Automatic Syringe Mechanical Power Transmission Improvements

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ABSTRACT

A company that manufactures medical devices, and which is located in the south of Puerto Rico, is presenting problems in a high-speed automatic syringe inspection line. The syringes are transported through conveyor lines which are having several failures with the mechanical power transmission components such as the couplings. A Finite Element Analysis showed that disproportionate torque forces created stresses that exceeded the yield point of stainless steel, therefore, causing failure of the couplings. Four possible solutions were developed; these solutions range from purely mechanical torque protection to digital monitoring of the torque in a jam. The most protective and reliable design for replacing the actual system at low implementation cost and complexity is the spider coupling with torque limiter. This system will also add a complete protective system to the motor, conveyor components and will guarantee the elimination of the current potential 39K losses in manufactured units per conveyor.

INTRODUCTION

A company that manufactures medical devices, and which is located in the south of Puerto Rico, has been presenting problems in a high-speed automatic syringe inspection line. A sensor in the inspection line detects several critical parameters and/or defects present on the syringes. It separates each syringe individually and spins it in front of several cameras in order to compare with the established acceptance criteria. Depending on the inspected syringe result, it would be accepted as good or rejected for a visual re-inspection.

The syringes are transported through conveyor lines that transport syringes by their flanges across the line between machinery. It is powered by means of an electric motor and a speed reducer. Syringes line counts with 8 ATM manufactured conveyors. The conveyors consist of an electrically powered motor with a speed reducer.

Conveyors are having several failures with the mechanical power transmission components such as the couplings. The coupling that serves as a connection between the speed reducer and the conveyor's mechanism has broken several times since these conveyor types were implemented in the production.

OBJECTIVE

The objective of this project is to reduce the number of failures of the mechanical transmission components.

FAILING COMPONENTS ANALYSIS

The first task of the project was to analyze the initial problem in terms of root cause and economics. For this reason, the failing components were designed and analyzed using Computer Aided Design (CAD) software and Finite Element Analysis (FEA) using Solid Works and NX Nastran.

By building the current coupling in Solid Works and analyzing it in Nx-Nastran when subjected to 15 N-m (which is the maximum torque that can be provided by the motor according to the transmission's plate), it can be observed that it undergoes tremendous stress when a jamming occurs. (up to 515 MPa). Most of the stress is concentrated along the neck of the coupling, due to its design as shown in Figure 1. Most of the stress is concentrated along the neck of the coupling, due to its design.

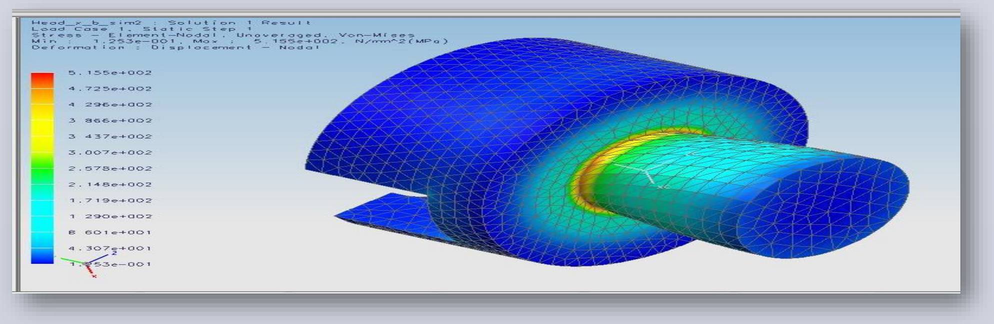

Figure 1: Failing Coupling FEA 3D Model

COUPLING SYSTEMS ANALYSIS

Four ideas have been proposed, each approach trying to solve the problem from a particular viewpoint. The options taken into consideration are the Spider Coupling with Torque Limiters, a Stub Shaft Coupling, Universal Coupling and Standard Spider coupling without Torque Limiter.

