Service Enhancer Tool

Design of a new Service Enhance Tool for Metso refiners.

Rikard Bjarnhagen
Abstract

Metso develops (among many other things) refiners. The refiner grinds the wood chips into pulp. The grinding is done by segments that are placed on a rotor inside the refiner hosing. In time this segments wear and needs to be replaced.

When changing refiner segments or performing service to the refiner the rotor needs to be rotated. To perform the rotating motion today the overhead crane is used. This procedure is both impractical, dangerous and takes precious time from the overhead crane. Because of this Metso wanted to create a new way to rotate the rotor.

The aim of this thesis is to create a tool or equipment which can be used to rotate the refiner rotor and can be installed as an upgrade on all Metso refiner models.

The proposed design is driven with a 1.1 kW electrical motor and a gearbox with a gear ratio of approximately 1:217. The torque is transferred from the outgoing gearbox shaft to the refiner shaft with the help of gearwheels. To connect the gearbox gearwheel with the refiner shaft gearwheel, the gear motor has to be moveable in a radial direction. This is done by the means of two shafts that glides in four bushings. On the gearbox shaft a gearwheel with 120 mm of face width is mounted. The large face width is used to take up the axial movement of the refiner shaft.

The proposed concept fulfills all of the demands set in the pilot study. The design is good because of the low cost and straightforward design that is easy to build and simple to use. The disadvantage is that the equipment is a bit large and heavy, but as stationary equipment this should not be a problem.
Sammanfattning

Metso utvecklar bland annat raffinörer och tillhörande serviceverktyg. Ett av dessa verktyg används till att under service rotera raffinörens rotor med hjälp av travers. Eftersom detta tillvägagångssätt är ett riskmoment ur personssäkerhetssynpunkt samt tar upp dyrbar tid från traversen vill man utveckla ett nytt sätt att rotera rotorn.

Examensarbetet går därför ut på att på utveckla ett verktyg eller tillsats med vilken man kan rotera rotorn, verktyget ska vara möjligt att applicera på samtliga av Metsos installerade raffinörer. Målet med projektet är att ta fram ett koncept inklusive beräkningar, skisser, prisuppskattning samt val av kritiska komponenter.

Det framtagna konceptet drivas av en 1.1 kW elmotor och en växellåda med en utväxling på 1:217. Kraften överföras till raffinörsaxeln med hjälp av kugghjul. För att få kugghjulen i ingrepp måste växelmotorn kunna röra sig radiellt, detta löses med hjälp av att motor och växellåda är upphängda på en motorvagga som kan röra sig radiellt med hjälp av bussningar. Ett kugghjul med en bredd på 120 mm används för att ta upp raffinörsaxelns axiella rörelse.

Preface

The last step in the program of machine engineering is to do a thesis. The thesis is 15 credits long, which corresponds to approximately 10 weeks. This thesis is done by Rikard Bjarnhagen on the behalf of Metso Paper Sweden AB.

I want to place a special thanks to my supervisor at Umeå University Staffan Grundberg and my supervisor on Metso Göran Byström which both has helped me during the project. I also want to thank Metso Sweden AB and the unit manager Magnus Monsell. Besides this I want to thank SEW for the help with gear motor choice.
# Table of Contents

Abstract ........................................................................................................................................ i

Sammanfattning ............................................................................................................................ ii

Preface .......................................................................................................................................... iii

Table of Contents .......................................................................................................................... iv

Introduction ................................................................................................................................... 1

Background ................................................................................................................................... 1

Objective ....................................................................................................................................... 2

Challenges ..................................................................................................................................... 3

Design goals .................................................................................................................................. 3

Limitations ...................................................................................................................................... 3

Theory .......................................................................................................................................... 4

Methods ....................................................................................................................................... 6

Pilot study ..................................................................................................................................... 6

Construction ................................................................................................................................. 6

Documentation .............................................................................................................................. 6

Results .......................................................................................................................................... 7

Gearwheel concept ......................................................................................................................... 7

Components for coupling large (RGP 268, RGP 76 CD, RGP82 CD, RGP68 DD) ....................... 8

Economics .................................................................................................................................... 14

Other models ............................................................................................................................... 14

Other concepts ............................................................................................................................ 15

Chain ............................................................................................................................................ 15

Worm gear ................................................................................................................................... 16

Discussion .................................................................................................................................... 17

Gearwheel concept ....................................................................................................................... 17

