New Product Development of Advanced Tube Conveyor Shrink Tunnel for Packaging Industry

Mathew Joseph[1] P. Lingeswaran[2]
[1]ME Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Shree Venkateshwara Hi-tech Engineering College, Erode, India

Abstract— There are so many factors that contribute to heat losses and low load capacity in shrink tunnels used in packaging industries, this is an attempt to understand the factors that are significant in reducing the heat losses, increasing load carrying capacity and thermal efficiency. Preserving the heat in a heat tunnel without loss is important for several reasons. Temperature adjustments, safe usage, environment friendly and conservation of heat energy are the major ones. As energy prices increasing day by day, saving benefits of energy should be examined. Manufactures are now pushing standards for ovens to gain thermal efficiency, but many manufacturers feel that the upgrading of tunnel will loose thermal efficiency and would affect their bottom line adversely. Further challenges in Heat tunnels is to incorporate openings to allow the conveyor for products to enter and exit the tunnel. The product design require solution to reduce the escape of heat from the tunnel and the increase in operating costs. The most common method for fast production rate in heat tunnel is achieved by using curtains. This study will help to understand the direction that a designer should concentrate to maximize the process settings such as loading capacity, temperature, conveyor speed, heat generation levels and insulation thickness by introducing a new model of shrink tunnel machine to market

Key words: Shrink Tunnel, Packaging Machine, New Product Development, Film Shrinking

I. Introduction

A shrink tunnel is a heated tunnel mounted over a conveyor system. Items for packaging is placed over the conveyor after sealing with air inside film loosely applied; with the heat in the tunnel, the film shrinks to fit snugly around the product in which the packaging is done. The heat source used in tunnels are finned heaters. Forced air by a blower fan is used to improve convection. Tunnels are available with or without a moving conveyor system. Some are built into a production line or are integral with machinery that also applies the shrink film. Others are movable by hand or by castors. A shrink tunnel, is similar to a hot oven, may be equipped with an integrated conveyor of two different kinds; the roller conveyor or the belt conveyor. Roller conveyors can be used with polyolefin, PVC, and polyethylene films. The space in between the rollers is filled with hot air from the bottom of the tunnel to shrink the film layer around the object, creating a sealed package. When used with polyolefin and PVC based films the rollers must be rotating or spinning. When used with polyethylene films the rollers are called static or non-spinning.

II. Literature survey

A. *R.Graham Bell Sandra M Moorhead, Dorota M Broda :*

Influence of heat shrink treatments on the onset of clostridial “blown pack” spoilage of vacuum packed chilled meat. Storage trials were conducted to determine if short duration high temperature treatments applied in commercial heat shrinking of vacuum barrier packs affect the onset of clostridial blown pack spoilage. Spore suspensions of six significant gas producers were used: Clostridium estertheticum NCIMB 12511, and five local psychrotolerant clostridial isolates. Beef striploins, pH 5.5 and 6.0, were cut into steaks and placed into vacuum pouches. Duplicate pouches were inoculated with each test spore suspension for each meat pH/heat treatment/storage temperature combination. After vacuum packaging and heat shrinking, packs were stored at −1.5, 1 or 4°C. Based on time to first-phase gas production (small bubbles in drip), the test strains were considered statistically as representing two groups. With both groups, post-packaging heat treatment had a significant effect on time to gas production. Mean times, pooled for the three storage temperatures, to gas production with Group A were 49, 39, 36 and 35 days for the no heat, 70, 80 and 90°C treatments, respectively. With Group B these times were 77, 42, 39 and 36 days, respectively. Post-packaging heat shrink treatments of vacuum packaged meat accelerate the onset of Clostridium spp. mediated blown pack spoilage during chilled storage. Possible mechanisms for accelerated onset of blown pack spoilage following heat shrinking of vacuum packs are discussed.

