Design and Fabrication of Magic Dog for Power and Free Conveyor

Prithviraj Vagambar Kamble[1], Snehal Ankush Samindar[2], Azim Shabbir Tamboli[3], Dr. J. A. Hole[4]

[1,2&3]Student, Department of Mechanical Engineering, JSPM's RSCOE, Tathawade, Maharashtra, India
[4]Professor, Department of Mechanical Engineering, JSPM's RSCOE, Tathawade, Maharashtra, India

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Abstract - *The "Magic Dog" power and free conveyor system is a groundbreaking innovation designed for low-load applications in diverse industrial settings, addressing a significant gap in the market, especially in India where importing such systems is costly. This project focuses on creating a low-cost, efficient solution to enhance material handling processes. The system features a robust trolley equipped with pusher dogs, pivotal in controlling load movement and positioning with precision. Driven by a blend of mechanical and electronic components, the pusher dogs facilitate smooth transitions across various conveyor tracks, making the system highly adaptable to complex manufacturing environments. Key attributes of the "Magic Dog" system include its modular design, allowing for easy customization and scalability, and an integrated drive mechanism that ensures consistent speed and torque for reliable operation. Advanced sensors and control units enable real-time monitoring and adjustments, minimizing system failures and downtime. The system's flexibility to handle a wide range of loads, from lightweight to heavy-duty materials, eliminates the need for multiple specialized conveyors, leading to significant cost savings and space optimization. Overall, the "Magic Dog" prototype represents a major advancement in material handling technology, promising improved productivity and operational flexibility. Future enhancements could further elevate its capabilities, solidifying its role in modern manufacturing and logistics.*

Key Words: Magic Dog, Power and Free Conveyor, Design, Chain, Load, Trolley, etc.

1. INTRODUCTION

Power and free conveyors are commonly employed to move components along an assembly line, facilitating the transition from one process to the next. Unlike basic continuously moving overhead monorail conveyor systems, Power and Free conveyors can stop individual loads without stopping the entire production line.

The Power-and-free conveyor is a conveyor that is inherent in its design. That is flexible routing, variable speeds, the ability to accumulate or stop carriers, sort products, and move through processes, overhead space utilization, precision to work with automation, and easily expandable and adaptable to product change. It consists of two tracks. The power track, or upper track, is powered by a chain, while the free track is where carrier trolleys move. The driving mechanism of power and free conveyor systems is the power chain, made up of forged and heat-treated side links, center links, and chain pins. Special side link pushers are installed at intervals on the chain to propel the power and free carrier. Drive power is transferred to the free trolley by pusher dogs attached to the power chain that operates in the upper track. These Conveyors can be used as floor conveyors termed Inverted Power & Free conveyor.

Standard Conveyors Available in India –

Table -1: Industrial Power and Free Conveyors.

Sr. No.	Particulars	Capacity Per Trolley
Light Duty	-CTPF 100	-100 KG
	-CTPF 250	-300Kg
Heavy Duty	-IBPF 300 333	-300 KG
	-IBPF 550 444	-550 KG
	-IBPF 1800 466	-1800 KG

In the Table above there are standard power and free conveyor systems available in India. The most light-duty conveyor capacity is 100 kg. there is no power and free conveyor system with less than 100 kg capacity in India.

In the heavy-duty models, the 333,444,466 refers to the size in inches of different parameters such as

For 466, 4 indicates 4” of I beam Power track, 6 indicates 6” of chain pitch (chain specification), and 6 indicates 6” of free track channel.

According to the capacity different materials are used for manufacturing keeping in mind the cost effectiveness, corrosion resistance, anti-wear properties, light weight, etc.

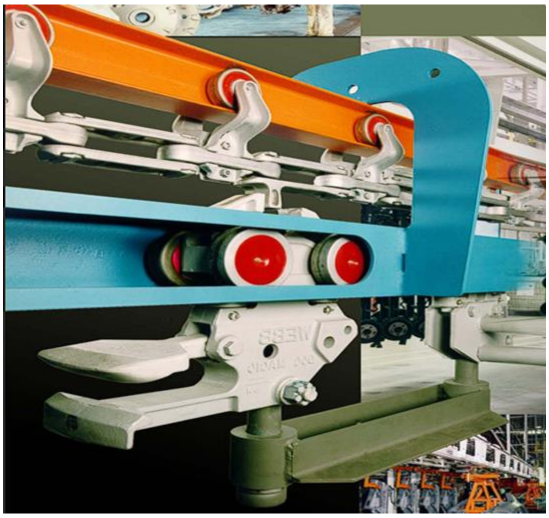


Fig - 1: Magic Dog

Power and free conveyors are the backbone of the overhead conveyor product range. These systems are primarily used to transport parts along an assembly line from one process to the next. Additionally, they allow products to buffer along the conveyor path. Their versatility lies in their ability to automatically stop and start parts as needed.