Chain concept ............................................................................................................................... 17

Worm gear concept ..................................................................................................................... 18

Other solutions ............................................................................................................................. 18

Conclusions ................................................................................................................................. 18

References ..................................................................................................................................... 19
Introduction
Metso Paper Sweden AB is a part of Metso Paper which is belongs to the Metso group. Metso is a big service, manufacturer and engineering company. Today they have about 30 000 employers deployed in over 50 countries. The Metso group has three main branches: “Mining and Construction”, “Pulp, Paper and Power” and “Automation”. Metso Paper is a part of the pulp and paper segment and is one of the world leading manufacturers on machines and accessories to the paper and pulp industries.

Metso Paper Sweden AB designs, sells and does maintenance work on (among many other things) refiners (Figure 1).

Background
The refiner (Figure 1) is a machine that grinds wood chips to pulp that later is used to make paper. The refiner separates the wood fibers and at the same time processes the fiber to facilitate further paper manufacturing. The grinding is done by segments that are placed on a rotor inside the refiner housing. In time the segments wear and needs to be replaced. When doing so the rotor needs to be rotated in order to access all the bolts that have to be loosened during the service.
To rotate the rotor today you have to use the overhead crane and a simple rotation tool (Figure 2), the tool is pretty much just a 90 degree angle that you fasten to the overhead crane in one end and with a round bar that you can hook to the rotor in the other end.

The rotation motion is created using the rotation tool as shown in Figure 3. You put the tool in one of the holes that is located on backside of the rotor, you then start to lift with the overhead crane. The rotor is then rotated about 50-60 degrees with the help of the overhead crane before you have to start the procedure over again. You will have to reposition the rotation tool and make a new lift about 6-10 times on every revolution.

The segment changes are almost always done during a service stop and during these stops the access to the overhead crane can be limited.

The procedure used today is both dangerous and time consuming as well as taking precious time from the overhead crane. Therefore it is essential to come up with a new way to perform this action.

Recently a service engineer got injured during a segment change. This happened because of a catastrophic failure of the tool used to rotate the rotor, the metallurgical examination [6] of the lifting tool failure pointed to misuse of the tool is most likely one of the reasons of the failure. After the accident a new tool was designed, this tool had a greater safety ratio and could because of that sustain heavier loads [7]. This solution straightens out some if the safety question marks but it could still be very dangerous if misused.

The refiner is driven by a big electrical motor with up to 30 MW of power, between the motor and the refiner it is a shaft that transfer the torque from the motor to the refiner, this shaft is shown in Figure 5, page 7. This shaft is the only movable part that is accessible when the refiner housing is closed. Many times it is an advantage to be able to rotate the refiner without having to open the refiner housing. Therefore the rotation motion is transferred to this shaft.

This is a problem Metso has had for some time and a prototype was built in the 80’s. But due to miscalculations in the torque needed to rotate the refiner the equipment did not work and the project was canceled.

**Objective**

The purpose of the thesis is to create a design sketch of a rotation tool or equipment including calculations, sketches, selection of critical components and a rough estimated
price of the material. The thesis will later be used as base for further development and possibly manufacturing.

The main purpose of the design is to ensure the safety of the mechanics, to simplify the segment change procedure and to free time from the overhead crane.

Metsos objective is to later on be able to market this product as an add-on to already delivered refiners. Because of this the design must be applicable on all of Metsos current models of refiners.

**Challenges**
The main challenges with the development of the equipment are the big torque and forces that has to be applied to the refiner in order to get it to rotate. The equipment should also be applicable to all Metsos different refiner models, it has to work with all different surroundings and be able to handle the axial movement of the refiner shaft.

**Design goals**
- The equipment has to be applicable on all Metso refiner models.
- The mechanics has to be able to stay in the work area during rotation.
- The equipment has to be able to be used without the use of the overhead crane.
- With the use of this equipment the mechanics has to be able to rotate the refiner with simple means.

**Limitations**
Because of the short amount of time which this thesis is done, the result of the thesis is not going to contain any production bill of materials or detail drawings for manufacturing.
Theory
In this section the calculations is going to be shown. With the help of this the reasoning in the result section can be understood.

The first thing to calculate was how much power the motor must to have. The power was calculated with [3]

\[ P = M \omega \]  

(1)

where \( P \) is the power in watt (W), \( M \) is the torque in newton meter (Nm) and \( \omega \) is angular velocity in radians per second (rad/sec).