B. *S Nanda, D.V Sudhakar Rao, Shantha Krishnamurthy:*

Effects of shrink film wrapping and storage temperature on the shelf life and quality of pomegranate fruits. The effects of individual shrink film wrapping with two polyolefin films (BDF-2001 and D-955) and skin coating with a sucrose polyester (SPE) Semperfresh™ on the shelf life and quality of soft-seeded ‘Ganesh’ pomegranates (Punica granatum L.) stored at 8, 15 and 25°C were studied. The shrink-wrapped pomegranates could be stored for 12, 9 and 4 weeks as compared to 8, 6 and 2 weeks by SPE coating at 8, 15 and 25°C respectively, whereas non-wrapped fruits could be kept for 7, 5 and 1 weeks under similar storage conditions. Peel thickness and freshness and firmness of the fruit were retained and weight loss greatly reduced by shrink wrapping. The weight loss in shrink-wrapped Fruits was 1.2–1.3% after 12 weeks of storage at 8°C and 2.2–3.7% after 10 weeks at 15°C. During the same period non-wrapped fruits lost 20.4 and 30.7% at 8 and 15°C, respectively. Changes in acidity, sugars and vitamin C of the shrink-wrapped fruits were lower than that of non-wrapped fruits during 12 weeks of storage at 8°C. Shrink wrapping also reduced the respiration rate of the fruit. No detectable levels of ethylene were produced during storage of pomegranates.

C. T.J. Cowell Montell Polyolefins Inc., Wilmington, Delaware, Usa:

Spherilene Process LLDPE for Conventionally Blown Shrink Film. Properties of blown shrink films produced from Spherilene Process LLDPE resins are detailed. These resins yield films with substantial transverse direction shrinkage and high resistance to pinholing, or burn through, during end use shrink tunnel processing. The current shrink film market is comprised largely of high pressure LDPE and LDPE-rich blends. Spherilene Process LLDPE may be used by replacing non-shrinking, conventional LLDPE in blends with LDPE. Further, these new resins may be used to decrease, or even eliminate, the LDPE content of shrink films. Examples are cited.

D. Alessandra R. Silva, Ana Cláudia C. Tahara, Rafael D. Chaves, Anderson S. Sant'ana :

Influence of different shrinking temperatures and vacuum conditions on the ability of psychrotrophic Clostridium to cause ‘blown pack’ spoilage in chilled vacuum-packaged beef . This study determined the ability of psychrotrophic Clostridium strains isolated from vacuum-packaged beefs and abattoir environments to cause ‘blown-pack’ spoilage of vacuum-packaged beef stored at 2 and 15 °C. The influence of shrinking temperatures (83, 84 and 87 °C) and vacuum pressure (6 and 9 mbar) on the occurrence of such spoilage as well as the effects of simulated transportation (500 km) on the integrity of packages was determined. At 15 °C and 2 °C, twelve and six strains caused ‘blown-pack’ spoilage, respectively. The combination of vacuum pressure (9 mbar) combined with shrinking temperature (87 °C) retarded the occurrence of spoilage. The simulated transportation under the experimental conditions did not affect the integrity of packages. More studies that assess the factors that may contribute for the occurrence of ‘blown-pack’ spoilage should be performed to avoid the occurrence of such spoilage during its shelf-life.

E. Gianpaolo Ghiani, Antonio Grieco,Universita` Del Salento Dipartimento Di Ingegneria Dell’innovazione Via Per Monteroni, 73100 Lecce ITALY :

Large-scale assembly job shop scheduling problems with bill of materials: models and algorithms In this paper, we study an assembly job shop scheduling problem with tree-structured precedence con- straints and jobs characterized by specific bills of materials. We propose a mathematical model to deal with a simplified version of the problem, as well as a fast and efficient constructive heuristic that is able to easily face real-world-sized instances. The production schedule takes into account the actual availability of materials in stock as well as the supply times and the capacity constraints, with the goal to minimize the average delay with respect to the due dates associated to the customers’ orders. Computational results on data related to real-life instances show that the mathematical model is able to solve (not always to optimality) small-sized instances only. On the other hand, our heuristic approach is able to solve efficiently very large problems. Moreover, the proposed heuristic turns out to be scalable as the instance size grows.