Spider Coupling with Torque Limiter:

The first solution is to implement a spider coupling with a torque limiter manufactured by R+W Company. The spider coupling with torque limiters is a mechanical device that connects two shafts in order to transmit both torque and rotation [1]. Figure 2 shows the spider coupling with torque Limiter Assembly Sketch. This coupling consists of a mechanical device that can be set to disengage at the prescience of a specified torque (in this case 15 N-m). Once the torque is restored to its operating range, the coupling will automatically re-engage [2]. Since the torque control is controlled by a purely mechanical perspective, this approach will be considerably less costly.

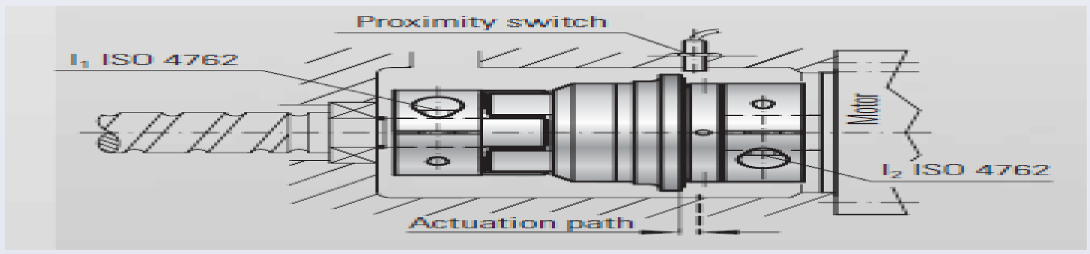

Figure 2: Spider Coupling with Torque Limiter Assembly Sketch

In order to integrate the spider coupling with torque limiter on the conveyor mechanism, a custom spacer had to be designed. Figure 3 shows the spider coupling with torque limiter and the custom spacer assembly. The custom spacer was designed to compensate for the difference in distance between the motor and the conveyor.

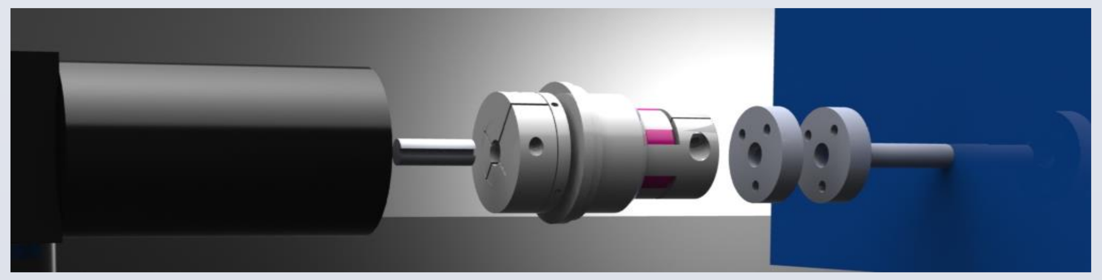

Figure 3: Spider Coupling with Torque Limiter and the Custom Spacer Design Assembly

For the Von Misses Analysis, a safety factor of 2 was assumed with only shear stresses caused by torsion of the shaft. In Figure 4 it can be seen that the yield strength of the Stainless Steel 302 is 500 MPa. Stainless Steel 302 is a chromium-nickel stainless steel which is a tough austenitic alloy and is widely used in the stamping, spinning, and wire forming industry [3].