When the power was determined the outgoing rpm of the gearbox due to the limitations in peripheral speed had to be decided. The maximum rpm of the outgoing gear motor shaft is determined by

\[ n_{refiner} = \frac{v_{limit}}{\pi d} \]  

(2)

where \( n_{refiner} \) is the maximum refiner shaft rpm (rpm), \( v_{limit} \) is the peripheral speed limit in meter per minute (m/min), \( d \) is the rotor diameter in meter (m).

To choose size of gearbox and motor to use you also have to have the needed torque on the gearbox shaft, the torque is determined by

\[ \frac{M_{refiner}}{h} = M_{motor} \]  

(3)

where \( M_{refiner} \) is the torque on the refiner shaft in newton meter (Nm), \( h \) is the ratio between the number of gears on the refiner coupling gearwheel and the gearbox shaft gearwheel, \( M_{motor} \) is the torque on the gearbox shaft in newton meter (Nm).

Besides the torque on the shaft the radial force on the gearbox shaft is needed. The radial force of the gear motor is depending of the tangential force and the angle between the tangential force and the total force as seen in Figure 7, page 9. The angle differ with different modules and gear engagement. The radial force is determined by

\[ \frac{M_{max}}{r \cos \alpha} = F_{max} \]  

(4)

where \( M_{max} \) is the maximum torque on the refiner shaft in newton meters (Nm), \( r \) is the radius of the refiner gearwheel in meters (m), \( \alpha \) is the angle between the tangential force and the maximum force in degrees (°), \( F_{max} \) is the total force in newton (N).
The stand to the gear motor uses an overlaying u-beam that sometime has to be lengthened to match the surroundings. The deflection of this u-beam is calculated as a simply supported beam (Figure 4) and is determined by [3]

\[ y = \frac{FL^3}{4BEI} \]  

(5)

where \( y \) is the deflection in meters (m), \( F \) is the force in newton (N), \( L \) is the length in meters (m), \( E \) is the elastic module in pascal (Pa) and \( I \) is the moment of inertia (m^4).

The sled that the gear motor is mounted on has two circular shafts that run through four bushings. In the load case shown in Figure 13, page 12 the deflection of this shaft is calculated as a cantilever and is determined with

\[ y = \frac{FL^3}{24EI} \]  

(6)

where \( y \) is the deflection in meters (m), \( F \) is the force in newton (N), \( L \) is the length in meters (m), \( E \) is the elastic module in pascal (Pa) and \( I \) is the moment of inertia (m^4).

The maximum stress in the circular shafts is calculated by [3]

\[ \sigma_{max} = \frac{M_{max}}{W} \]  

(7)

where \( \sigma_{max} \) is the maximum stress in newton per cubic meter (N/m^2), \( M_{max} \) is the maximum torque in newton meter (Nm) and \( W \) is the bending resistance (m^3).

To calculate the maximum stress of the circular shaft you will need the bending resistance, the bending resistance of a shaft with a circular cross section is decided by

\[ W = \frac{\pi d^4}{32} \]  

(8)

where \( W \) is the bending resistance (m^3) and \( d \) is diameter of the shaft in meter (m).
Methods

Pilot study
A pilot study was done during the first two weeks of the project, this study contained introduction to Metso, gathering of information, learning about the refiners and similar solutions, benchmarking, control of safety regulations and time planning. The pilot study was done in the first two weeks.

Construction
The design was drawn based on the results and experience gathered in the pilot study. Different power alternatives and transmissions were written down and evaluated. Very rough sketches were drawn with paper and pencil. Three dimensional models were drawn of the best solutions. The best solutions with improvements were drawn again, this time a bit more detailed.

During the study many concepts have evolved and they all had their own different pros and cons.

Continuously during the design phase simple strength calculations were made to see if the design in question were viable to build. When the final ideas started to take form, further calculations and simulations in the CAD-program Solid Works were made. When a finished design started to take form, dimensioning calculations were made.

Because of the lack of time and space there was not an option to do any experiments.

Documentation
Notes of the progress and the following tasks were written at the end of every day. Approximately once a week my mentor, the manager of the department and I had a meeting were we discussed the progress and how to go forward in the project. About two weeks before the thesis was going to be handed in the writing of the report started.
Results
In this section the results and sketches are going to be presented.