Power and free conveyors offer direct, precise control over each load, making them ideal for industrial applications requiring high versatility, productivity, and efficiency. This control is achieved through their dual-track design. The primary (or 'power') track is a chain-driven conveyor that moves carriers through the system. The secondary (or 'free') track enables individual carriers to detach from the main track and switch onto a nearby spur line.

The 'free' track, which carries the product load, runs parallel and directly below the power track. It is an assembly composed of two formed channels designed to accommodate the free trolley load and guide wheels.

Attached to the motor-driven chain are the magic dogs, which convey the free trolleys around the system. The ability for the trolleys to disengage from the magic dog is what makes a conveyor "Power and Free".

Currently in the Indian market, Power and Free conveyors are available for only heavy load applications starting from 100 kg. there is no such low-cost system available for material handling of say 10 kg to 20 kg weight. It is very uneconomical for industries to import this type of system with low load-carrying capacity.
The efficient movement of materials within industrial settings is crucial for optimizing productivity and reducing operational costs. Chain conveyor systems are widely used in various industries such as manufacturing, warehousing, and logistics for the seamless transportation of goods. However, designing an optimal chain conveyor system requires careful consideration of factors like load capacity, speed, energy efficiency, and reliability.

1.1 Objective

- To design a power and free conveyor for low load application of 10kg to 20kg load.
- To reduce the overall cost of manufacturing and installing the power and free conveyor system
- To Enhance the overall performance of power and free conveyor systems across different industries for lightweight applications.

2. LITERATURE SURVEY

Future studies in power and free conveyor systems might explore advancements in energy-efficient technologies, integration of smart sensors for real-time monitoring and optimization, and the development of materials with enhanced durability and reduced environmental impact. Additionally, research could focus on automation and machine learning applications to improve system intelligence and adaptability in various industries.

"Study of Advance Manufacturing Through Power and Free Conveyor System" Author: V. Navaneethan

Power and Free conveyors are built on a two-track system and can help optimize and improve your available space through automation and expert systems.

"Improvement of Mechanism of Conveyor System" Author: M.A. Muda, F.I. Malek

In this paper, the conveyor system is successfully improved using a drive chain. This paper helps to utilize their engineering information and improve the skill of students in solving mechanical problem

"Design & Analysis of Heavy-Duty Overhead Conveyor System" Authors: Rutwij Kulkarni, Shantanu Palwe, Siddhant Adep, Prof. Dr. P.G. Kulkarni

This paper describes the design and analysis of a heavy-duty overhead conveyor system. The goal is to create a system that can handle a 100 kg payload, which is double the capacity of the existing system. The new system needs to be cost-effective and meet current market demands.

" Modified Power and Free Conveyor" Authors Prof. H.D. Sarode, Gaurav Hadavale, Abhay Adekar.

This paper discusses a new design for a power and free conveyor system. Power and free conveyor systems are widely used in logistics for transporting goods. They are ideal for situations where goods need to be accumulated or sorted.

3. METHODOLOGY

First, we have done all the basic research and study on how the Power and Free Conveyor Work. Then we observed what is the importance of the Magic Dog/ Pusher Dog in this Conveyor. It is the most important part of Power and Free Conveyor. All the automatic operations of Loading, Travelling, changing from one line to another line, and starting and stopping the movement are Performed by the magic Dog.

We did a basic Study on the Magic dog design and work. Also, we did a study on what are the different parts of the Power and Free conveyor. The study of the different parts is also important as it gives us the idea of which factors need to be considered for studying the behavior of Magic Dogs in different Conditions.

The Different Steps that we have gone through are as follows: -

❖ Data Collection:

Collecting data on existing pusher dog behavior. This involves measurements of force, displacement, contact angles, and wear and tear under different operating conditions. Different materials used for manufacturing Magic Dog behave differently under different conditions. So, we needed to collect data on different Materials.