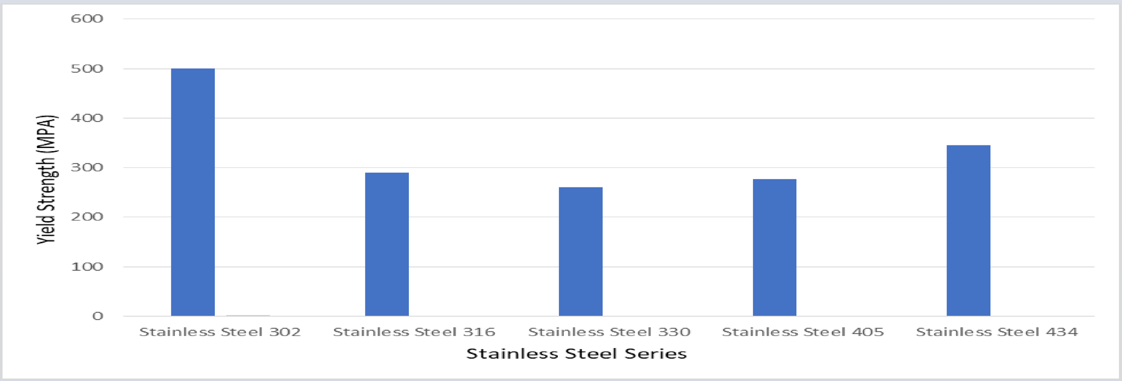

Figure 4: Stainless Steel Series Yield Strength Comparison

Equation (1) shows the Von Misses Stresses calculation used to determine the yield strength of the spider coupling with a torque limiter. Since the yield strength of Stainless Steel 302 is 500 MPa and the resultant yield strength of the component is 153 MPa, the component meets with the given safety factor and it should not fail.

$$\sigma_{vm} = 3.46 * \frac{T}{(\frac{\pi}{2})r^3} = \frac{2.203*T}{r^3} \leq \sigma_y \quad (1)$$

Stub Shaft:

In order to increase the strength of the coupling, the possibility of a Stub Shaft type Coupling is being considered. This type of coupling consists of a drive shaft with ridges that transfer torque and maintains communication with the coupling part [4].

This approach consists in developing a design of a stub shaft that can be custom made to fit in the system and it will be designed with the necessary specifications to avoid failure. Figure 5 shows the stub shaft custom design. The design is composed of two separate pieces. The male component will be connected to the transmission while the female component will be connected to the conveyor mechanism.

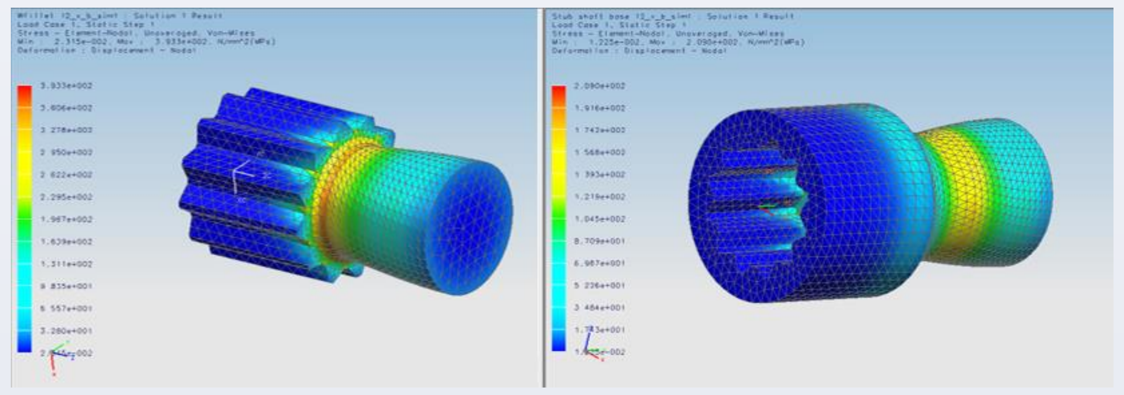

Figure 5: Stub Shaft Custom Design

In order to implement these components into the system, it is required to replace both the external shaft of the motor's transmission and the internal shaft of the conveyor's mechanism. Because it is a custom made coupling, manufacturing of both components is considerably expensive.

Universal Joint:

The universal joint is a spherical articulated mechanism very used to connect two shafts whose axes are cut [5]. In terms of toughness, this type of joint is usually a little bit weaker than spider hubs.

In order to integrate the universal joint on the conveyor mechanism the Inner Shaft and the motor shaft components had to be custom designed. Figure 6 shows the inner shaft and motor shaft custom design assembly. The custom design of the inner shaft consists of an extended length in order to be clamped with the universal joint.