Gearwheel concept

The main concept developed (Figure 5) is an idea that uses gears to transfer the torque from the gear motor to the shaft. It uses a gear motor that is geared down approximately 217 times, the gear motor is dimensioned so that it could take up all the radial force in its own internal bearing. A gearwheel with 120 millimeters of face width was used so that the gear would still be in operation even if the shaft moved in an axial direction. The gearwheel that is mounted on the gearbox had to have a large diameter so that the gearbox would not interfere with the refiner shaft when in operation. The gear motor is mounted on a motor sled that can move in a radial direction with the help of four bushings. This motion is shown in Figure 6.
Figure 6, Shows the gearwheel concept in operation (left) and out of operation (right).

Components for coupling large (RGP 268, RGP 76 CD, RGP82 CD, RGP68 DD)
Under this section all the concept components are described and evaluated. These calculations are done with the largest refiner in mind, but are applicable to all refiner models.

Gearbox
To be able work smoothly during the use of this equipment you will have to be able to use the equipment without having to evacuate the machine during movement of the rotor. The restriction speed for pulp and paper mills is 15 m/s in peripheral speed [1].

With a rotor that has a diameter of 1.8 meters and max 15 m/min in peripheral speed the maximum rpm of the refiner is 2.64 accordingly to the equation (2).

\[
\frac{n_{\text{refiner}}}{\text{rpm}} = \frac{v_{\text{limit}}}{\pi d} \tag{2}
\]

\[
n_{\text{refiner}} < \frac{15 \text{ m/min}}{\pi 1,8 \text{ m}}
\]

\[
n_{\text{refiner}} < 2,64 \text{ rpm}
\]

If the maximum rpm of the refiner is 2.64 rpm and it is a ratio between the two shafts of 2.08 the maximum rpm of the gear motor is 5.5 rpm.

\[
n_{\text{motor}} = n_{\text{refiner}} \cdot h
\]

\[
n_{\text{motor}} < 5,5 \text{ rpm}
\]

In order to choose the right gearbox the maximum torque on the gearbox shaft and the gearbox radial force also has to be determined. With a moment of 3 000 Nm on the refiner shaft and a gear ratio of 1,3:1 you will accordingly to equation (3) have a torque on the outgoing shaft of 2 300 Nm.

\[
\frac{M_{\text{refiner}}}{h} = M_{\text{motor}} \tag{3}
\]
To start rotate the refiner a torque of 3000 Nm has to be applied to the large gearwheel and because of the large diameter gearwheel radius and the geometry of the gears the maximum radial force of the gear motor is 15 500 N accordingly to equation (4), this is shown in Figure 7.

\[
\frac{M_{\text{max}}}{r} \cos \alpha = F_{\text{max}}
\]

\[
\frac{3000 \text{ Nm}}{0.2 \text{ m}} \cos 15^\circ = 15 \ 500 \text{ N}
\]

The gearbox chosen is a SEW-gearbox with an ingoing outgoing ratio of 216.54. This gearbox could take 15 600 N in radial force [5] and can therefore be used to all the refiner models as shown in Table 1, page 14.

**Motor**

To rotate the shaft you will accordingly to equation (1) need a motor with the power of 1000 W when the torque on the gearbox shaft is 2 300 Nm and the angular velocity is 4.2 rpm = 0.44 rad/sec.

\[
P = M \cdot \omega
\]

\[
P = 2300 \text{ Nm} \cdot \left(\frac{4.2 \cdot 2\pi}{60}\right) \text{ rad/sek} = 1000 \text{ W}
\]

Therefore the chosen electrical motor is a 6-pole asynchronous 1.1 kW SEW-motor, this motor can be used to drive all of the refiner models as shown in Table 1. An asynchronous motor is used because it is cheap and robust [8].

With the selected gearbox the rotation speed of the outgoing gearbox shaft is 4.2 rpm and the torque is 2 500 Nm. The motor and gearbox have a weight of about 90 kg together.

**Gearwheel with small diameter**

The sprocket mounted on the gearbox has 120 mm of face width so that it can take up the refiner shaft axial movement. To make the gearbox not interfere with the shaft before the gear is in operation a quite large diameter (312mm) had to be used.

**Gearwheel with large diameter**

The larger sprocket is fastened on the refiner shaft. The shaft is connected to the motor and the refiner with a shrink fit by two SKF movable couplings. These couplings are hard and time consuming to take off the shaft, there is also a risk of seizing the coupling during these
kinds of operations. Because of the mentioned drawbacks a solution with a divided gear was chosen.

