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.*

Key Terms *— Coupling, Design, Shaft, Torque.*

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.

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

LITERATURE REVIEW

A variety of different couplings are offered in the market at relatively low cost. However, many of them did not fit the production's applications since either they were too big for the space required or their maximum torque load rating was too low. Also, another constraint of many of the couplings offered in the market was their lack of protection to the equipment and product.

The big majority of these couplings had to work with torque monitoring and controlling devices in order to provide the required level of protection [1]. This, of course increases the price and complexity of the design solution. However, it could provide more benefits at long term to the solution since more specific and precise monitoring can be achieved through these types of machines.

Four possible solutions had been considered; these solutions range from purely mechanical torque protection to digital monitoring of the torque in a jam. The first solution is to implement a spider coupling with torque limiters which is a mechanical device that connects two shafts in order to transmit both torque and rotation. The spider coupling with torque limiters is a mechanical device that connects two shafts in order to transmit both torque and rotation [2]. It can be greatly modified to fit several different design scenarios. This feature shall also simplify the design process of the modification of the current conveyor system.

This system can have an optional proximity sensor which senses when the coupling has been disengaged because of a torque overload and thus send a signal to the motor or controlling device to either stop the operation or to sound an alarm. Also, this protection system has the advantage of automatic engagement. In other words, if a torque overload is sensed, the coupling will fully disengage. However, when the overload has been removed, the coupling automatically will engage once again and continue with its normal operation [3].

Also, another considered approach was the stub-shaft coupling. This type of design is very common in the axles of automobiles because of its durability and great torque loading capabilities. This type of coupling is often present in the union between the spindle and the wheel of a car because of its relatively small size and shear stress resistance capabilities [4].

Another option that could be used to solve the problem was the Universal Union (U-Union) with a torque monitoring device. Basically, the universal joint is mounted in pairs, so that non-uniformity of the first gasket is compensated by the second. It is used to connect two non-aligned axes whose ratio of angular velocities is non-constant and is a function of the angle formed by the axes [5]. The Universal Union (U-Union) is normally used in the industry, so it could be easily replaced and brought from suppliers. This design option is good because of its good torque load capabilities but it provides an additional degree of freedom that is not necessarily needed in the conveyor and could cause additional bending moment and stresses [5].

The fourth approach analyzed was the standard spider coupling without Torque limiter; which is a mechanical device that connects two shafts in order to transmit both torque and rotation. The main constraint of this system is that the torque overload protection is by means of an electric device [6].

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. 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. Since the torque control is controlled by a purely mechanical perspective, this approach will be considerably less costly.

In order to integrate the spider coupling with torque limiter on the conveyor mechanism, a custom spacer had to be designed. Figure 1 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.

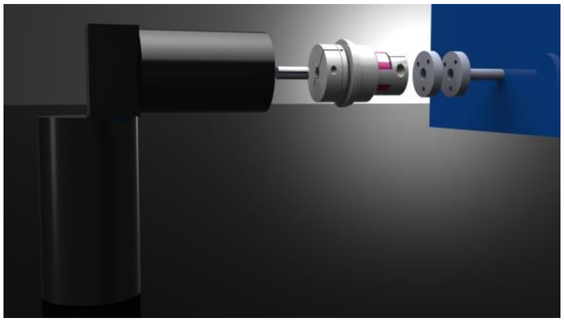

Figure 1
Spider Coupling with Torque Limiter and the Custom Spacer Design Assembly

The design analysis of the coupling was really in terms of choosing a coupling rate that could handle the maximum torque of 15 N-m that the motor provides. For this reason, the chosen coupling 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 [2]. In addition, it has a maximum torque capacity of 34 N-m, which gives a safety factor of more than two.

For the Von Misses Analysis, a safety factor of 2 was assumed with only shear stresses caused by torsion of the shaft. In Figure 2 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.

