Conveyor Production Capacity Validation

Executive Summary

Problem:

The proposed chain tensioner for a conveyor is the largest quick ship off the shelf chain tensioner available, but the limits of this tensioner are unknown. The limits of this tensioner directly affect the rate of production.

Findings: Production variables were translated into an engineering equation so that the largest off the shelf chain tensioner could be analyzed. The limits of the chain tensioner were discovered so that production can be set to run at reliable limits and maximize profit. These recommended production settings for this chain tensioner are shown in our recommendation.

Options:

a) Guess and hope it works
b) Run production lines at limit off the shelf chain tensioner (optimizes time and money)
c) Custom solution for chain tensioner (expensive and long lead time)
d) Complete redesign of conveyor line (extremely expensive)

Recommendation

At the stated operating conditions the proposed tensioner provides a minimum safety factor of 2.0. Future production increases beyond these operating conditions should be evaluated before implementation.

Table 1: Recommended Production Settings

Variable	Description	Value
Q	Production Rate	2 Parts per Second
w	Weight of Part	5.4 Lbs per Part
v	Speed of conveyor	1.0 Feet per Second
L_{flat}	Length of Conveyor (Flat)	15 Feet
L_{slope}@45°	Length of Conveyor (Slope)	7.07 Feet

Background

The conveyor geometry establishes the physical assumptions used throughout the analysis.

A manufacturing facility has successfully operated a conveyor system for several years. Increased customer demand now requires the production line to operate at a higher throughput than originally intended. A sketch showing the layout of the conveyor is shown below.

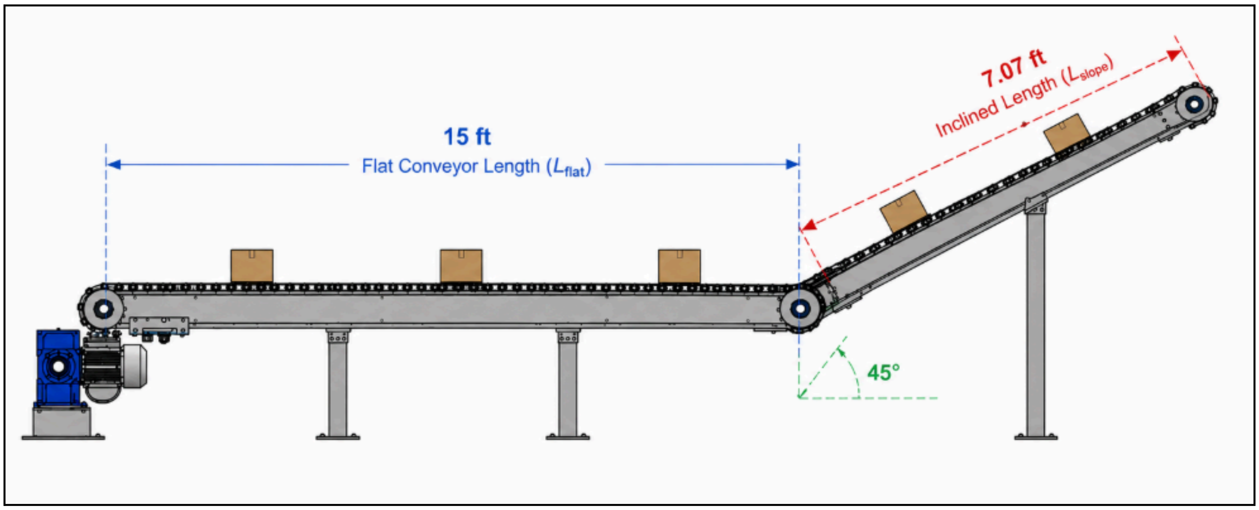

Image 1: Defines conveyor geometry

The engineering team has determined that the conveyor chain tensioners should be upgraded to support the additional loading associated with the production increase.

Multiple standard catalog tensioners are available with increasing load capacities and costs.

One option is simply to purchase the largest standard tensioner available.

