Study & Analysis of Wire Rolling Process in Drawing Operation to Modify Power Transmission System

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Abstract- The aim of this project worked is to analyze and redesign a machine to upgrade it to expand its manufacturing capabilities. With the Vinayaka Industry, Nagpur being an excellent metal wire producer, this machine required redesign to meet their quality standards. Their current machine set-up could not properly produce material at its largest incoming material size of 16 mm. The technical team at the Vinayaka Industry had a general idea of how they thought the machine could be upgraded. Our project group worked together with the Vinayaka Industry to gather all the details of the necessary capabilities the machine must possess. From there, we have begun designing upgrades to the machine including the larger bull drum. We have used calculations to ensure these changes did not compromise any of the machine's components. We calculated the maximum draw force needed to pull the 16mm diameter wire. Using the results, calculations were completed to find the maximum torque that will be put onto the gearbox and motor of the machine. These results were then compared to the published torque curve by the manufacturer for both the gearbox and motor. With all changes implemented, the machine worked as planned and allowed the machine to roll more than 16mm diameter of wire material without surface defects from improper setup.

Index Terms- Torque, Force, Study and analysis.

INTRODUCTION

Vinayaka Group is a well-established in the manufacturing & traders of Stainless Steel Mild Steel, Carbon Steel, Alloy & Tool Steel, Die Steel & Bright Bars, Copper, Brass, Aluminium, Gun Metal, P.B. in various shapes & sizes. Vinayaka Group was incorporated in Nagpur year 1997. The Group has been scaling new heights in the market. Vinayaka Industry has one of the drawing units with them. In the existing system, they can draw & roll the wire of a maximum 16 mm diameter. But now they want to increase the drawing capacity which may process higher diameter wires. They had tested by taking 24 mm diameter wire but during operation, they found vibrations, jerks, surface deformation & improper rolling. Therefore the company is trying to improve the existing system by modifying the current transmission system with optimum cost. Vinayaka Industry, a wire manufacturing company located in Hingna MIDC Nagpur, is in need of improving one of their wire-drawing machines. The previous machine was not designed to process the desired size of the product they would like: the Wire encounters itself, which in turn breaks down the quality of the wire and causes surface deformation. Outlining the progress we have has made since beginning this project. In this final report, we will outline the machine's previous state, and compare it to its current state.

With our newly designed methods. The machine being evaluated for this project is a wire-drawing machine, which pulls intermediate sized wire through wire-drawing dies to reduce the cross-sectional area. Typically, the machine is largest capable of producing wire from incoming diameters of 16mm (smallest) to 24mm (largest). The dies used for this process are usually made up of either polycrystalline diamond or carbide. When operating the machine, the wire is fed through a die box that contains an abrasive material and a wire die. The abrasive material is applied at the face of the die where the wire enters, which reduces the size of the wire. After the die, the wire is transferred onto a bull drum. The bull drum is what drives the motion of the wire; they
are large circular objects that are each attached to a gearbox and a motor that causes continual rotational speed.

LITERATURE REVIEW

From the literature review, we found that the machine being evaluated for this project is a wire-drawing machine, which pulls intermediately sized wires through wire-drawing dies to reduce the cross-sectional area. Typically, the machine is capable of producing wire from incoming diameters of less than or equal to 16 mm. The dies used for this process are usually made up of either polycrystalline diamond or carbide. When operating the machine, the wire is fed through a die box that contains a lubricant and a wire die. The lubricant is applied at the face of the die where the wire enters, which reduces the size of the wire. After the die, the wire is transferred onto a bull drum. The bull drum is what drives the motion of the wire; they are large circular objects that are attached to a gearbox and a motor that cause continual rotational speed. We were able to obtain information regarding this motor from their website. The purpose of the motor is to use to drive the gearbox, which drives the speed rate of the wire-drawing machine. On average, the motor is set to 20 hp and 1440 RPM. An idler is a slightly smaller circular object that controls the alignment of the wire around the bull drum and prevents it from encountering each other. The wire is then transferred to the cutting machine where it cut at the required length.