F. Maria C. Yang, Daniel J. Epstein Department Of Industrial And Systems Engineering, 3715 Mcclintock Avenue, GER 201, University Of Southern California, Los Angeles, CA 90089, USA:

A study of prototypes, design, and design outcomes The building of prototypes is an important facet of the product design process. This paper examines factors in prototyping, including part count and time spent on various design activities, and their correlations with design outcome. The research questions asked: Do simpler prototypes mean a more successful design? Does the amount of time spent on a project, both overall and on different activities over a project cycle, relate to design success? And does it matter when this time is spent? One of the main findings of this study is that prototypes with fewer parts correlate with better design outcome, as do prototypes that have fewer parts added to them over the course of development. This paper also finds that committing more time to a project is not necessarily associated with a successful design outcome.

G. Dr. Lash B. Mapa, Purdue University, Calumet,Mr. Avanish Reddy Vancha, Purdue University, Calumet :

Design of experiments modelling of a heat tunnel. There are many factors that contribute to heat losses in tunnels used in processing and this is an attempt to understand the factors that are significant in reducing the heat losses, with the long term goal of making design improvements to increase the efficiency of the equipment to provide value to the customer. Retaining the heat in a process heat tunnel is important for several reasons. Temperature settings, safety, environmental pollution and energy conservation are the major ones. As energy prices continue to escalate, economic benefits of energy conservation should be examined. State and federal teams are now pushing standards for ovens to gain energy efficiency; but many manufacturers feel that the upgrading of heat tunnel energy efficiency would affect their bottom line adversely. Heat tunnels present further challenges as they all incorporate openings to allow the conveyor and products to enter and exit the oven. These 'product apertures' require measures to reduce the escape of heat from the tunnel and the consequential increase in operating costs. The most common method in fast production lines is the use of curtains. The present study was performed to understand the direction that a designer should concentrate to maximize the process settings such as curtain design, temperature, conveyor speed, heat generation levels and insulation thickness. This was achieved by constructing a Design of Experiments (DOE) model to investigate the factors that affect heat losses at high (+) and low (-) levels.

H. Wankhade Nitesh Prakash, V. G. Sridhar And K. Annamalai School Of Mechanical And Building Science VIT University, Chennai, India :

New Product Development by DFMA and Rapid Prototyping. In any manufacturing process, design is the first step where most of the important decisions are made which affects the final cost of the product. In this paper the researchers have used Design for manufacturing and assembly (DFMA) to re-design a fluid flow control valve and optimized its design to ensure the reduced number of parts, safety, reliability, time to market and customer satisfaction. In this research work the main emphasis was given to the design stage of a product development to obtain an optimum design solution for an existing product, DFMA concepts were used to produce alternative design ideas and the rapid prototyping process was used to develop a prototype for testing and validation of these alternative designs. Optimum design, low cost and good quality with quick delivery was the outcome of this research work.

I. Machinespeng Sheng You, Yi-Chih Hsieh, Ta-Cheng Chen, Yung-Cheng Lee. :

Heuristic Approach for Assembly Scheduling and Transportation Problems with Parallel Many firms have to deal with the problems of scheduling and transportation allocation. The problems of assembly scheduling mainly focus on how to arrange orders in proper sequence on the assembly line with the purpose of minimizing the maximum completion time before they are flown to their destinations. Transportation allocation problems arise in how to assign processed orders to transport modes in order to minimize penalties such as earliness and tardiness. The two problems are usually separately discussed due to their complexity. This paper simultaneously deals with these two problems for firms with multiple identical parallel machines. We formulate this problem as a mixed integer pro- gramming model. The problem belongs to the class of NP-complete combinatorial optimization problems. This paper develops a hybrid genetic algorithm to obtain a compromised solution within a reasonable CPU time. We evaluate the performance of the presented heuristic with the well-known GAMS/CPLEX software. The presented approach is shown to perform well compared with well-known commercial software.

J. Xiulin Sui1, Yan Teng, Xinling Zhao And Yongqiu Chen,School Of Mechanical And Power Engineering Harbin University Of Science And Technology, Harbin, China:

Research on Improvement of Structure Optimization of Cross-type BOM and Related Traversal Algorithm. Based on an analysis of the advantages and disadvantages of single-layer and multi-layer BOM structure, and combine with specific examples of products, a more practical—cross-type BOM structure method is presented. Aiming to solve the system efficiency problems brought by the BOM operation in manufacturing. Regarding the queue as a temporary table, we put forward an improved multi-layer BOM traversal algorithm, makes full use of the basic operation characteristics and setting marks in related fields queue and simplifies the complexity of the algorithm.