While this approach is easy to implement, it does not answer an important engineering question:

> **What is the highest volume of production that the largest easily available chain tensioner can support before the tensioner fails and production stops?**

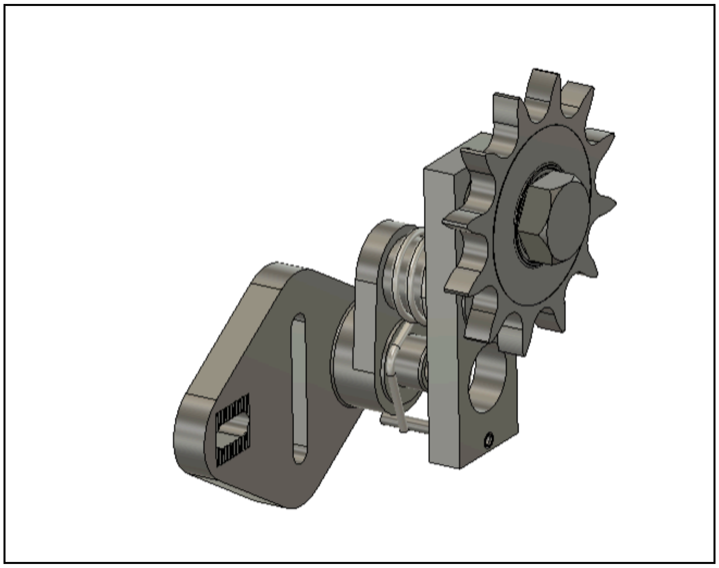

Image 2: Proposed Tensioner

Without that answer, management cannot determine whether the selected component will support future production goals or whether the next increase in throughput will require another redesign.

Beyond the largest standard catalog option, specialty components become necessary. These components typically involve longer lead times, higher procurement costs, potential mounting modifications, and increased project complexity.

The objective of this study is to determine the operating envelope of the largest standard catalog tensioner and identify the production level at which custom solutions become necessary.

The Business Problem

Understand what drives the study

Increasing production requires capital investment.

Management can confidently justify purchasing a larger catalog tensioner if it supports both current production goals and future growth.

However, if the production target exceeds the capability of even the largest standard component, the company enters a different category of investment involving specialty components, custom engineering, longer lead times, and additional cost.

The value of this Design Review is not selecting the largest catalog component.

It is identifying where the boundary exists between standard, readily available components and custom-engineered solutions.

That information allows management to plan production increases with confidence, understand when additional capital investment becomes necessary, and avoid discovering those limits only after production has already outgrown the equipment.

The Engineering Challenge

Production variables must be converted into engineering inputs before analysis can begin.

The challenge is not selecting a larger component.

The challenge is determining the production capacity that the larger component enables. Where is the limit of what a component can do? How do you take the available information and make it usable for engineering purposes?

Operational conditions such as parts per hour, weight of the part, conveyor speed and other variables are measurable, but they don't give engineering the information needed to determine what the tensioner experiences under those operational conditions. Engineering needs the following inputs to solve the engineering challenge:

- Mechanical Load Case
- Thermal Load Case
- Specific Material Data (what kind of materials are being used)
- Identifying how the part is being mounted to a larger assembly

Solving the engineering challenge is critical to establish:

- Whether the selected tensioner is appropriate for the target production rate.
- The production level at which the largest standard catalog tensioner reaches its practical limit.
- When specialty components should be considered.

Connecting the Engineering Challenge to the Business Problem

How to make the business goals solvable

What is critical to answer now is how we take the information that is available and connect the engineering problem to the business problem. The first important part is establishing the mechanical load case. This is accomplished by using production objectives with an engineering equation that tells us how much force the chain tensioner sees. This will establish the mechanical load case. The particular equation to translate production variables into a mechanical load case is called:

The Money Equation.

$$F_{tensioner} = K\frac{Qw}{v}(\mu(L_{flat} + L_{slope}) + L_{slope}sin\theta) \quad (1)$$

Table 2: Production Input Table

Variable	Description	Value	Units
$F_{tensioner}$	Force on tensioner	-	Lbf
K	Startup/shock Factor	2.0	Unitless
Q	Production Rate	2.0	Parts per Sec
w	Weight of one part	5.4	Lbf per Part
v	Conveyor speed	1.0	Feet per Second
μ	Friction Coefficient	0.15	Unitless
L_{flat}	Loaded flat conveyor length	15	Feet
L_{slope}	Loaded inclined conveyor length	7.07	Feet
θ	Conveyor incline angle	45	Degrees

When anyone asks why the tensioner had to be sized for a particular force, this is the equation that you show them. Now that we have the money equation and we can take the variables of real world parameters shown in Table 2 and understand what force the chain tensioner experiences,

$$F_{tensioner} = 180\ lbf$$

The calculated 180-lbf load now becomes the engineering load case used to evaluate whether the proposed tensioner can safely support the desired production rate.

