CHAPTER 8

TECHNICAL FACTORS THAT AFFECTED THE TECHNOLOGY TRANSFER PROJECT

Besides the cultural factor which is totally dependent on the human aspect, there is another key element that stands in the way of easy implementation of TPM standards in new technology transfer projects. Of course, many of these problems are of human origin, mainly those who arise during the design, development, construction and installation processes and which seriously affect those processes as well. Some design flaws that may be (and usually are) overseen during the early stages of the project, come to be real nightmares when it comes to installation, operation and/or maintenance. Some of these design flaws may remain hidden for several years until for one reason or another, someone has to inspect and pull out an element through a totally unrealistic maneuver.

In this section examples will be given on what this technology transfer project has taught the organization regarding technical difficulties found along the way. The important thing to do about them is to work hard enough with the supplier and the engineering team themselves to eradicate them from their very root causes, otherwise, many of these problems will keep on popping up in one engineering project after another. This is a clear example of how synergy can take us to a state in which a thorough communication process can ensure a defect-free environment that promotes a higher rate of reliability on the shop floor.

8.1 Suppliers

Pastra, the Italian supplier, showed a rather defensive attitude from the very beginning concerning the comments that were issued in terms of their design. Changes were a matter of harsh discussions among the engineering team of the company and the Italian designers all through the designing stage and continued over with even worse attitudes during the installation and construction ones.

Upon agreement of the contract, which included a 1% daily penalty (over the final bill) for any delay for which Pastra was held responsible, trips back and forth between Italy and Mexico were quite often, in spite of discussions over changes that A&B requested to be made, the design process was fluent and fully complied with the project's schedule, which was actually modified upon request of the site for production supply purposes on a couple of times.

8.1.1 The Italian Attitude

It is important, within the scope of this research project, to make a brief analysis of the Italian working culture to try and understand why there were so many arguments between both parties during this project.

A good 80% of the Italian crew did not speak either English or Spanish fluently, which was one of the main difficulties in terms of effectively communicating each others' needs. There were a couple of translators but they were mostly useful at meetings, rather than the shop floor, where most of the interaction was taking place. Particularly interesting is the fact that Italians like to speak loudly and animatedly, with interruptions to chat among each other throughout a meeting considered to be normal. This was very awkward for the Mexican and American teams, which considered this to be extremely rude, so there were usually some unexpected reactions of anger from somebody during a meeting.

Although Italians are very receptive to critique, there will rarely ever be any change in their behavior. This was very clear when it came to calling up their attention, repeatedly for not wearing their PPE on the shop floor. Particularly difficult for them was to accept this type of safety feedback from younger persons, since the Italians, in terms of business, prefer dealing with the elder and most important persons in the organization. The Italians show a great respect for power and age. They leave the final decisions to the heads of the company, opposite to what A&B does, which is promoting a more direct involvement of all levels of the organization in whatever decisions it takes.

Regarding AM issues for instance, they particularly disliked being pointed out defects by the mechanics or the contractors, while they had no problem receiving this information directly from the local senior engineer or from the American engineering consultant.

Their body language, facial expressions and voice tone many times led the local team to think that they were witnessing a crucial battle among the Italians; it took some days before realizing that this was their normal way of communicating among themselves.

Issues like the ones that were just mentioned didn't make the interaction any e asier. The stubbornness that they showed and the explosive reactions that were common among them and sometimes even towards a local project member made the joint venture a difficult and not very welcoming memory.

8.2 Modifications to the Mechanical Design of the Machine

As thorough as a mechanical design process is required to be, many times there are issues that are not taken into account either because there was a lack of knowledge or because the communication process between the designer and the customer was not clearly established. This chapter pretends to show examples of this kind of design flaws that have come to affect the easiness with which a technology transfer process is fully implemented and taken to completion.

Due to the high sensitivity of this project for the company and considering the fact that the supplier has developed this technology solely for A&B, the technical specifications and characteristics of the machine through the rest of this chapter will be totally altered up to a level in which they make no sense at all to avoid any chance of data relating that allows a third party to recreate the basics of this new technology.