III. RESEARCH METHODOLOGY

It was observed that shrink tunnels need to be operated at a much higher temperature than the temperature recommended for the shrink films. Even then finish and perfection is not satisfactory. Based on the problem an analysis was carried out and certain observations were made. For POF recommended temperature is 140 °C but in ST best performance achieved is recorded at 180 °C. It is the same PVC and LDPE. The recommended temperature for PVC is 120°C, in our shrink tunnel PVC shrinks at 150°C. For LDPE the recommended temperature is 160°C – 180 °C, our machine needs to be set at 220°C.

Shrink Film	Thickness (Microns)	Conveyor Speed	Temperature (o C)
POF	8	1 - 6	135 - 140
PVC	40	1 - 6	110 - 120
LDPE	60	1 - 6	150 - 160

Table 1: Film Testing

The centrifugal blower inside the tunnel creates an upward draft that will pull the film upwards. This draft together with the heated air inside the sealed pouch cause ballooning of the film. When the temperature of the air inside the pouch becomes equal to the shrinking temperature of the film, the film will start to shrink. The air inside the pouch will escape through the tiny punctures in the film, causing the film to wrap around the product. Ballooning is essential for a wrinkle free shrinkage. In the preliminary testing itself it was noted that there is not enough draft generated by the blower and no ballooning was taking place. The machine under test was 3520 and it was using a blower 180mm Diameter spinning at 1340rpm.When the blower was replaced with a blower of diameter 217 mm and operated at 1340 rpm the results improved. There was a sufficient draft for ballooning. The result was that increased diameter of the blower resulted in a lot if air being flushed out of the machine. To overcome this thick silicon curtains had to be used. Instead of replacing the current blower with a larger diameter blower, it is better to have a motor with higher RPM of 2800 and use the 180mm diameter blower.

Fig. 1: Finned Heater

IV. SHRINKING OPERATION

Special plastic films which shrink on application of heat are used for shrink wrapping. The temperature required for shrinking each film varies and this information can be obtained from the film manufactures. Shrink films commonly available are,

1) Low Density Poly Ethylene (LDPE)
2) Polyvinyl Chloride (PVC)
3) Polyolefin (POF)

Insert the article in a preformed sleeve or tube of shrinkable film of suitable size. Seal the open ends and make a few holes on the film by pricking it with a pin. The corners of the film may also be sealed cut off for better appearance. If open ends are desired, the ends of the tube need not be sealed. An L – Sealer can be used to make this easier and for better productivity. Place the wrapped article on the conveyor at the inlet. The article will come out of the outlet properly shrunk. Inspect the article.

If the shrinking is not sufficient increase the temperature setting or reduce the conveyor speed. If over shrunk, reduce the temperature setting or increase the conveyor speed. By manipulating the temperature and conveyor speed one could get the best result and productivity.

Make final adjustment of speed and temperature after the temperature has reasonably stabilized.

If POF or PVC film used, to avoid the conveyor rod marks on the product then adjust the conveyor rod support so that conveyor rod support will fret conveyor rods and the rod will rotate.

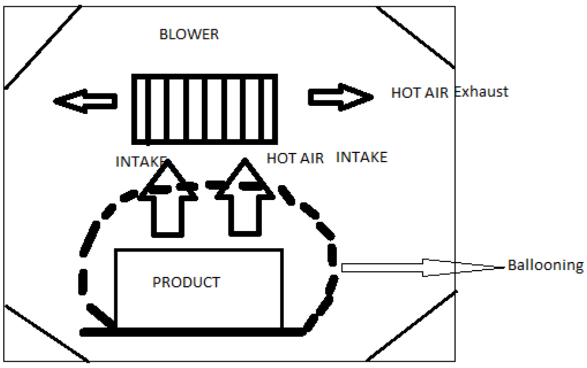

Fig. 2: Ballooning process

V. FILM SHRINKING SYSTEMS

Hot air in tunnel causes ambient air inside the bag to expand, but with the heavy blow from blower fan vent holes bleed-off to reduce excess pressure and prevent the bag from rupturing and the bag got shrink.To get proper shrinking, polyolefin films and polyethylene films need an air escape hole or puncturing. A bag formed with PVC film does not need artificially created air escape holes. Because the PVC film available in markets are already punchered and is full of small pinholes; through this pinholes the air escapes during the shrinking process.