The sprocket halves have 12 mm of face width and goes about 3 centimeters outside the coupling outer diameter.

**Fastening nut**
The main shaft and the couplings are bolted together with the use special fitting bolts. These bolts have very tight tolerances. Because of that, it is designed to keep these screws and use a special nut (Figure 8) to fasten the large diameter gear on to the refiner shaft as shown in Figure 9.

The nuts are designed so that you replace the already mounted nuts with the special nuts, the new nuts has a thread in the opposite end. These threads are used to fasten the two sprocket halves.

**Gear motor stand**
The stand is built in a triangular shape in order to take up the radial forces in a good way. It is built with the help of standard steel beams for economic reasons. The legs use VKR 60x60x5 beams and a 20 mm sheet metal to the foot mounts. The stand is built so that it could be extended and shortened if there would be a foot stand from the shaft hood in the way. This is done with the help of the u-beam (USP300) that serves as the overlaying beam in which you fastened the motor sled. The u-beam seen in Figure 10 and 11 has accordingly to equation (5) close to no deflection even when it is extended to 1 meter and affected by a force of 15,6 kN. To get an indication of the displacement and stress in the stand, simulations in Solid Works where done. The maximum displacement of the motor stand is 0.3 mm (Figure 10) at the tip of the outgoing shaft. The maximum stress is approximately 50 MPa (Figure 11). The steel in use has a yield limit of 260 MPa [3] which gives a safety margin of 5.2.

\[
y = \frac{F l^3}{48 E I}
\]

\[
y = \frac{15 \ 665 \ N \cdot 1^3 \ m}{48 \cdot (1,9 \cdot 10^{11}) Pa \cdot (5,69 \cdot 10^{-6}) m^4} = 3,0 \cdot 10^{-4} \approx 0,3 \ mm
\]
Figure 10, Displacement simulation with the maximum displacement of 0.3mm

Figure 11, Stress simulation with the maximum stress of 50 MPa.
**Motor sled**

In order to get the gears in operation you have to be able to move the gear motor in a radial direction. The motor sled (Figure 12) is the moving part that the motor is mounted on. The sled has two underlying circular shafts that are sliding in four bushings. The underlying shafts are in the material ss2225-04. Accordingly to the equations (6), (7) and (8) the deflection of the shaft is 0.03 mm and the maximum stress is 368 MPa. The material in use has a yield limit of 590 MPa, this means that the shafts have a safety margin of 4.3 times. The shafts has a diameter of 0.045 m, has a length of 0.1 m and is affected with a force of 12 000 N.

![Figure 12, Picture over the motor sled (orange) and the bushing holders (blue).](image)

![Figure 13, Force and deflection of the circular beam.](image)

Deflection bushing shaft:

\[
y = \frac{FL^3}{24EI}
\]

\[
y = \frac{12 000 \cdot N \cdot 0.1 \cdot m^3}{24 \cdot (2.2 \cdot 10^{11}) \cdot Pa \cdot (7.3 \cdot 10^{-8}) \cdot m^4} = 3.11 \cdot 10^{-5} \text{ m} = 0.03 \text{ mm}
\]

Max stress of bushing shaft:

\[
\sigma_{\text{max}} = \frac{M_{\text{max}}}{W}
\]

\[
\sigma_{\text{max}} = \pm \frac{-1 550 \cdot Nm}{\left( \frac{\pi \cdot 0.045^3}{32} \right) \cdot m^3} = \pm 134 \cdot 10^6 \text{ N/m}^2
\]
This gives a factor of safety of:
\[
\frac{590}{134} = 4.3
\]

**Bushings/bushing holders**
The motor sled had to be able to move, this was solved with bushings (Figure 12). Bushings were chosen because of its cheap, maintenance free and simple design.

**Bushing force**
On the worst case scenario all the force is taken up by only one of the bushings.

The angle which the gears are joined together is 65°, due to the gear teeth shape a force angle on 50° is given. The total amount of force is 15 500 N and therefore the vertical force is 12 000 N as shown in Figure 7, page 9.

Vertical force:
\[
15 500 \cdot \sin 50 = 12 000 \text{ N}
\]

**Trapezoidal screw**
To move the sled in the bushings a trapezoidal screw were used. This screw works like a standard bolt with a bit larger pitch. The trapezoidal screw uses a bolt head to transfer the force from the operator to the screw. The force that is applied to the trapezoidal screw is 10 000 N, to sustain this force a 20 mm trapezoidal screw must be used [4].