8.2.1 The Design Process

A design process always starts from a need. As diverse as these needs may be, they all require the same exceptional degree of satisfaction. In order to satisfy a certain need some work must be carried on, either by an individual or by a team.

When talking about design in engineering, one can certainly recognize it as a multi-stage process nowadays. In each stage, a particular solution is given to a certain need. Engineering has taught that there are many ways to achieve the same objective, some may be better than others, but as long as they work, they comply with the ultimate purpose of the task, which is the satisfaction of a need. The following chart identifies each and every one of the agreed design stages from the concurrent engineering point of view:

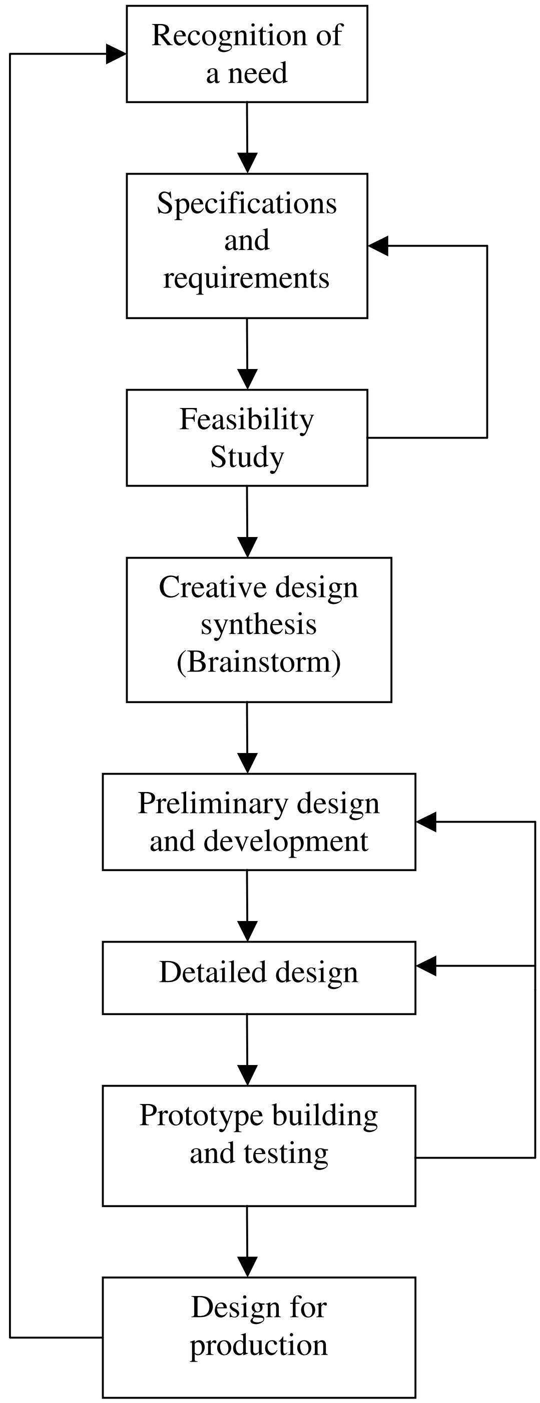

Figure 8.1 Mechanical Design Flow Chart (Mott, 1992)

As clear and simple as this process seems in the chart, there are always some issues that arise during any of the stages that can alter considerably the smoothness with which the process can flow. There are many factors to control and most of the time, not enough people to control them all. Each of the arrows that the figure shows represent the communication process that must take place. There are some stages that are pretty straight-forward but there are many others that require continuous feedback in order to move on. The most important communication channel is the one that must be established between the customer and the designer in order to clearly rule out any misinterpretations that may lead to the delay of the project or even the its cancellation. A successful designing project should start with the customer clearly stating his or her need and with the designer really listening to what the customer has to say. Needless to mention, it rarely happens this way, on the total opposite, it is extremely difficult to get the customer to tell the designing team exactly what is required and how. If a good level of communication is not achieved from the very beginning, there is no point in moving on to further design stages.