In order to get proper shrinkage, polyolefin film and polyethylene films must be exposed to the appropriate temperature for the specific amount of time (which can be controlled by conveyor speed), and also be provided with a appropriate air velocity or wind turbulence. The air allows the film to keep away from the product, and a bubble is formed around it. A good and even shrink will result when this occurs.PVC films shrink readily when exposed to heat, and therefore air velocity is not critical. In the market there are low cost tunnels which have no settings to control air velocity and it is difficult to get a good shrink in such machines.

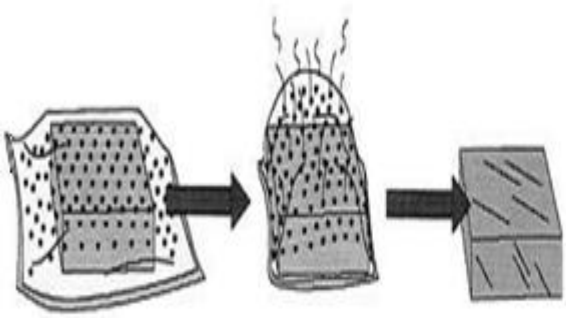

Fig. 3: Ballooning and air escape for shrinking

VI. SCOPE OF THE PROJECT

- Shrink labels on small bottles
- Packing foods such as cheese, meats and fish.
- Skin packs
- Better use of human resources.
- Easier to automate.
- Easier to control..
- Reduced material handling and transit time.
- Reduced set up time.
- Reduced work-in-process inventory.