PROPOSED METHDOLOGY

From the literature review, We have has collected information for the machine's motor, gearbox, differential, bull drum and have put forth this information into useful data calculations. From the analysis of collected data on these four machine components, we will try to find out which of these factors are critical and need to be modified or replaced by our redesign of the machine. Using this information, we can calculate the torque of the motor, as well as the average force applied. After performing design calculation we will use Ansys software to verify that our design calculations are conforming with the obtained result of the simulation. Then we will suggest these changes to be made in the wire drawing machine to the Vinayaka industry and achieve the outputs of the experimentation that our project results in successful operation of the machine without failure.

CALCULATION

1) Drawing force calculation

i) For SAE1040 without considering friction

\[ \text{Drawing Stress (Ϭ2)} = \frac{\text{Ϭy} ((1+B)/B) \left[1 - \frac{A_i}{A_o} \right]^B}{143.13/201.060.727} \]

\[ \text{Ϭ2} = 415 \times \left(\frac{1+0.727}{0.727}\right) \times \left[1 - \frac{143.13}{201.06}\right]^{0.727} = 215.814 \text{ MPa} \]

\[ \text{Drawing force (F)} = \text{Ϭ2} \times A_i = 215.814 \times 143.13 = 30889.561 \text{ N} \]

\[ \text{Torque required} = F \times r = 30889.561 \times 0.409 = 12633.830 \text{ N-m} \]

ii) By considering Friction

\[ \text{GT} = 6y + (Ϭ2 - 6y) e^{-2µL/R1} \]

\[ \text{Radius of work piece at exit (R1)} = 6.75 \text{ mm} \]

\[ \text{Length of deformation cone (L)} = 13.03 \text{ mm} \]

\[ \text{GT} = 4165 + (215-415) e^{-2*0.3*13.03/6.75} = 352.191 \text{ MPa} \]

\[ \text{Force (F)} = \text{GT} \times A_1 = 5049.126 \text{ N} \]

\[ \text{Torque (T)} = F \times r = 20617.332 \text{ N-m} \]

<table>
<thead>
<tr>
<th>Diameter (Do-DI) in mm</th>
<th>Area (Ao-Ai) in mm²</th>
<th>Stress without considering friction in mpa</th>
<th>Respective force in N</th>
<th>Stresse considering friction in mpa</th>
<th>Respective force in N</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-11.5</td>
<td>153.938</td>
<td>245.232</td>
<td>25471.75</td>
<td>371.41</td>
<td>38577.82</td>
</tr>
</tbody>
</table>
Motor torque at 1455 rpm

\[ P = \frac{2\pi \times Dg \times N_g \times T}{60} \]
\[ 15 \times 10^3 = \frac{2\pi \times 1455 \times 1 \times T}{60} \]
\[ T = 98.78 \text{ Nm} \]

Maximum torque generate at 2.472 rpm

\[ 15 \times 10^3 = \frac{2\pi \times 2.472 \times 1 \times T}{60} \]
\[ T = 57944.76 \text{ Nm} \]

For 16 mm rod

\[ F = 50409.13 \]

for safety assuming 20% extra

\[ F = 50409.13 \times 1.2 \]
\[ F = 60490.96 \text{ N} \]

Required torque at output

\[ T = F \times r \]
\[ T = 60490.96 \times 1/2 \]
\[ T = 30245.48 \text{ N m} \]
\[ T_{req} < T_{output} \]

For 24 mm rod

\[ F = 103422.416 \]
\[ F = 103422.416 \times 1.2 \]
\[ F = 124106.8992 \text{ N} \]

Required torque

\[ T = F \times r \]
\[ T = 124106.8992 \times 0.2 \]
\[ T = 51711.208 \text{ N m} \]
\[ T_{req} < T_{output} \]

From above, we can say that the motor is generating enough power to draw the 24 mm rod.

Safety calculation

1. Gear

\[ 1) \text{Tooth Load (ft)} = Pd/Vp \]
\[ Vp = \frac{\pi \times Dg \times N_g}{60 \times 1000} \]
\[ = 0.095 \text{ m/s} \]

Where,
\[ Vp \] – Pitch line velocity

Dg – Diameter of gear
Ng – speed of gear
Ft = Pd/Vp
\[ = 15000/0.075 = 200000 \text{ N} \]

This force is transmitted by two gears so the load on each gear equals to

\[ Ft = 200000/2 = 100000 \]

for safe condition \[ Fb \geq Ft \]

\[ Ft = Fb = 100000 \text{ N} \]

\[ Fb = So \times Cv \times b \times y \times m \]

Where,
\[ Fb \] – Bending strength
So– Basic Strength
Velocity factor \( Cv \) = 3/3 + Vp = 0.97
Face width of gear \( b \) = 110 mm
Modified Lewis factor \( y \) = 0.44
Module \( m \) = 10

\[ 100000 = So \times 0.97 \times 110 \times 0.44 \times 10 \]
\[ So = 213 \text{ Mpa} \]

As \( So (213) < So \) of material of shaft i.e. \( En = 9 \) \( (So = 240) \) design is safe.