❖ Define Project Scope and Objectives:

The type of magic dog we are going to study and design. Will it be a passive, spring-loaded, or actuated design? Considering factors like cost, complexity, and desired controllability. Here we studied and designed a spring-loaded Magic Dog.

Defining the conditions we are going to study: This includes conveyor speeds, load weights, material types, and incline angles relevant to our target application. Setting objectives for our project like optimizing pusher dog performance, reducing wear and tear, or developing a new design.

❖ Design and Modelling:

This involves calculations of forces, moments, and contact mechanics based on chosen design and operating conditions. Creating detailed CAD drawings of our pusher dog design. This includes dimensions, material specifications, and any specific features. This is used for prototype construction and analysis.

❖ Prototyping and Testing:

We built a prototype of a pusher dog design using the required materials. Measured the pusher dog's performance according to our objectives. This involved force measurements, displacement behavior, and wear analysis. Compared our test results and initial objectives. Identified any differences and corrected the design.

❖ Analysis and Optimization:

Analyze the data collected from testing. Analyse pusher dog behavior under different conditions. Identify areas for improvement based on our objectives. Optimize the pusher dog design. This involves adjusting dimensions and operating parameters.

❖ Documentation and Conclusion:

This includes research, design, testing procedures, and results. Creating a report with clear conclusions and recommendations for future work. We considered factors like cost, and manufacturability when designing the magic dog. These are the steps in this project. We did this project under the full guidance of the Company Guide sir as they are experts in this field