VII. ASSEMBLY DRAWINGS

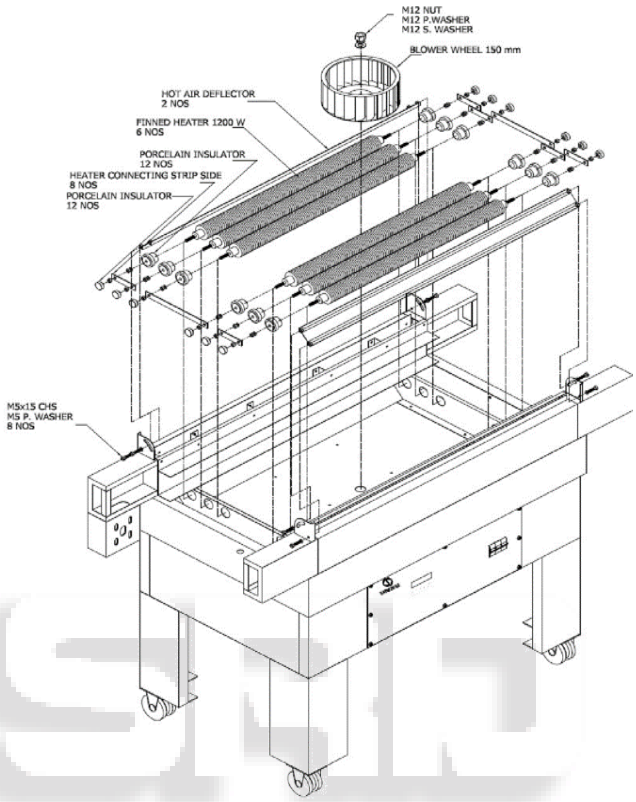

Fig. 4: Heater and blower fan Assembly

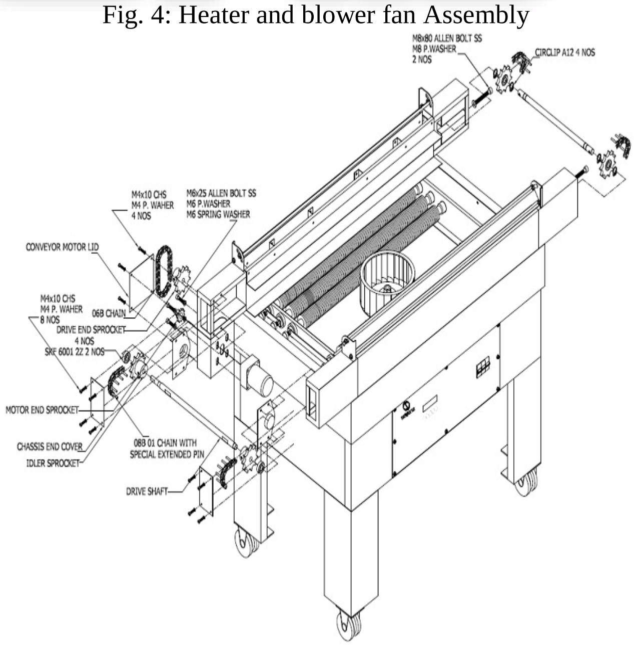

Fig. 5: Assembly of chain and sprockets Drive mechanism

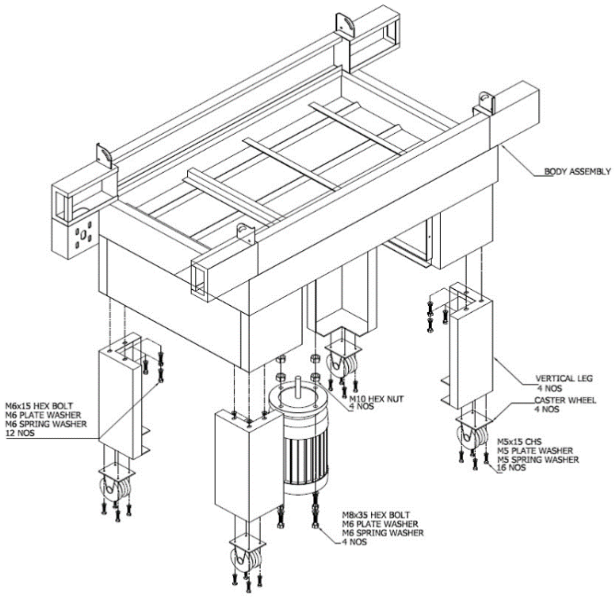

Fig. 6: Leg and blower motor assembly

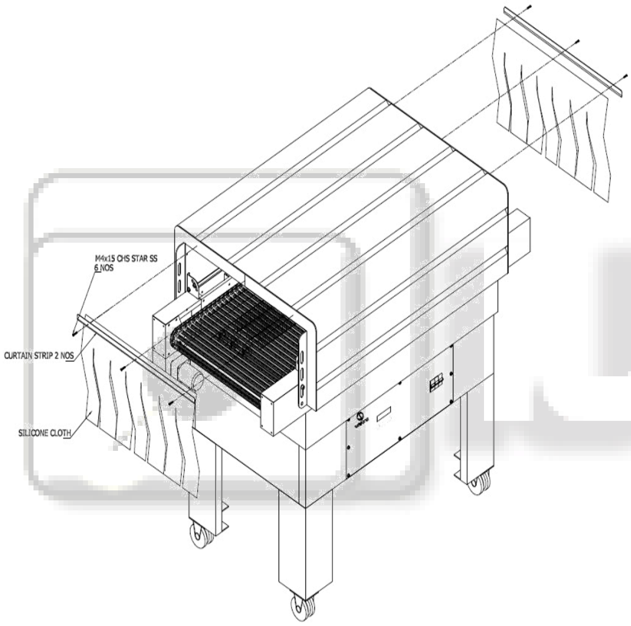

Fig. 7: Curtain Assembly

VIII. TECHNICAL SPECIFICATIONS

A. Three Phase Induction Motor:

Application : Blower motor
Type : YS7124
Output : 0.5HP and 0.37KW
Poles : 4
Voltage : 220V/380V 50Hz
Current : 1.94A/1.12A
Rpm : 1400rpm
INS : B IP44
Mounting : Flange type
Allen key : 6mm