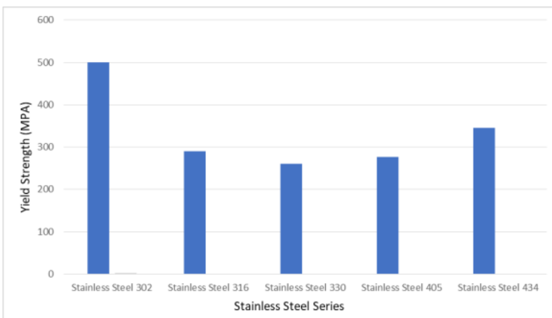

Figure 2
Stainless Steel Series Yield Strength Comparison

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.

$$\sigma_{vm} = 3.46 * \frac{T}{\left(\frac{\pi}{2}\right)r^3} = \frac{2.203*T}{r^3} \le \sigma_y \qquad (1)$$

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.

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 3 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.

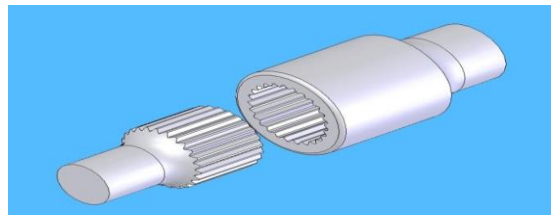

Figure 3
Stub Shaft Custom Design

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. Since the system's torque overload protection is by means of an electric device adds a higher degree of flexibility to the system, it adds complexity as well since this device has to be programmed and adjusted to the control logic of the motor and the conveyor in order to work properly. 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. In terms of toughness, this type of joint is usually a little bit weaker than spider hubs.

The material utilization of the universal joints has their particular advantage. U-joints can transmit relatively high torque with minimal radial loads. Made of high-grade steel (aluminum and stainless steel), because of that it is easy to repair.

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 4 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.

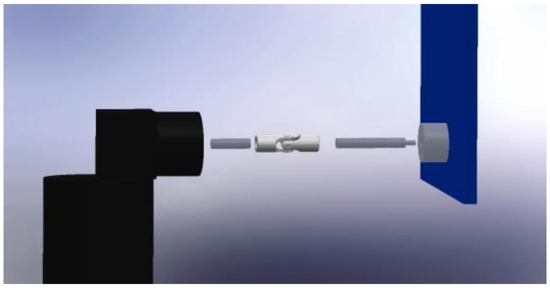

Figure 4
Stub Shaft Custom Design Assembly

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. These couplings provide us with a great maximum torque capability (25 N-m), they are easy to replace, are made of very durable materials like aluminum and stainless steel, they do not need lubrication [6]. Also, since it has an electric torque monitoring system, this could represent a more advanced protective method of the product, the conveyor, motor and the coupling.

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 5 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.

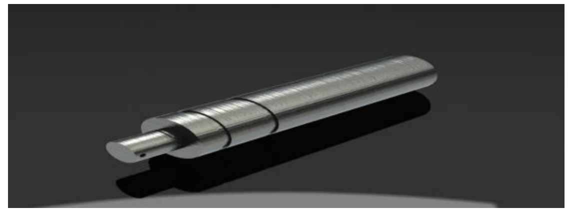

Figure 5
Modified Inner Shaft

DESIGN SELECTION

The design process began with the determination of the problem, in essence, the form of better performance conveyor both an efficient and secure as possible, which does not affect the daily functioning of other components. Once the emerging options that have been identified are understood, some are already pre-established, requiring a few design improvements in order to finding ways to improve them according to their needs.

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. The more suitable coupling of these types for the project was the one offered by R+W. 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.

The system offers an adjustable range of torques in which the coupling can disengage and engage once again. This feature enables 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.

Costs 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.

Following are the modification costs of the current components:

- Inner shaft= $470
- Aluminum Spacer= $400
- Replace actual motor shaft: $100
- Coupling Unit= $300/conveyor
- Total: $1,270/conveyor

Implementation Costs:

- Technician hourly salary: $40/hr.
- Mounting Time= 3hrs/conveyor
- Total: $120/conveyor

The total project cost will be approximately $1,390 per conveyor. This cost outline was based on a quotation made by an external machine shop. These costs can be even lower since both of the parts can be manufactured locally inside the firm's machine shop since they have their own tool makers and the raw materials and geometry of the designs are simple and common.

CONCLUSION

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 The great protecting capabilities of the design make it a good "Glass Monitoring Program" project. 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).

Recommendations

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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