4. SOLID MODELLING

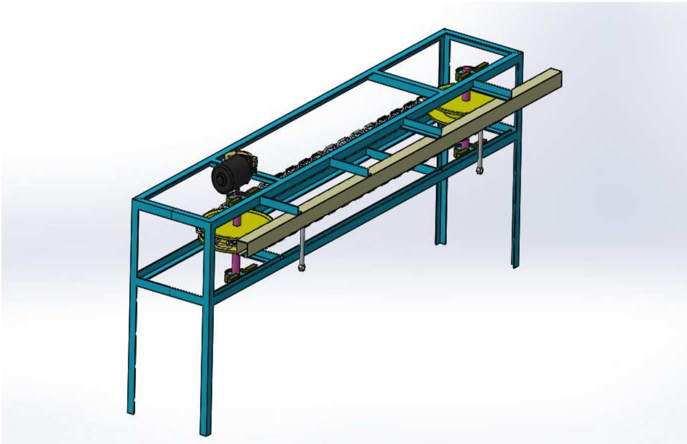


Fig - 2: Assembly isometric view

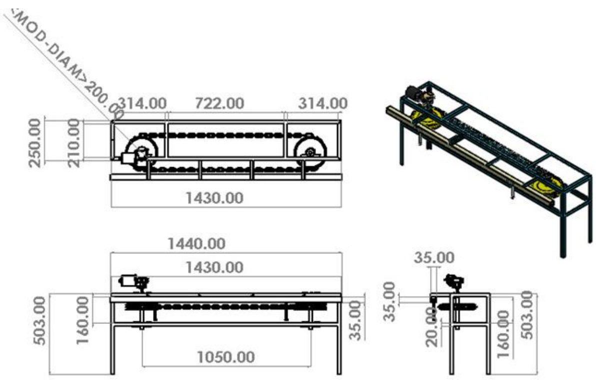


Fig - 3: Drafting

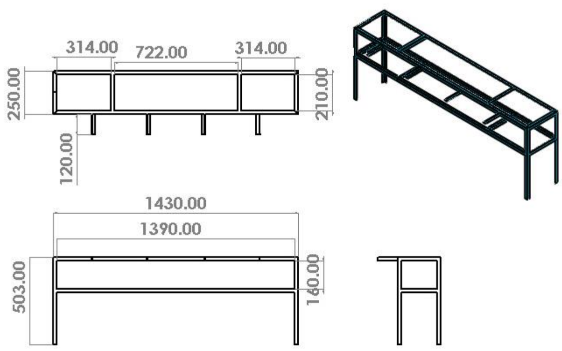


Fig - 4: Frame

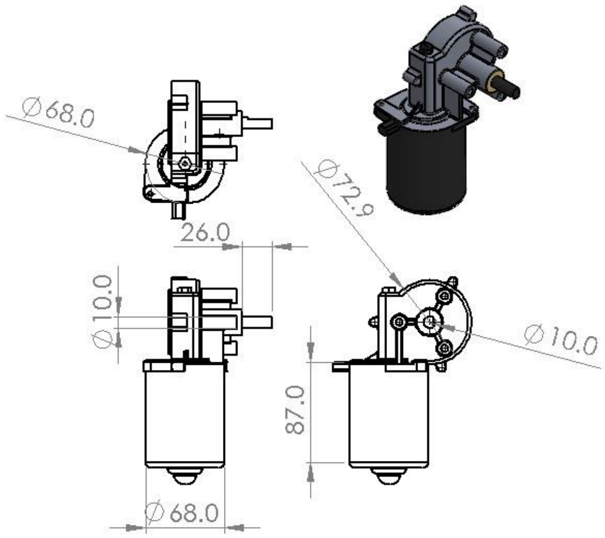


Fig. - 5: Gear motor

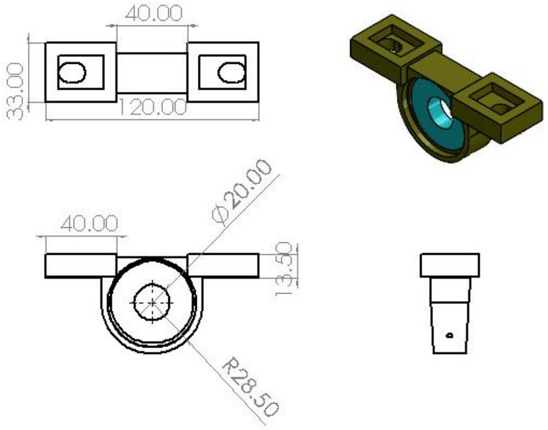


Fig - 6: Bearing

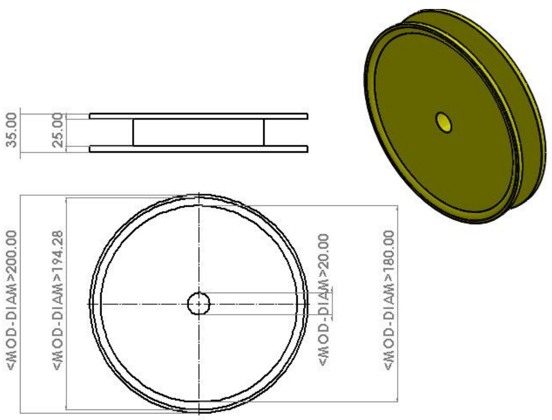


Figure 7: Sprocket

4. DESIGN CALCULATIONS

Material = C 45 (mild steel)
Take Factor of Safety 2
$\sigma_t = \sigma_b = 540/fos = 270\ N/mm^2$
$\sigma_s = 0.5\ \sigma_t$
$= 0.5 \times 270$
$= 135\ N/mm^2$

4.1 Power transmitted by shaft

Calculation for final speed & torque

$$P = \frac{2\pi NT}{60}$$

$$15 = \frac{2\pi x 30 x T}{60}$$

T = 4.77 N-m
T =4774 N-mm

4.2 Force generated by shaft

T = Force × radius of chain sprocket

4774= F× 100
F = 47.74 N

$$F = \frac{47.74\ N}{9.81}$$

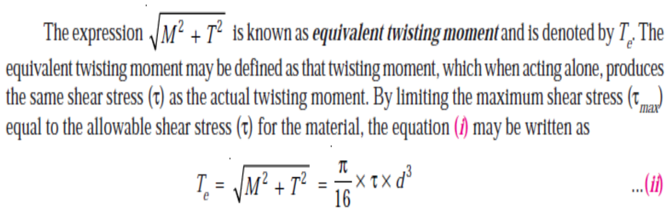
<u>F = 4.86 Kg</u>

4.3 Design of shaft

Shafts Under Combined Twisting and Bending Moments

When a shaft experiences both twisting and bending moments simultaneously, it must be designed to accommodate both types of stress at once. Several theories have been proposed to explain the elastic failure of materials under various combined stresses. Two of these theories are particularly significant for this subject:

1. Maximum shear stress theory or Guest's theory. It is applicable to ductile materials like mild steel.
2. Maximum normal stress theory or Rankine's theory. It is applicable to brittle materials such as cast iron.
Let τ represent the shear stress induced by the twisting moment, and
σb denote the bending stress (either tensile or compressive) caused by the bending moment.
According to the maximum shear stress theory, the maximum shear stress in the shaft is given by:


The expression $\sqrt{M^2 + T^2}$ is known as ***equivalent twisting moment*** and is denoted by T_e. The equivalent twisting moment may be defined as that twisting moment, which when acting alone, produces the same shear stress (τ) as the actual twisting moment. By limiting the maximum shear stress (τ_{max}) equal to the allowable shear stress (τ) for the material, the equation (*i*) may be written as

$$T_e = \sqrt{M^2 + T^2} = \frac{\pi}{16} \times \tau \times d^3 \quad ...(ii)$$

Fig - 8: Expression

The total weight on the shaft coming is by tightening of chain
Let us assume that it is pulled by a 5kg weight
W=5 kg= 50N
M= FxL/4
M= 50x150/4=1875 N-mm
$T_e = \sqrt{M^2+T^2} = \sqrt{1875^2+4774^2}$
T_e=5129.00 N-mm

$T_e = \pi/16 \times 135 \times d^3$
$T = \pi/16 \times \tau \times d^3$
Select permissible shear stress (τ) from the design data book. C45
Therefore, $5129 = \pi/16 \times d^3 \times 135$
$d^3 = 6.76 \times 10^3 \times 16/3.142 \times 135$
d = 5.78 mm
But we are boring a 20mm shaft for fitting the motor shaft inside it, therefore our shaft design is safe.

4.4 Design of bearing

But the standard size available is 20mm, therefore we will select 20mm Dia
Therefore, the shaft size will be 20mm.
When the shaft diameter is 20mm, we use the standard break number P204.
P=pedestal bearing
2=spherical ball
=04=5 * 4 = 20mm
The bore diameter of the bearing

4.5 Linear velocity for conveyor

$V = \pi DN/60$
$= 3.142 \times 0.2 \times 30/60$
$V = 0.3141$ m/s. = 1.13 km/hr.

4.6 Angular velocity for conveyor sprocket

$\omega = 2\pi N/60 = 3.142$ radians

4.7 Design of bolt for sheer stress failure

The bolt needs to be securely fastened and will experience a load from rotation. Determine the stress for C-45 steel. The bolt's standard nominal diameter is 9.31 mm. According to the design data book, the M10 bolt corresponds to a diameter of 8 mm as per the table. Let us check how much load the bolt can sustain -
P =? N is the value of force
Stress = load/area

$\sigma = \frac{P}{A}$

$A = \frac{\pi}{4} d^2$

$A = \frac{\pi}{4} 8^2 = 49.98$

$P = 135 x 49.984$

P = 6747.84 N = 687 kg
Our design is safe because the calculated load exceeds any applied load.

4.8 Battery Calculations

Charging Time:
Battery - 12V/5 Amp = 60 watts
Total watt consumed
1 motor = 15watt
Discharge Time = (Battery watt/Total watt Consumed)
= 60/15
≈ 4 Hrs.
= 240 min

4.9 Design of frame

Let the total weight (P) of our machine be 20 kg, now this 20 kg weight is kept on four angles
The design is safe because the induced bending stress is lower than the allowable bending stress, which is 270 N/mm2.
Frame
P = 20 kg.
P = 20 x 9.81 = 200 N.
L = 300 mm.
M = WL/4 = 200 × 300/4
= 15000 N-mm
Section of modulus = $Z = B^3/6 - b^4/(6 \times B)$

$Z = 20^3/6 - 17^4/6 \times 20 = 1333.3 - 696.4$
$Z = 638\ mm^3$
Bending stress = M/Z = 15000/638 = 23.51 N/mm^2
As induced bending stress is less than allowable bending stress i.e., 270 N/mm^2 design is safe.

4.10 Design of transverse fillet welded joint.

Hence, selecting weld rod size = 3.2mm
Area of Welding = 0.707 x Weld Size x L
= 0.707 x 3.2 x 25
= 56.56 mm^2
Force exerted = ---N
Stress-induced = Force Exerted / Area of Weld
21 = F / 56.56

F= 1187.76 N = 121.07 kg
Maximum Allowable Stress for Welded Joints = 21 N/mm^2

4.11 Design of Spring:

Design of extension spring to handle load of 10 kg
Let us find the force required to push the trolley containing a 10 kg load
So, 10 kg = 10 × 9.81
= 98.1 Newton

For nylon roller on the aluminum surface consider the coefficient of rolling resistance = 0.005
So, push force or fiction = normal load × coefficient of rolling resistance
= 98.1 × 0.005
= 0.49 Newton

For the extension spring, we cannot find out the sideways force at which it gets deflected. But we can find out at which load vertically applied the extension spring deflects.
This load will be always Less than sideways load.