The angle which the gears are joined together is 65°, due to the gear teeth shape a force angle on 50° is given. The total amount of force is 15 500 N and therefore the horizontal force is 10 000 N as shown in Figure 7, page 9.

Horizontal force:
\[
15 500 \cdot \cos 50 = 10 000 \text{ N}
\]

**Shaft hood hatch**
The shaft hood hatch is used so that you cannot hurt yourself by putting in your fingers inside the shaft while it is running for full speed. The lid also makes sure that the main motor cannot be started unless the hatch is closed and the gear motor is out of operation. This is done by an inductive sensor that sense if there are any metal in the way (Figure 14). The hatch slides open to the side and are fastened with a lockable fastener (not in the picture).
**Control**

To control the rotation equipment in a safe manner you have to use a control that is activated with an active button that needs to be hold down during the rotation of the rotor. The person who controls the equipment has to have complete view of the risk areas [2].

**Economics**

The main cost in this design is the gear motor and the gears. The gear motor will cost approximately 12 000 SEK. After having contacted three different suppliers and gear manufacturers the gears will most likely cost somewhere between 3 000 and 6 000 SEK each and the divided gear will count as two gears.

Gears and gearmotor:

\[
12 000 + (3 000 \rightarrow 6 000) \cdot 3 = 21 000 \rightarrow 30 000 \text{ SEK}
\]

Besides this it is the trapezoidal screw, the special nuts, the bushings, the beams and the material to the stand and the motor sled.

\[
1 000 + 1 000 + 300 + 1 000 = 3 300 \text{ SEK}
\]

The total price of the material is somewhere between 24 000 SEK and 35 000 SEK.

**Other models**

Because it accordingly to the machine directive says that the maximum rotation speed is limited by peripheral speed the rpm will differ with different refiners. Due to the different diameter on the rotor but because of different diameters on the shaft as well the same gearbox can be used to all different refiner models as shown in Table 1.
To start the refiner you will need about 3 000 Nm due to the high tension in the bearings.

<table>
<thead>
<tr>
<th>Refiner</th>
<th>Rotor dia. (mm)</th>
<th>Coupling dia. (mm)</th>
<th>Max n (rpm)</th>
<th>Shaft (rpm)</th>
<th>Torque on transmission (kNm)</th>
<th>Force on transmission (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGP 244</td>
<td>1130</td>
<td>346</td>
<td>4.22</td>
<td>3.4</td>
<td>2.35</td>
<td>15,5</td>
</tr>
<tr>
<td>RGP 250</td>
<td>1310</td>
<td>389</td>
<td>3.64</td>
<td>3</td>
<td>2.35</td>
<td>15,5</td>
</tr>
<tr>
<td>RGP 256</td>
<td>1460</td>
<td>389</td>
<td>3.27</td>
<td>3</td>
<td>2.35</td>
<td>15,5</td>
</tr>
<tr>
<td>RGP 262</td>
<td>1604</td>
<td>457</td>
<td>2.97</td>
<td>2.5</td>
<td>2.00</td>
<td>13</td>
</tr>
<tr>
<td>RGP 268</td>
<td>1804</td>
<td>585</td>
<td>2.64</td>
<td>2</td>
<td>1.50</td>
<td>10</td>
</tr>
<tr>
<td>RGP 76 CD1</td>
<td>1506</td>
<td>585</td>
<td>3.17</td>
<td>2</td>
<td>1.50</td>
<td>10</td>
</tr>
<tr>
<td>RGP 76 CD2</td>
<td>1568</td>
<td>585</td>
<td>3.04</td>
<td>2</td>
<td>1.50</td>
<td>10</td>
</tr>
<tr>
<td>RGP 82 CD1</td>
<td>1577</td>
<td>585</td>
<td>3.02</td>
<td>2</td>
<td>1.50</td>
<td>10</td>
</tr>
<tr>
<td>RGP 82 CD2</td>
<td>1651</td>
<td>585</td>
<td>2.89</td>
<td>2</td>
<td>1.50</td>
<td>10</td>
</tr>
<tr>
<td>RGP 68 DD</td>
<td>1810</td>
<td>585</td>
<td>2.63</td>
<td>2</td>
<td>1.50</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 1, Table of the maximum rpm and forces on the outgoing gearbox shaft.

