Designing a Rotary Die Cutter and Increasing the Efficiency of Delamination Process

Shubham Kotian[1], Swaraj Naik[2], Jatin Nawar[3], Anuj Pal[4], Rajkumar Devkar[5]

[1,2,3,4]UG students, Department of Mechanical Engineering, VIVA Institute of Technology, Maharashtra- 401 305
[5] Assistant Professor, Department of Mechanical Engineering, VIVA Institute of Technology, Maharashtra- 401305.

---***---

Abstract - *Blanking operation is used for the production of seals (wads). Previously blanking operation was carried out by using gravity as a force to blank out the seals. A rotary die cutter has to be designed as manufacturing of complex seals is not possible on traditional machines since they exert large amount of force on the laminated sheet. Blanking operations also have a huge amount of scrap left which cannot be recycled together as it consists of aluminium foil and paper cardboard. Thus in order to tackle this issue, a delamination machine needs to be designed.*

A seals manufacturing company was selected for this study. The main aim of this project is to design a rotary die cutter for production of complex seals and also improvement in delamination process is desired as it will help in recycling the scrap.

***Key Words*: blanking operation, complex seals, delamination, recycling, rotary die cutter.**

1. INTRODUCTION

Lamination is the technique/process of manufacturing a material in multiple layers, so that the composite material achieves improved strength, stability, sound insulation, appearance, or other properties from the use of the differing materials. A laminate is a permanently assembled object created using heat, pressure, welding, or gluing. The project work presented in this report is based on improvement of a machine such that it can easily delaminate the seals (wads). The process involves heating. PID controller is used to control the temperature variation. Apart from this productivity of complex seals are required by the company for which a roller die cutter with designated complex design has to be fabricated. Arrangement of gear & rollers, rpm will be implemented in systematic manner in order to achieve improved productivity.

A long sheet or web of material will be fed through the press into an area known as a "station" which holds a rotary tool that will cut out shapes, make perforations or creases, or even cut the sheet or web into smaller parts. A series of gears will force the die to rotate at the same speed as the rest of the press, ensuring that any cuts the die makes line up with the printing on the material. The machines used for this process can incorporate multiple "stations" that die cut a particular shape in the material. In each of these stations lie one or more of these geared tools or printing cylinders, and some machines use automatic eye registration to make sure the cuts and/or printing are lined up with one another when lower tolerances are required.

1.1 Research Objective

After researching many journals and patents we have decided to follow these necessary things,

a) In order to achieve blanking of complex dies, we have to design a rotary die cutter with considering various factor such as material selection and withstanding wear and tear. We also have to maintain proper pressure while punching operation to avoid wear and tear and to have a proper blanking action.

b) In order to achieve delamination process, we have to design a guide way in order to avoid slippage of the scrap sheet. We also have to stabilize the temperature of roller using PID controller and to find the optimum speed to get the proper output and efficiency.

2. PROBLEM DEFINATION

a) Problem Definition 1:

After visiting the company for several times at Maauli Associates, there was a problem for production of complex seals as there were no special purpose machine were present which could carry out such kind of task. Due to which there was a huge chances of loss of order for the company as their clients were demanding such kind of seals. The company requirement was to design a rotary die cutter and its mechanism to perform blanking operation for production of complex seals (wads).

b) Problem Definition 2:

At Maauli Associates there was also a problem found that the company was unable to solve the problem of recycling the scrap which would left behind after the production of seals takes place. They had to keep these scrap as part of inventory but keeping it would not be beneficial. With further digging into the matter following causes were identified; Lack of information regarding temperature required to separate board and aluminium foil without burning it also the sheets had holes punched out already. Removal of foil was difficult to carry out without any breakage due to induced strain. In order to perform the delamination task smoothly and efficiently planning for optimum speed of roller was required..