This establishes the mechanical load case required for engineering analysis.

For the thermal load case, we will note that the mounting bracket is at the same temperature of the air which is at 68.0 ℉. Due to the motion of the bearing, heat is generated and the temperature of the gear that interacts with the chain is at 85.0 ℉. The temperatures would be determined by taking temperature readings under operational conditions. While this temperature change is minimal and not likely to be a significant factor, accounting for it provides a more accurate analysis. Table 3 identifies the material assigned to each component within the model.

Table 3: Material Properties

Part within Model	Material
Bracket Assembly, Rotational Arm, Spring Pin	A36 Steel
Spring	302 Stainless Steel
Gear	1045 Steel
Bolts, Hex Nut	A36 Steel
Bearing	1045 Steel

Now we have a mechanical load, a thermal load and specific material data. The model shows a slot where a bolt would go through. This geometry represents how the entire assembly would be mounted to a bracket or other solid fixture and have no movement. Constraining this slot would represent the tensioner placed at the desired location where it is interacting with the chain that drives the conveyor. This constrained slot will be shown in the analysis setup. Now we have all of the inputs that engineering needs to run an analysis of the model.

Analysis

With the engineering inputs defined, the model can now be evaluated.

This model and representative analysis has assumptions about the variables, model and parameters of the inputs, every engineering analysis has assumptions. These assumptions are listed below for clarity and transparency.

Assumptions:

1) The model does not have any manufacturing defects or issues that would affect the material strength
2) The startup factor (K = 2.0) accounts for startup acceleration and operational loading variations
3) The weight of the chain from the conveyor is ignored
4) Material properties are based on ASME values for the materials listed in Table 3
5) The load is interacting evenly over two faces of the gear
6) The assigned materials are representative of commonly used materials for this application
7) Equivalent static analysis; transient dynamics are not modeled
8) Bearing failure is not addressed in this analysis
9) The freedom of rotation that the bearing allows is accounted for in this analysis
10) Conveyor is under continuous load
11) Parts are evenly spaced on the conveyor
12) Proper tension on the chain is maintained at all times
13) Conveyor is rigid relative to the tensioner assembly
14) Wear is not affecting the system

With the list of assumptions and force developed from the money equation, the model was prepared for analysis.

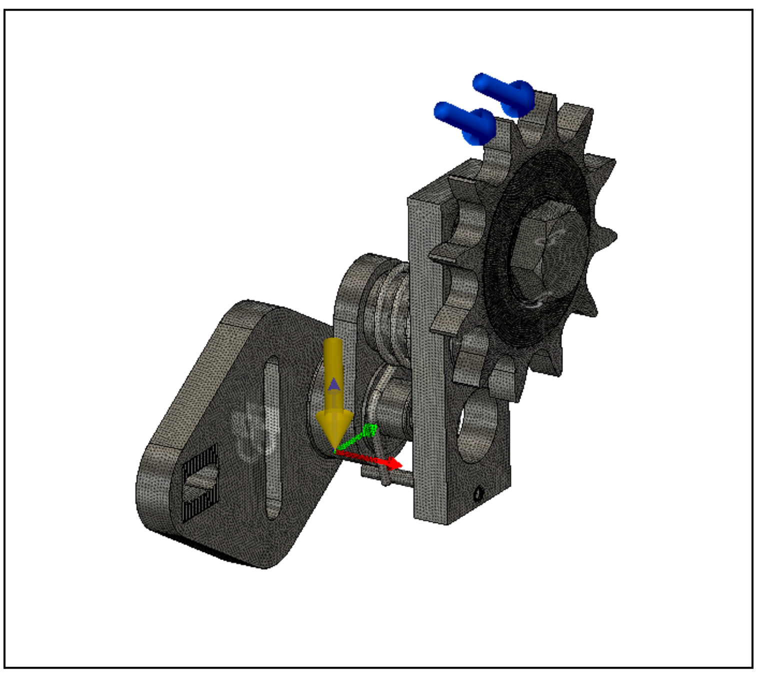

Image 3: Load Cases, Constraints and Material Assignment

Image 3 shows how the model was prepared for the analysis. The setup involves specifying each component with a specific material, mechanical load case, thermal load case and constrained geometry that we have previously determined. The yellow arrow represents gravity acting downward. The blue arrow represents the calculated mechanical load. The locked symbols represent constrained geometry, and the temperature symbol identifies the applied thermal load.