Other concepts

Chain
A second concept developed was an idea that used a chain to rotate the refiner shaft (Figure 15). To take up the axial movement of the refiner shaft and to be able to connect the chain the gear motor had to be moveable in both radial and axial direction. This was solved with the motor and gearbox mounted on a plate that was secured to the ground with two bushings that made the gear motor turn both axial and be flipped during the chain rigging.

Figure 15, Schematic picture over a chain design.
**Worm gear**

A third concept (Figure 16) developed used a worm gear to transfer the torque to the shaft, due to this you could get a great amount of gear ratio and could because of that use a smaller gear motor and could therefore make the gear motor easier to make portable.

The gear motor and the worm gear screw were mounted on a trolley with wheels. The trolley is rolled on two wheels and is built with a leg behind the wheels so that when it is mounted on the shaft the wheels is a few millimeter in the air. The trolley weight is about 60 kg (about the same weight as a big lawn mower).
Discussion
Even though many ideas and concepts came up during this thesis it was one of the first ideas that came to mind that finally become the most advantageous when the pros and cons had been weighted against each other.

**Gearwheel concept**
This design fulfills all of the before set demands on the design and the concept is good because of its simplicity. From a user perspective the gearwheel concept is the easiest to use. When you want to use the rotations tool you just remove the shaft hood hatch and then turn the trapezoidal screw until the gear motor is in position. When the gear motor is in position you push the button and the shaft starts to rotate.

The main problem with this idea was the heavy gear motor and gearwheel (totally a weight of 150 kg), this makes the construction quite big and heavy, but as stationary equipment this does not seem like such a big problem.

**Fastening nut**
The fasteners (Figure 8) which you fasten the refiner shaft gearwheel makes the assembly much easier and makes the risk of problem during installation of the equipment considerably less.

**Trapezoidal screw**
The trapezoidal screw uses a bolt head to transfer the torque from the operator to the screw, you can therefore use the tool or power tool of your choice to rotate the trapezoidal screw.

To make the operation even easier a step motor can be used. The step motor then controls the trapezoidal screw and put the gear motor in operational position. Doing so the only manual thing the operator has to do is to remove the hatch to start using the equipment.

**Shaft hood hatch**
Special attention should be attended when the inductive sensor is mounted. This because the sensor could, if misplaced sense the gearwheel and therefore think that the hatch is closed, this will result in great risks.

**Economics**
The economics part is a very rough estimated price of the material. In addition to this the work of manufacturing the stand and the motor sled will be added. There is also quite a bit installation work on site.

The gear motor price is the price exclusive the Metso discount. This due to the SEW corporation policy which says that the special agreed prices are confidential.

**Chain concept**
This idea is easy to build and is smooth to implement on already existing refiners due to its flexibility. The finished design had problems with hard and time consuming startup. This could be somewhat minimized if you use one chain for each refiner and you hang it up under
the refiner shaft hood when not in use. Despite this the idea was thought to be too time consuming and was therefore rejected.

**Worm gear concept**

This solution is difficult to mount because of need to rebuild the shaft hood stands. Due to the lack of space under some of the refiners this idea is not applicable on all refiner models and because of the difficulties in mounting this idea was canceled.

**Other solutions**

The use of a worm gear could be a good solution if found a better way to do the insertion and a cheaper way to get the gearwheel. This because of the great amount of ratio you will get between the gear motor shaft and the refiner shaft. You will get much less torque on the gearbox due to the larger ratio and because of that all the radial force in the worm screw is taken by external bearings this means that you can use a smaller gearbox. But the disadvantages with this idea besides the price is the axial force you will get in the worm wheel, the more complex solution you have to build to take up the axial movement of the refiner shaft and the lack of space under some of the refiner shafts will make it hard to implement on all the different models of refiners.

**Conclusions**

In my opinion the gearwheel concept is the concept with the most advantages. This due to the low cost straight forward design that is easy to manufacture and simple to use.

But I also think it would be good to examine the use of worm gears a bit further because this is a good way to transfer the force. This is due to the high gear ratio of the worm gear.

This thesis only starts this project, to take it forward more evaluations of the different concept have to be done. If chosen to use the concept I recommend, more strength calculations and dimension work has to be done. New detailed models have to be made, drawings have to be drawn, prototypes have to be built and evaluated.
References