3. METHODOLOGY

3.1 For blanking of complex seals

Laminated sheet on feed rollers is pulled into the rotary die cutter by using pull rollers. For which two rotary die cutter in series is used. Rotary die cutter 1 will be used to punch out complex design required, this complex design will be wrapped on the die. Rotary die cutter 2 will be used as a blanking die to blank out the seals. The blanked out seals will be collected by a carriage placed below the rotary die cutter.

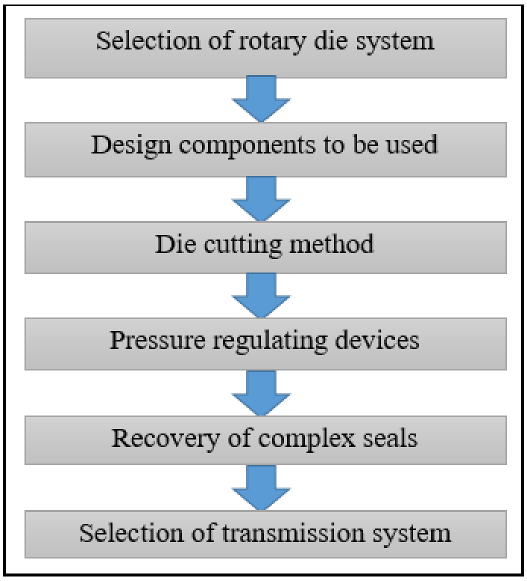

Fig: 3.1 Flowchart for blanking of complex seals

1. Selection of die system:

The selection of die was decided by analyzing the nature of the cut, amount of seals to be produced, the material of the seals and overall layout of the machine. Interchangeability and ease of operation with better die life were the main criterion of the design.

A flexible die cutting system with anvil was chosen. One of the most significant benefits of flexible rotary cutting dies over solid dies is cost. Because flexible dies are composed of a thin sheet of metal rather than a solid cylinder. They are simpler and less expensive to manufacture.

Due to their comparatively low manufacturing cost, flexible dies are readily replaced when damaged or fatigued. They can also be easily switched out from process to process with little downtime. The ease of change out allows for faster lead times and shorter turnaround.

2. Design components used/implemented:

- Magnetic Cylinder:

1. Magnetic cylinders are designed and manufactured with high precision and accuracy.
2. These cylinders are manufactured with the materials such as high quality ferrite magnets and non-magnetic stainless steel which provides excellent corrosion resistance.
3. Ferrite magnets are non-corrosive as they are made from iron oxide which is already corrode and thus corrode further. They can be used in high temperatures of up to 250 degree Celsius.
4. For improved corrosion resistance high chromium steel was selected.
5. For grade 420 of high chromium steel, the density is 7800 kg/m^3.

- Flexible dies:
  1. Flexible dies are made of a thin sheet steel material.
  2. They fold around the magnetic cylinder and get attached to it.
  3. Solid dies are also used in some application. Solid die is a solid steel cylinder and they are traditionally used for long run applications and extended die life.
  4. The density of flexible dies should be 8038.7 kg/m^3.
  5. The ultimate tensile strength of the flexible dies should be 400-500 MPa.
  6. These properties are taken into consideration when designing the dies.

Table 1: Specifications of Flexible dies

Material	Thin steel sheet
Tensile strength, Yield	250 MPa
Brinell hardness	121
Modulus of Elasticity	200 GPa
Bulk Modulus	140 GPa
Shear modulus	80.0 GPa
Electrical resistivity	0.00001170 ohm-cm

- Anvil roller:
  1. The material for Anvil roller selected was high tensile steel as it met the requirements.
  2. Designing of this roller was done so that it can be used for cutting the web.
  3. Surface finish of the roller plays a crucial role in order to perform efficient operation.
  4. The design was done such that the roller is more durable.