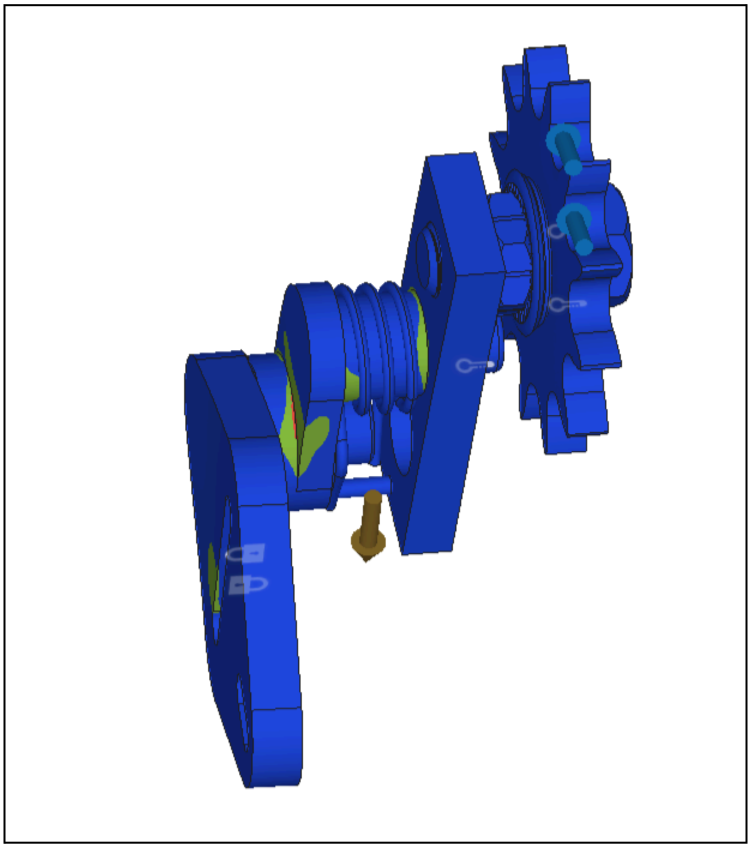

Image 4: Design Hotspots Under Production Conditions

Image 4 shows the physical locations where the design is approaching its limits. The blue has a minimum safety factor of 8.0, green has a minimum safety factor of 6.0 and red has a safety factor of 2.0. As noted in Image 4, the areas of green and red are the principal interest. The colors indicate the locations where the assembly is reaching its limits under the specified production conditions. The force that is exerted on the assembly wants to bend the tensioner. If production demand increases beyond the conditions evaluated in this study, these Design Hotspots are the locations where failures would be expected to initiate first. A safety factor of 2.0 provides an appropriate margin that variations in the assumptions, variances in manufacturing tolerances or operational conditions do not cause reliability issues with the tensioner.

Key Takeaway and Outcome

With a minimum safety factor of 2.0, the proposed tensioner is capable of supporting the stated production rates. This analysis accounts for the stated operational conditions and the assumptions stated. This analysis optimizes minimal disruption of the current equipment and maximizes production capacity to make a facility as profitable as possible. The table below provides recommended settings to run a conveyor in conjunction with the proposed chain tensioner.

Table 4: Chain Tensioner Production Recommended Limits

Variable	Description	Value
Q	Production Rate	2 parts per second
w	Weight of Part	5.4 lbs per part
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If additional production or demand is required then an additional line built in a similar manner could be installed. If limiting factors such as space are in play then a new or redesigned conveyor system could also be considered. The associated cost implications should be considered before increasing production beyond the recommended limits. Operating below the recommended production rate reduces profitability, while operating above the recommended production rate increases the likelihood of reliability issues and unplanned downtime. By translating production objectives into an engineering load case, this Design Review establishes the operating limits of the proposed tensioner and provides management with production recommendations supported by engineering analysis.