A design, as simple as it may seem, must meet certain basic requirements such as:

a) functionality.- how well can it perform and satisfy the need that originated it

b) producibility.- nowadays the lowest possible manufacturing cost is a must which is obtained with the highest possible volume in the shortest possible time.

c) maintainability.- the least possible maintenance requirements make it more attractive, and if some is needed, the easiest, the better

d) flexibility.- under particular circumstances may a flexible system be required in order to meet certain producibility requirements

e) lifetime.- a long lasting solution is considered the best one

For A&B this project had to comply with all these five points mentioned before because a lot of money was going to be invested. It had to be functional because the company required a higher production rate; it had to allow the lowest manufacturing costs possible in order to shorten the recovery time through higher production volumes; it required the least effort to maintain the modifications that were to be performed in order to focus all the efforts in IWS standards rather than maintenance; finally, it had to be designed for a long period of usage, the first machine lasted 25 years as originally designed, so why not think about another 25 ahead?

In order to meet this 5 main expectations of a good design the traditional process has been set aside by the simultaneous or concurrent engineering approach which has proven to be far more effective than the first one. The main difference strives in the fact that traditional design processes are usually based upon a series of time-constrained rigid and unilateral decisions that are only focused in lower costs rather than manufacturability and under which usually no changes are documented. On the opposite, concurrent engineering is based upon multi-party decisions that are taken in a structured and sequenced way dealing at the same time with the design of the product and its manufacturing process, focusing not only on low costs, but also on high quality and reliability for the customer (see Fig. 8.1). A successful designer is that who rather than simply coming up with a product, provides an integral solution to the customer's needs.

A mechanical design has to consider also some very basic concepts such as:

a) materials and their properties

b) process, materials and tooling costs

c) size and complexity

d) surface finish

e) production volume

f) dimensional precision

g) industrial safety and environmental issues

Once all these factors are taken into account, most likely, the solution that is obtained and ultimately provided to the customer will be, of course not the only one possible, but most certainly one of the best.

8.2.2 Tissue Paper Making Process

Paper is a web made of cellulose fibers from plants. The cohesion of the fibers is based on mechanical interlocking and chemical bonds (hydrogen bridges). As a rather interesting fact we can mention that the ultimate tensile strength of certain papers can exceed that of ordinary construction steel. There are several grades of paper but this project deals with tissue paper only. Tissue paper is the one that is used for toilet paper, napkins and paper towels. The paper machine that is going to be explained is a tissue one which greatly differs from that of the paper machines that produce ordinary writing paper.

This is a typical tissue paper machine:

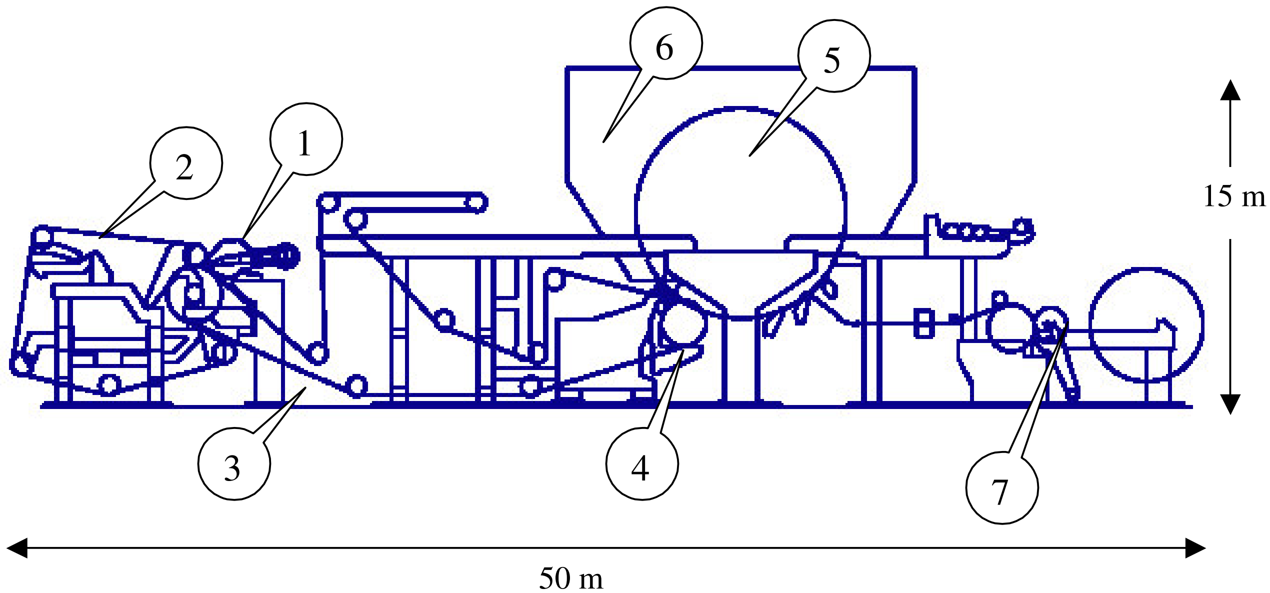

Fig 8.2 Conventional Tissue Paper Machine Layout

The paper making process is made up of 7 main stages, each of which will be briefly described in the following paragraphs:

1) **Headbox**.- the headbox deposits a several thousand liters per minute paper stock flow at extremely low consistency along the width of the forming wire (2). Consistency is the equivalent to density but it is reported as a percentage of fibrous matter diluted in a given volume of water. This suspension must be gradually dried up to become tissue paper as we know it with no more than a 5% moisture content, this is a consistency of 95%!
2) **Forming wire**.- the paper web is formed in this porous clothing. The water extraction process is started by drainage. The paper web is in contact with the

forming wire for barely a fraction of a second before it is transferred to the drying felt (3)

3) **Drying felt**.- this is where most of the water will be extracted. At speeds exceeding 1000 m/min (actual speed rate is confidential) the paper web loses water very quickly but this is still not enough and it has to go through the suction press (4)

4) **Suction press**.- this is an enormous roll that is connected with vacuum pumps in the basement of the paper machine (along with all the other pumps and tanks). The vacuum created sucks up more water from the paper web. By the end of this stage that is also infinitesimal, the moisture content of the web has been reduced only 50% and that is where the yankee dryer comes into action.

5) **Yankee dryer**.- this enormous one piece steel cylinder is actually a pressure vessel. Tiny steam pipes distribute an even flow of steam that heats up the surface of the roll allowing a heat transfer process from the cold paper web to the hot surface. The condensate leaves the cylinder through drainage lines. The yankee dryer is rolling at the same linear speed than the drying felt. It has a 5 m diameter and it is approximately 3 m wide. The drying capacity of the yankee is still not enough to extract all the water content out of the paper web and that is why there is a burner hood (6) on top of it.

6) **Burner hood**.- the burner uses natural gas to heat up air at close to 500°C, this air is blown over the upper half of the yankee dryer. This finally reduces the moisture content to the required 5% and additionally kills any germ that may have survived the process making paper as sterile as an operating room. It is now time to form the parent roll in the reel (7).

7) **Reel**.- the paper web is removed from the yankee dryer by a steel blade. The web is then pulled by a roll that winds it up in a cardboard core. Over 30 km of paper are winded in this cores and the output is what is known as a parent roll, which weighs more than 1.5 tons. The paper making process ends up here, the next stage is the converting process in which the parent roll is unwinded to give birth to the regular toilet paper rolls we buy at the supermarket.