Table 2: Specifications of anvil roller

Material	High tensile steel
Brinell Hardness	62 HRC
Bending stress	3800 N/mm^2
Charpy impact value 10mm r-noch	25 J/cm^2
Compressive strength	3500 N/mm^2
Thermal expansion coefficient × 10^{-6}/degree Celsius	12.2

Thermal conductivity	16.5 W/(m.k)
Young's modulus	209 Pa

3. Die-cutting method:
As constant shearing action is performed by the dies, the proper die-cutting method was chosen. Kiss cutting method was implemented in the system. With this method die cutting and kiss cutting can be performed at the same time by using a die that has two different blade heights. This method makes the machine compact. By implementing this method the efficiency of overall system was increased.

4. Pressure regulating device:
After analysing different pressure regulating techniques, we implemented pneumatic pressure regulator in the system. This system accurately controls the lowering of the die cutter onto the support roller that is the anvil

Fig: 3.2 Air pressure regulator

5. Recovery of complex seals:
Recovery roller arrangement for collection of seals a carriage system was employed. A simple and cost-effective system was designed which enables ease of retrieving complex seals.

6. Selection of transmission system:
Since high accuracy is required. A proper transmission system was selected. This system is called timing belts.
Timing belts were selected on following basis:

1. They are non-slipping mechanical drive belts.
2. They were selected on the basis of parameters such as less noise, lubrication bath is not necessary, better accuracy, etc.
3. The belts type selected was AT series.
4. The material used for the timing belt is molded polyurethane.
5. As these belts have no splice or welding, they have no weak cross sections.

Table 3: Specifications of timing belts

Material	Polyurethane
Belt length	1490 mm
Distance between pulleys	510 mm
Allowable tensile strength	190-1400 N
Belt pitch	15
Belt width	100 mm
Maximum length	20,000 mm
Tension members	Steel standard, Kevlar optional

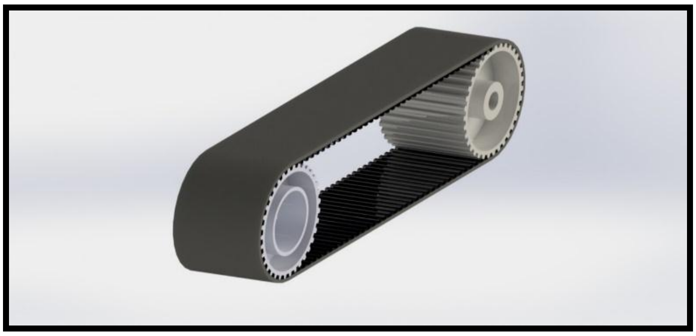

Fig: 3.3 Timing Belt

3.2 For Delamination Process

Scrap after blanking process will be pulled into the guideway and then into the pre-heated roller. This roller uses resistive heating coils but this can be also carried out by induction heating. The temperature and the speed roller is controlled by using the PID controller. Therefore, due to the heat transfer the wax between the aluminium foil and cardboard paper melts. After that, separation roller sends aluminium foil in upward direction and cardboard paper in downward direction. On both the direction pull rollers will guide the separated material into the recovery rollers.

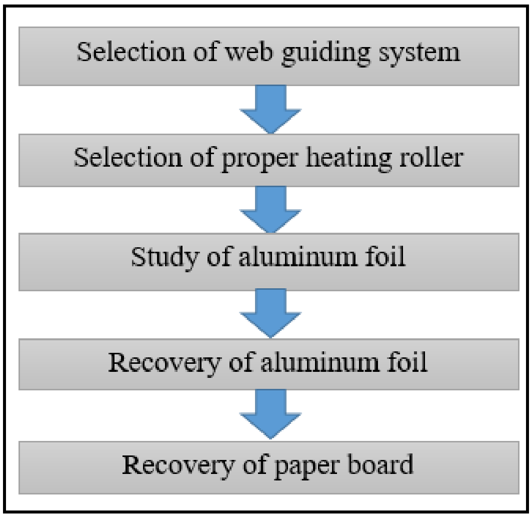

Fig: 3.4 Flowchart for Delamination process

1. Selection web guiding system:
A web-aligner was selected to counter the problem of slippage. In this system a flexible material is transported over rollers; the web tends to align itself perpendicular to the axis of rotation of the rollers. This is called the normal entry rule and this is the reason for web misalignment when

the rollers in a converting machine are not aligned properly. Web guides that align the material use the same normal entry principle. By deliberately changing the axis of rotation of the guide roller, the web guides steer to a different position.

