulative slippage of 42 % to convey 100 kg of unit load, the narrow belt had a cumulative slippage of 20 %. Also the loop length required for a 5 metre long conveyor is approx. 10.75 metres, this loop length is rarely available in V-belt (type A) and narrow belts are endless belts and thus are a better option when considered from maintenance and replacement point of view. Also, the working temperature of the V-belt increases to 48 degrees as compared to that of narrow belt which as a working temperature of 32 -35 degrees. Because of this increase in temperature, the V-belt gets softened and starts getting worn out at a faster rate as compared to the narrow belt. The narrow belt is reversible, has a coating on both the sides. The selected belt could easily run at high speeds up to 200 meters per minute. For the above reasons, it was concluded that the narrow belt will be used instead of the V-belt to drive the rollers tangentially.

The plastic tensioning pulleys will be of self-centring type for the proper alignment of the belt. The material selected for the moulding of the plastic pulleys will be delrin. The selection of material was done to assist ease of machining to get the bearing size and the material should not get heated up when continuously rotating and in contact with the rubber belt. If the temperature increases, it will wear out the belt eventually.

The cumulative slippage of the belt is mainly dependent upon the slippage between the drive pulley and the belt and dependent upon the slippage between the belt and the rollers. The slippage between the drive pulley and the belt can be reduced by rubberizing the drive pulley with a 10 mm thick rubber coating of 60-80 Rc. This will ensure that the belt gets a gripping on the drive pulley to transmit the motion. However, looking at the statistics the narrow belt can easily convey a weight of 60 kg at a high speed with no impact of the belt life. The slippage between the belt and the rollers can be reduced by providing the appropriate tensioning to the belt. From the various experiments performed it is concluded that the tensioning % would be 1.2-1.5 for conveying unit loads in the range of 10- 50 kgs, whereas the tensioning % would be 1.8-2.1 % for conveying unit loads in the range of 60-100kgs.

Usually when conveying unit loads greater than 50 kgs, a high amount of slippage is observer for the first 10 seconds till the carton box gains momentum and gets delivered at the required speed. For this purpose, the initial 10 rollers of the conveyor should be rubberized with a hardness of 80 Rc and thickness of 2 mm. this will provide grip to the moving carton to gain momentum from the start and reduce slippage.

It can be concluded that to convey unit loads up to 50 kgs, running at approx. 80 meters per minute, a 0.18 kW motor will easily serve the purpose as per the data captured during the current check experiment. Also to convey unit load from 50 to 100 kg per meter, a 0.37 kW motor can be used.

### *B. PROJECT AND INSTALLATION CONCLUSION:*

The throughput of the customer was increased from 42 boxes per minute to 80 boxes/ minute (increase by approximately 85 %). This system will cater the needs of the customer for the next 5 years considering an increase in throughput from 80 boxes/ minute to 85-90 boxes per minute.

The customer underwent a heavy maintenance cost prior to the modification. As per the data provided to us, he was spending 24,000 Rs. Per month on maintenance. As compared to that, NBC has just had maintenance cost of 4,100/- in the past 6 months. This has resulted in savings of approximately 2 lacs on maintenance per year.

The maintenance downtime has reduced drastically. It precisely takes 6 minutes to change the belt and 15 minutes for the alignment and the tensioning of the belt. So, in 21 minutes, the system is ready.

The module length earlier was 3 metres which has now changed to 5 metres. For a stretch of 160 metres, approximately 53 motors were used which has now come down to 32. So there was a saving of 21 motors. Hence not only savings in terms of money but also an energy efficient option was provided to the customer.

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