B. Single Phase AC Motor:

Application : Conveyor motor
Specification :Small Parallel-shaft
Gear Motor :60W single phase 220V 1350rpm
Gear box :51K60RGN-CFT

C. Speed Controller:

Application :To vary the speed of conveyor motor
Specification :AC motor speed controller 60W

D. Conveyor Tube:

Length : 400mm
Outer diameter :10mm

E. Temperature Sensor:

Platinum tip, 2 wire type
Resistance : 9.2 - 10.1 ohm
Length : 100mm

Window width (mm)	450
Window height (mm)	250
Voltage (V)	415/3P
Power (KW)	8
Conveyor speed (M/Min)	0-10
Maximum load weight (Kg)	20
Machine length (mm)	1200
Machine width (mm)	660
Machine height (mm)	1040

Table 2: Technical Data

IX. TEST RESULTS

Specified Operating voltage :415V
Technical Observations

A. Power Consumption:

At 415V :7.20KW
At 400V :6.68KW
At 380V :6.04KW
Insulation Resistance before HV test : >100Megaohms
Dielectric strength : Withstood 1500V AC RMS
Insulation Resistance after HV test :>100Megaohms

B. Mechanical Dimensions:

Length :1280mm
Width :8300mm
Height :1240mm
Window :450mmX250mm

C. Performance Test Results:

Speed of Conveyor Regulator:
@ Speed 9 : 6.3 Mts/Min
@ Speed 8 : 6.0 Mts/Min
@ Speed 7 : 5.5 Mts/Min
@ Speed 6 : 5.2 Mts/Min
@ Speed 5 : 4.8 Mts/Min
@ Speed 4 : 4.4 Mts/Min
@ Speed 3 : 4..0 Mts/Min
@ Speed 2 : 3.6 Mts/Min
@ Speed 1 : 3.3 Mts/Min
Time Required to build up Temperature to 150 0C : 15 Min

D. Temperature Rise of Parts After 1 Hour Of Operation Conveyor Motor : 45 0C

Fan Motor: 46 0C
Out side Heating Chamber : 70 0C
Shrinkability of PVC Sleeves : OK
Shrinkability of Polyolefin : OK
Shrinkability of LDPE Sleeves : OK
Fabrication : Good


Fig. 8: Shrink Tunnel Machine

X. CONCLUSION

The project is completed with all design works, fabrication, assembling and testing.This project is a research design and development of shrink tunnel. I define product development as the transformation of a market opportunity and a set of assumptions about product technology into a product available for sale. My review is deliberately broad, encompassing work in the academic fields engineering design , prototyping and production - manufacturing.The review is intended primarily for two audiences, to benefit new researchers entering the field of product development and to experienced researchers who are interested in learning about the research in Shrink Tunnel Development for packaging industries.

REFERENCES

[1] R.Graham Bell, Sandra M Moorhead, Dorota M Broda, Influence of heat shrink treatments on the onset of clostridial “blown pack” spoilage of vacuum packed chilled meat.Volume 34, Issue 4, 2001, Pages 271–275.
[2] S.Nanda,Shantha Krishnamurthy, Effects of shrink film wrapping and storage temperature on the shelf life and quality of pomegranate fruits.Volume 22, Issue 1, March 2001, Pages 61–69.
[3] T.J. Cowell Montell Polyolefins Inc., Wilmington, Delaware, USA, Spherilene Process LDPE for Conventionally Blown Shrink Film,A volume in Plastics Design Library 1998, Pages 299–304.
[4] Ana Cláudia C. Tahara, Influence of different shrinking temperatures and vacuum conditions on the ability of psychrotrophic Clostridium to cause ‘blown pack’ spoilage in chilled vacuum-packaged beef. Volume 92, Issue 4, December 2012, Pages 498–505.
[5] AC 20125108: Design of Experiments Modeling of a heat tunnel , Dr. Lash B. Mapa, Purdue University, Calumet,Mr. Avanish Reddy Vancha, Purdue University, Calumet.
[6] New Product Development by DFMA and Rapid Prototyping,Wankhade Nitesh Prakash, V. G. Sridhar and K. Annamalai School of Mechanical and Building Sciences, VIT University, Chennai, India.