- Web guiding system (web aligning system):

Table 4: Quantity of parts required

PARTS	DIMENSIONS/SPECIFICATIONS/QUANTITY
Motor	0.5 HP
Air pipe	5 meters
Oil pipe	5 meters
Sensor	1 piece
Adjuster	1 piece
Oil filter	1 piece
Hydraulic cylinder	4"; 1 piece

1. The suggestion offered by us was KEW-17 type web aligner.

Table 5: Specifications of web aligner KEW-17

TYPE	KEW 17
Motor rating (3 phase,50Hz)	0.5 HP
Pump flow rate	3.4 litres/minute
Tank capacity	17 litres
Oil type	Servo 32, Enklo 44, Hydro 37
Line pressure	14 bar
Maximum operation force	260kg
Weight including oil	40kg
Air sensor pressure	5 to 28 mbar

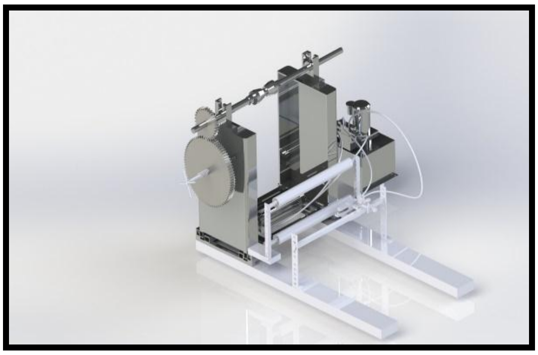

Fig: 3.5 Web guiding system

2. Selection of a proper heating roller

There were two methods available namely resistive heating and inductive heating. We have selected inductive type heating because of the following advantages.

- Increased process speed
- Faster start-ups and roll changes (very fast roll heating)
- Improved control of lamination and profile or patterns transfer
- Fewer waste products
- High power efficiency (up to 95%)
- Lower energy costs
- Higher and more consistent temperature.
- The temperature attained by the heating roller is above 400 degree Celsius.
- Alloy steel contains various elements which can enhance the properties of the material such as mechanical, thermal, corrosion resistance.

Table 6: Material selection for heating roller

Element	Symbol	Weight %	Function
Aluminum	Al	0.95-1.30	Alloying element in nitrating steels
Chromium	Cr	0.5-2.0	Improves hardenability
		4-18	Corrosion resistance
Nickel	Ni	2-5	Increase toughness
		12-20	Improves corrosive resistance

1. Following listed are the SAE grades of the induction heating roller:

Table 7: SAE grades of induction heating roller

Grade	Ultimate tensile strength(minimum) [Psi (MPa)]
950A, B, C, D	67,000 (462)
950X	65,000 (448)
955X	70,000 (483)

The suggested SAE grade of induction heating roller for this machine is SAE 950X

3. Study of aluminium foil:

Foil is a very thin sheet of rolled aluminium supplied in its pure form ('commercial purity') or in a variety of alloys and tempers which gives a wide choice of tensile property.

The thickness of foil ranges from the thinnest currently produced commercially at about 0.0065 mm to the defined upper limit of 0.2 mm. Material thicker than 0.2 mm is defined as sheet or strip.

Aluminium foils are made of element aluminium, which is silvery-white metal with chemical symbol Al. Its atomic number is 13 and the atomic weight is 26.9815. A foil is a very thin sheet of metal, usually made by hammering or rolling. Foils are most easily made with malleable metals such as aluminium, copper, tin, gold.