Dimensions of spring-
Wire diameter (d) = 1.5 mm
Mean coil diameter (D) = 8.6 mm
Number of active coils (N) = 38
Modulus of rigidity of spring material (G) = 79000 N/mm^2
Initial tension factor = This is an imperial factor that depends on the spring's manufacturing process and design. It usually ranges from 0.2 to 0.5 for most extension springs.
Let us consider it 0.5
Therefore, (Kt) = 0.5

So, the force required to change the shape of the extension spring = the initial tension (preload) of the spring which does not allow the spring to change its shape.

Therefore, the initial station (preload) can be found from the following formula.
Force= Kt× Gd^4/(8D^3N)
= 0.5 × 79000×1.5^4/ (8×8.5^3×38)
= 1.07 Newton
So, the actual force required to change the shape of the spring from the sideways force will be more than 1.07 Newton.
The spring will not bend at the pushing force of 0.49 Newton. It will only bend win the topper is present and the sideways for the exits 1.07 Newton force.

Fig - 9: Pusher Dog Spring

5 SCOPE OF FUTURE WORK

- In-depth analysis of Magic Dog behavior: Conducting simulations and experiments to analyze the behavior of the Magic Dog under various loading conditions, conveyor speeds, and inclines. This will involve studying factors like contact forces, stresses, wear and tear, and potential failure modes.

- Optimizing Magic Dog design: Based on the results of the behavior analysis, the design of the Magic Dog can be optimized for enhanced performance, increased safety, and extended service life. This may involve exploring different materials, geometries, and contact surfaces.

- Material characterization and selection: Evaluating the suitability of various materials for the Magic Dog, considering factors like strength, wear resistance, fatigue life, and compatibility with other components.

- Cost-benefit analysis: Conduct a comprehensive cost-benefit analysis to assess the economic viability of implementing the optimized Magic Dog design compared to existing solutions.

- Real-world validation: Testing the optimized Magic Dog design in a real-world conveyor system to validate its performance and effectiveness under practical operating conditions.

- By thoroughly investigating these areas, the project can achieve its objective of designing a highly efficient and reliable Magic Dog for improved performance and longevity within the power and free conveyor systems.

6 RESULTS

1) **Efficiency of Material Handling:** The "Magic Dog" prototype demonstrated significant improvements in the efficiency of material handling within the power and free conveyor system. The unique design allowed for smooth transitions between powered and free-moving sections, reducing delays and enhancing overall throughput.

2) **Versatility and Flexibility:** The system proved to be highly versatile, accommodating a variety of load sizes and weights. The trolley and pusher dog mechanism effectively managed different types of cargo, showcasing the system's flexibility for diverse industrial applications.

3) **Precision and Control:** The integration of advanced control mechanisms allowed for precise positioning and movement of trolleys. The "Magic Dog" system ensured accurate stops and starts, crucial for processes requiring exact timing and placement.

4) **Reliability and Durability:** The prototype exhibited robust performance with minimal maintenance requirements. The components, particularly the pusher dog and trolley interface, showed high durability under continuous operation, indicating the system's reliability for long-term use.

5) **Safety:** Safety features were successfully integrated, preventing collisions, and ensuring smooth operation even in complex conveyor layouts. This reduced the risk of accidents and equipment damage, enhancing workplace safety.

7 CONCLUSION

This project successfully explored the design, fabrication, and operation of a power and free conveyor system with a 10 kg load capacity.

Theoretical Foundation: A comprehensive study of power and free conveyor systems has been completed, providing a strong theoretical foundation for the project.

The "Magic Dog" prototype within a power and free conveyor system demonstrated substantial benefits in terms of efficiency, versatility, and cost-effectiveness. Despite some initial challenges, the long-term advantages in operational performance and energy savings make it a promising solution for modern industrial material handling needs. Future developments focused on automation, user interface, and sustainability will further enhance the system's capabilities and applicability across various industries.

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