8.2.3 Mechanical Characteristics of the Project

The rebuild project for PM 7F is a major engineering challenge. Only about 45% of the original paper machine will be modified, mainly from the drying felt section and before, so the interaction of both the old and new parts and pieces must be nothing less than excellent. New pieces of the structure will have to fit into the original frame and no chemical reactions are expected to occur between the old and new steel parts. Evidently, corrosion should be prevented at all cost. Different rolls will be installed and along them, a whole new set of journals and bearings must be put in place. The rolls will have a tangential speed of more than 1000 m/min, they weigh more than two tons and they will be subjected to high temperatures. The conditions that these pieces will be subjected to are rather aggressive and thus require an excellent design process.

Hundreds of meters of stainless steel pipelines will be installed to replace most of the old ones. Twenty-two pumps and seventeen motors are going to be either changed or installed. Most of these pumps will require mechanical seals that must avoid any leakages. Hundreds of lubrication hoses will have to be put in place as well. Eight different kinds of lubricants, both greases and oils, will have to be handled. A brand new water cooling tower will be installed with a capacity of over 50 000 l/min.

With the clear expectation set to this project that a vertical start-up is required, the engineering effort that must be carried out is overwhelming. The time constraints are extremely rigid but once the project team acknowledges that every extra down day is worth over 140 thousand dollars, the hurry to finish the project in less than two weeks makes sense.

8.3 Recommendations to the Mechanical Design of the Machine

After reviewing the project some recommendations can be drawn and they are presented as follows.

8.3.1 Rolls Longer than Expected

PM 7F is over twenty years old, it was designed as a conventional paper machine and it worked as such for most of its life. The rebuild project will allow a different width of the parent roll to be achieved. This dimension is established by the width of the formation wire upon which the diluted stock is deposited. For some reason, the Italian designers provided the project with rolls that are 65 cm longer than the previous ones. Although they were designed according to the original frame's dimension, the extra length allows a greater space for the wire and the felt to move sideways which is not a desirable behavior since it makes it far more difficult to control the paper web formation.

What happened here is that no information exchange occurred between the Italian team and the Mexican one. The Italians were designing according to the original blueprints, but the Mexicans had already modified the rolls design to match their operational needs and they just failed to share that with the designers. If this design constraint had been taken into account, over 15 000 USD would have been saved only in material utilization, and the freight costs would have dropped another 4 000 USD due to a lower weight of the seven smaller rolls. Obviously, this can't be considered an example of what concurrent engineering is all about.

The basic recommendation here is to carefully take into account whatever additional restrictions exist and to properly communicate them to the designing team. It is highly possible that not even the Mexican team was aware of this issue, perhaps due to a lack of proper documentation of changes that have occurred in the machine over the past two decades.

8.3.2 Felt Tensing Power Screws

A new tensing roll for the forming wire was installed and the two power screws that provide it with movement have already failed twice from the start-up date. Power screws are designed to convert rotational movement into a linear one and to exert at the same time the necessary force to move a piece of equipment along a desired path; they operate under the basic principles of a worm gear powered by a pinion. In this particular application, the pinion is kept static, it only rotates, and this makes the screw the one that has to move linearly. It basically works like a mechanical jack. The power screws in this case have buttress threads. A picture is showed below:

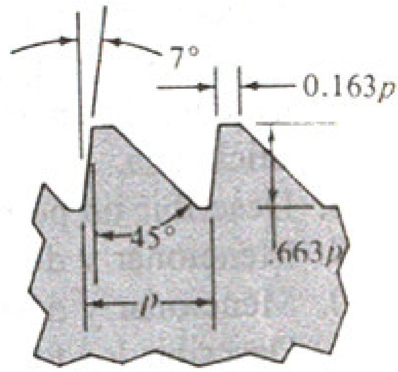

Figure 8.3 Buttress Thread (Ref.: ANSI B1.9-1973)
(Mott, 1992)

Buttress threads are very efficient; they require a minimal torque to move a given load along its length. They are particularly recommendable when the force has to be transmitted only in one direction. Whenever performing tension forces in the screw the most appropriate and safe method is to calculate the area that corresponds to the smaller diameter, either for compression or tension stresses (Mott, 1992).