Attributes:

- Abundance- aluminium is plentiful with no danger of world depletion.
- Barrier efficiency to light, gases, oils and fats, volatile compound and water vapour.
- Temperature resistance from deep-freeze to over-processing.
- Heat conductivity and reflectivity.
- Electrical conductivity.
- Strength and durability.
- Compatibility with foods and pharmaceuticals.
- Ease of lamination and coating.
- Flexibility.
- Formability and non-returning dead fold.
- Decorative potential, brilliant or matt surface.
- Printability by flexo, gravure and offset litho.
- Nontoxicity.
- Low weight.
- Recyclability.
- Corrosion resistance.
- Cost-effectiveness- optimum performance yet resource economy.

4. Recovery of aluminium foil

1. We have to design a recovery rod and assembled it on the top of the heating roller setup.
2. The recovery rod was assembled such that there was very less tension acting on the aluminium foil after delamination as it has low strength.
3. Due to the holes present in the laminate, it was necessary to design a system where the heating and recovery rollers are in sync.
4. The placement of the recovery rod which would collect aluminium will be above the roller because if the aluminium foil comes in contact with the heating roller it would stick to it. Hence, the side of aluminium foil is inserted such that it does not come in direct contact with the heating roller and it is collected on the recovery roller above.

5. Recovery of paper board

1. We have to design the recovery rod for the paper board and assemble it on the bottom side of the heating rollers.
2. There was no problem of tension in the paper board as it has sufficient strength to withstand the tension acting on it during the delamination process.
3. The web was inserted into the heating roller such that the paper board was in contact with the heating roller. There was no problem of the paper board sticking to the heating roller.

We have to design recovery rod and heating rollers to work in sync. This is ensure that the material is smoothly recovered without any breakage

4. CONCLUSION

This project will help Maauli Associates in production of complex seals which was not possible with the conventional machines. Also with the improvement of delamination process reduce and recycle their scrap which was not possible before due to the inefficiency of that machine and helps them to attract more customers and grow their business. This also helps in saving their money as inventory carrying cost and waste handling cost decreases.

ACKNOWLEDGEMENT

We are very thankful to those without them it was difficult to complete the project, **Mr.Mehul Mane, consultant at Maauli Associates, Virar** and Ms. Ujwala Babar, director at Maauli Associates. Other than this **Mr.Saurabh Singh and all employees of Maauli Associates** were so cooperative. We are also thankful to my professors **Mr.Rajkumar Devkar, faculty Advisor; Mr.Chinmay Pingulkar, guide; Mr. Pratik Raut, project head; Mr.Priyank vartak, project head** for being our mentors and guiding us throughout the project.

REFERENCES

Journal Paper

[1] Sudhir Ranjan, Abhishek Sharma, Puneet Chaudhary, An effective temperature control system using PID mechanism, IEEE, 2014.

[2] Prabhu Ramanathan, Sukanya.K.C,Sidhanta Mishra,Sudha Ramasamy, Study on Fuzzy Logic and PID controller for temperature regulator of a system with time delay, IEEE, 2013.

[3] Ahmet Kucukkomurler, Environmental, low cost, energy efficient, electromagnetic indoor induction space heating system design, IEEE, 2009.

[4] Byung Chul Ji, Young A Han and Jietae Lee, Temperature control of Multizone Heated Rollers, IEEE, 2008.

[5] Montenegro Criado, An effective temperature control system using PID mechanism, IEEE, 1996.

[6] Peter G. turner, Exposure meter for use with induction heat sealing of container, U.S. Patent, 1992.

[7] Douglas Treat, Raymond Jorgenson, Rotary die cutting mechanism, U.S. Patent, 1991.

[8] Karl Singer, Double sided lamination machine, U.S.Patent, 1990.

[9] Gregory A Kent, Phillip D Frye, Russell S Brayton, Rotary die cutter, U.S. Patent, 1998.

[10] Philip S. Carter, John F krumme, Alternating current electrically resistive heating element having intrinsic temperature control, U.S. Patent, 1979.