2) Pinion

\[ 1) \text{Tooth Load, Ft} = Pd/Vp \]
\[ Vp = \frac{\pi \times Dg \times Ng}{60 \times 1000} \]
\[ Vp = \frac{\pi \times 178 \times 8.654}{60 \times 1000} = 0.08 \text{ m/s} \]
\[ Ft = 15000/0.08 = 187500 \text{ N} \]

This load is transmitted by two gears \( Ft = 187500/2 = 93750 \)

let \( Ft = Fb \)

\[ 93750 = So \times 0.97 \times 110 \times 0.341 \times 10 \]
\[ So = 237.66 \text{ Mpa} \]

As \( So (237.66) < So \) of material of shaft i.e. \( En = 9 \) \( (So = 240) \) design is safe.

3) Differential

\[ 1) \text{Tooth Load, Ft} = Pd/Vp \]
\[ Vp = \frac{\pi \times Dg \times Ng}{60 \times 1000} \]
\[ Vp = \frac{\pi \times 460 \times 8.654}{60 \times 1000} = 0.20 \]
\[ Ft = 75000 \text{ N} \]
\[ 75000 = So \times 0.93 \times 102 \times 0.44 \times 7 \]
\[ So = 244.7 \text{ Mpa} \]

As \( So (244.7) < So \) of material of shaft i.e. \( SAE 1045 \) \( (So = 245) \) design is safe.
1] Force on Shaft due to gear 1
Force = \( \rho g \) \( \frac{\pi}{4} \) \( d^2 \) \( w \) = 0.02463 m³
\( \rho = 8055 \) Kg/m³
\( F = 0.02463 \times 8055 \times 9.81 = 1950 \) N

2] Force on Shaft due to bull drum
Force = \( \rho \) \( \frac{\pi}{4} \) \( d^2 \) \( w \) = 0.02463 m³
\( \rho = 8055 \) Kg/m³
Force = 0.02463 \( \times \) 8055 \( \times \) 9.81 = 1950 N

3] Tangential Force, \( F_t = \frac{T}{R_g} \)
\( F_t = 104294.82 \) N
Where,
\( T = Torque = 5794 \) N\( \cdot \)m
\( R_g = Radius \) of gear = 0.5 m

4] Radial Force, \( F_r = F_t \cdot \tan \phi \)
\( F_r = 3796.21 \) N

5] Reactions on gear
\( R_A + R_B = 214545 \) N
\( \varepsilon_Ma = 0 \)
106245\( \times \)0.15 + 106245\( \times \)0.77 + 2055\( \times \)0.12 = \( R_B \) \( \times \)0.92
\( R_B = 108925.43 \) N
\( R_A = 105619.56 \) N
Bending Moment on shaft,
In Vertical plane
\( A = E = 0 \)
\( B = 575.4 \) Nm
\( D = -15455.16 \) Nm
\( C = 2055 \times 1.05 + 106245 \times 0.62 - 108925.43 \times 0.77 = -15842.93 \) Nm
In Horizontal plane
\( R_A + R_B = 179342.83 \) N
\( = 179343 \) N
\( \varepsilon_Ma = 0 \)
37960.021\( \times \)0.15 + 37960.21\( \times \)0.77 + 103422.41\( \times \)1.2 = \( R_B \) \( \times \)0.92
\( R_B = 172859 \)
\( R_A = 648398 \)
Bending moment on shaft,
\( A = E = 0 \)
\( B = 28963.71 \) Nm
\( C = 24138.40 \) Nm
\( D = 28963.71 \) Nm
\( \tau = \frac{16 \times 103}{\pi d^2} \sqrt{K_b \times M + K_t \times T^2} \)
Where,
\( \tau = \)Shear stress
\( d = \)diameter
\( K_b = \)moment constant
\( K_t = \)torque constant
\( T = \)torque
\( M = \)Bending moment
\( 232.5 = \frac{16 \times 103}{\pi d^2} \sqrt{1.75 \times 28963.22 + 1.5 \times 57944^2} \)
\( d = 119.88 \) mm
\( = 120 \) mm