These power screws are identical to the ones that the previous tensing roll had so we can assume that the extra load that a bigger roll implies is making it fail unexpectedly. The screws are bending slightly in operation; no plastic deformation has been identified in any of the four screws yet. As the screws bend the pinion is jumping over some teeth, causing some damage that leaves the screw operational but useless for precision purposes and a new set is required. It is obvious that an overload is responsible for the deflection and thus, a new design is required in order to bear the load of a bigger roll. However, this is a classic example of a resistance-based designed in which what was looked for was the stress to which the piece was subjected to be less than a certain admissible stress. Following this same design criteria this is what the approach would look like.

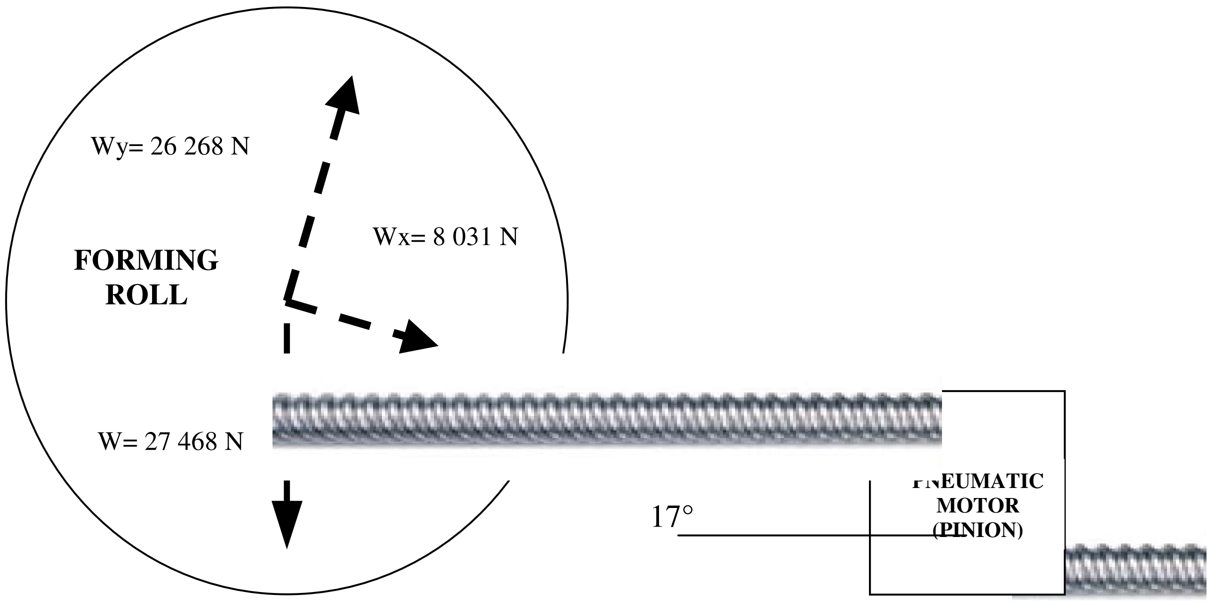

Fig. 8.4 Schematic Representation of the Forces Exerted on the Power Screw

m= 2 800 kg

W= 2 800 kg * 9.81 m/s^2 = 27 468 N Eq. 8.1

Wy=27 468 N cos 17° = 26 268 N Eq. 8.2

Wx= 23 053.50 N sin 17° = 8 031 N Eq. 8.3

Required speed = 0.3 m/min

The power screw will be obviously in compression, so it will tend to bend if the load exerted is excessive. Therefore, the design calculations should make it possible to bear the load of the extra weight of a bigger roll as it happened in this case. The following table shows the preferred sizes for buttress thread power screws, it has been obtained from a power screws manufacturer:

Screw		**Axial load speed required [m/min]**												
Dia [mm]	**Pitch**	**0.15**	**0.30**	**0.45**	**0.60**	**0.70**	**0.90**	**1.00**	**1.20**	**1.30**	**1.50**	**1.60**	**1.80**	
12	3	660	500	380	280	210	160	120	90	60	50	30	20	
16	4	970	730	550	410	310	230	170	130	100	70	50	40	
20	4	1220	860	610	430	300	210	150	100	70	50	30	20	**kg**
25	5	2400	1810	1360	1030	770	580	440	330	250	180	140	100	
32	6	4010	3020	2280	1710	1290	970	730	550	410	310	230	170	
40	6	4600	3260	2300	1630	1150	810	570	400	290	200	140	100	
		kg												

Table 8.1 Preferred sizes for a given load and axial speed (Roton Power Screws)

Example: find a suitable screw to move 200 kg at 1100 m/min. From the table, the 1200 mm/min column shows that a 25 mm diameter by 5 mm pitch is suitable for loads up to 330 kg.

Since the load values are given back in kilograms, Wx has to be converted back from weight to mass in order to pick the appropriate value in the table:

Wx= 8 031 N

m= 8 031 N / 9.81 m/s^2 = 819 kg Eq. 8.4

For a 0.3 m/min displacement the 20 mm diameter screw with a pitch of 4 is suitable for a load of up to 860 kg. In fact, the current power screw has a 16 mm diameter with the same pitch of 4 but it can only bear up to 730 kg, no wonder why this screw is failing.

The recommendation in this resistance-based design approach, since the pitch is the same and thus the pinion would not have to be modified, is to buy a set of 20 mm diameter power screws to solve the problem. This size of power screws is a standard one, so there is no issue with cost or delivery times. In the next paper machine down day, this set of screws can be installed instead of replacing the current ones with another set of the same size that will fail in no time.

This same design can be carried out under a rigidity criterion, in which one as the designer should first establish what the maximum deflection for the screw can be in order to avoid the failure. Just for illustration purposes let's assume a maximum deflection (δ_{max}) of 0.25 mm as the main constraint to follow.

$$\delta_{max} < \delta_{adm} = 0.03 \text{ mm} \qquad \text{Eq. 8.5}$$

$$\varepsilon = \frac{\delta}{L} \qquad \text{Eq. 8.6}$$

Where ε is the strain (adimensional of course), and L is the total length of the screw expressed in meters.

Therefore:

$$\varepsilon = \frac{0.00025\,\text{m}}{1.20\,\text{m}} = 2.1x10^{-4} \qquad \text{Eq. 8.7}$$