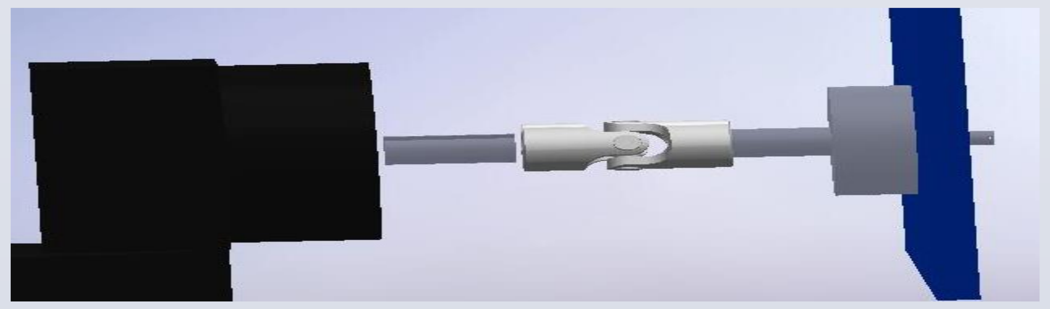

Figure 6: Stub Shaft Custom Design Assembly

The universal joint coupling is not a good candidate to solve the problem because it has some drawbacks: it can produce vibrations in the engine area, which may mean the emergence of other problems through the conveyor and this, in turn, affect production directly, this added to the high costs of implementation and modification of components, do not they represented the most viable option.

Standard Spider Coupling without Torque Limiter:

The standard spider coupling without torque limiter is a mechanical device that connects two shafts in order to transmit both torque and rotation [6].

In order to integrate the standard spider coupling without torque limiter on the conveyor mechanism, the Inner Shaft component had to be custom designed. Figure 7 shows the inner shaft custom design. The custom design of the inner shaft consists of a completely solid and extended length in order to be clamped with the new coupling.

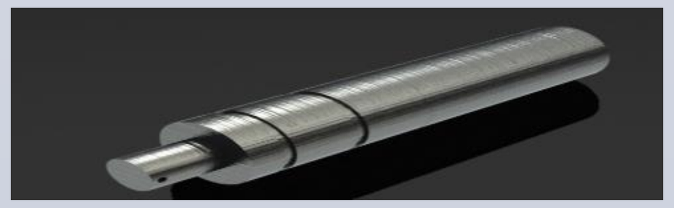

Figure 7: Inner Shaft Custom Design

DESIGN SELECTION

The entire new coupling designs were tested analytically in terms of stress and failure, cost effectiveness, protection of the equipment and syringe product, and reparability in order to determine which will be the overall best design. The Torque Limiter Spider Coupling was selected as the main solution to the problem. These couplings provide a great maximum torque capability (34 N-m), they are easy to replace, are made of very durable materials like aluminum and stainless steel, they do not need lubrication, their cost is relatively low and they provide torque overload protection [1].

Cost Analysis:

The only two components that need to be custom made are the spacer and the inner shaft in order to implement the spider coupling with torque limiter approach. Table 1 shows the total project costs:

Table 1: Total Project Costs

Device	Cost
Inner shaft	$570
Spacer	$400
Coupling Unit	$300/conveyor
Total	**$1,270/conveyor**
Implementation Costs	
Technician hourly salary	$40/hr.
Mounting Time	3hrs/conveyor
Total	**$120/conveyor**
Total Project Cost	**$1,390/conveyor**

CONCLUSION AND RECOMENDATIONS

It was determined that the spider coupling with torque limiter was the most protecting and reliable design for replacing the actual system because the same has an overload torque sensing technology that disengages the motor from the conveyor at unsafe torque levels. This feature will enable the technicians and engineers to adjust the disengaging torque of the coupling to one in which will assure that in case of a conveyor jam the torque provided by the motor will not break any syringe. Losses of 39K units per conveyor of potential manufacturing due to conveyor line downtime are avoided while protecting the conveyor components and WIP syringes at low implementation costs ($1390/conv).

A test run it is highly recommended to be made before implementing the new system on the 8 conveyors. This test run shall validate that the conveyor speed is not affected. Also, it should validate that the torque at which the coupling disengages is low enough to not break any syringe. Finally, this test run should be made for several hours of continuous operation in order to validate the endurance of the new coupling system.

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