2] For Shaft 2,
1) Reaction on gear, In Vertical
\( R_A + R_E = 447740 \) N
\( \varepsilon_Ma = 0 \)
\( R_E = \frac{31480 + 12880 + 1616}{0.92} \)
\( R_E = 223870 \) N
Bending Moment on shaft,
\( M_A = M_E = 0 \)
\( M_D = 33580.65 \) N\( \cdot \)m
\( M_C = 37920.96 \) N\( \cdot \)m
\( M_B = 33581.27 \) N\( \cdot \)m

2) In Horizontal
\( R_A + R_E = 225585 \)
\( \varepsilon_Ma = 0 \)
\( R_E = \frac{11480 + 33550 + 58770}{0.92} \)
\( R_E = 112795 \) N
Bending Moment on shaft,
\( M_A = M_E = 0 \)
\( M_D = 16920 \) N\( \cdot \)m
\( M_C = 28225 \) N\( \cdot \)m
\( M_B = 16920 \) N\( \cdot \)m
Total,
\( M_D = 37603 \) N\( \cdot \)m
\( M_C = 47273 \) N\( \cdot \)m
\( M_B = 37605 \) N\( \cdot \)m
\( D^3 = \frac{16 \times 103}{\pi \times 232.5} \sqrt{1.05 \times (16775)^2 + 1.75 \times (47273)^2} \)
\( = 112.97 \) mm
\( = 115 \) mm
\( M = C \)
\( V = g = V = g = \rho \)
\( \frac{\pi}{4} \times d^2 \times L = \frac{\pi}{4} \times d^2 \times L \)

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L = 1246.07 mm

Weight of wire (W) = V*g

Weight of wire = 10.47 Kg

Force = g*W

= 102.72 N

Speed,

74/15 = N2 / 8.65

N2 = 42.62

Torque = Force / Speed

103.85/42.62 = 2.43

Torque = 2.43 N-m

Project Model

Software Analysis

1. Geometry

2. Fixed Support

3. Boundary Condition, Vertical - Force 1

4. Vertical - Force 2

5. Vertical Force 3
6. Horizontal Force 1

7. Horizontal Force 2

8. Horizontal Force 3

9. Total Deformation

10. Equivalent Stress

11. Shear Stress

12. Max. Principal Stress
RESULT

Based on the calculations and using those values for the software analysis the following results are obtained as shown in table.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>EXISTING SYSTEM</th>
<th>PROPOSED SYSTEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIAMETER OF MAIN SHAFT</td>
<td>100 MM</td>
<td>120 MM</td>
</tr>
<tr>
<td>DIAMETER OF 2ND SHAFT</td>
<td>85MM</td>
<td>110MM</td>
</tr>
<tr>
<td>TORQUE</td>
<td>30245.48 N-M</td>
<td>51711.208 N-M</td>
</tr>
<tr>
<td>WIRE DIAMETER</td>
<td>16-13.5 MM</td>
<td>24-21.5 MM</td>
</tr>
</tbody>
</table>

Graphical representation

From the above calculation we have seen that the current setup of wire drawing machine is generating enough power to draw 24 mm diameter rod or bar but if we draw the greater diameter bar some components may get damage. So to reduce the stresses we are increasing the diameter of shaft and providing an extra support. And From the analysis we are cross checking our work. The graph shows the relation between the diameter and stresses produced in shaft. we see that as diameter increases the stresses induced in shaft decreases.

CONCLUSIONS

From the project we can conclude that it is not feasible to draw wire of 24 mm in the present setup of drawing machine but after changing the diameter of shaft from 100mm to 120mm also the internal diameter of gears, bearings and pulleys mounted on shaft changes, providing support to it from bull drum side with no changes in power consumption. Hence our proposed design can be implemented for drawing machine of “Vinayaka Industries”.

REFERENCES