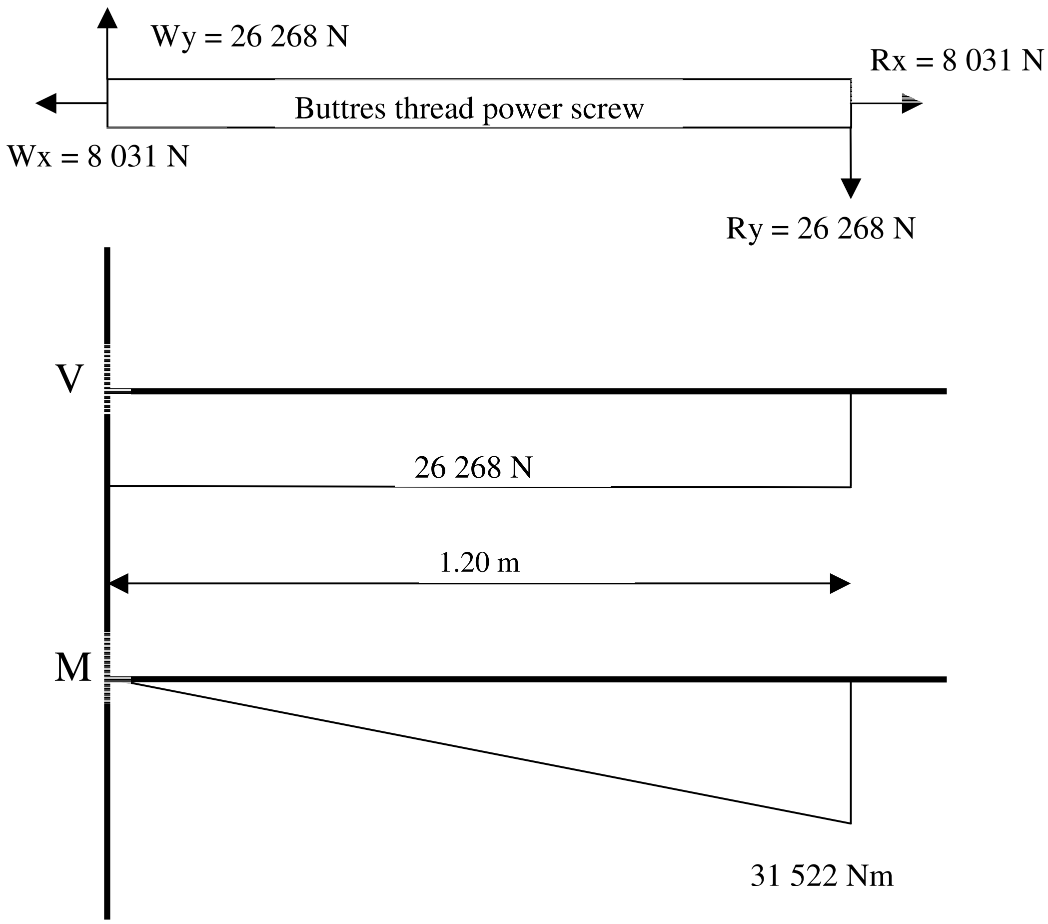

Fig. 8.5 Shear Force and Momentum Diagrams for the Power Screw

According to Hooke’s Law: $\sigma_{max} = E\,\varepsilon_{max}$ Eq. 8.8

$$\acute{o}_{max} = \frac{Mc}{I} \qquad \text{Eq. 8.9}$$

$$\acute{o}_{max} = \frac{Mc}{I} = E\,\varepsilon_{max} \qquad \text{Eq. 8.10}$$

$$\varepsilon_{\max} = \frac{Mc}{EI} \qquad \text{Eq. 8.11}$$

What is looked for is the radius of the screw, which is obtained from its moment of inertia I:

$$I = \frac{Mc}{E\varepsilon_{\max}} = \frac{1}{4}\pi r^4 \qquad \text{Eq. 8.12}$$

Being a circular element, c and r are equal, which yields:

$$\frac{M}{E\varepsilon_{\max}} = \frac{1}{4}\pi r^3 \qquad \text{Eq. 8.13}$$

Solving for r:

$$r = \sqrt[3]{\frac{4M}{E\varepsilon_{\max}\pi}} = \sqrt[3]{\frac{4(31522N \cdot m)}{200GPa(2.1x10^{-4})\pi}} = 0.098m \qquad \text{Eq. 8.14}$$

Which allows to choose the nearest standard diameter size of 20 mm again from the Roton Power Screws table and that allows a linear speed of 0.3 m/min to be obtained.

8.3.3 Welding Quality

The environment in which a paper machine operates is extremely moist and aggressive over time due to the chemical vapors that are freed either by the substances used in the paper machine as additive or cleaning agents or by the paper stock itself which is treated with several chemicals that prevent bacteria colonies to develop. This makes the use of stainless steel a must in all the structural parts and mechanical components. These components are extremely heavy and they are welded together to perform the function they were designed to. Welding as it is commonly known is a method to join metals by concentrating heat, pressure or both at a given point. A good welding is as good as the base metal, sometimes better, as some applications require the welding to be the last element to fail. The welding process that was used in this project was a manual SMAW type (shielded metal-arc welding) which is one of the most common ones (Doyle, 1988). It was chosen because the parts that were going to be welded were mostly unique and there wasn't a need to provide any more shielding than the electrode coating does. However, the best welding method for stainless steels is TIG (Tungsten Inert Gas) or GTAW (Gas Tungsten Arc Welding) which generally does not require any post weld finishing as SMAW does (emery stone to remove slag formations) and it is slightly more expensive (Doyle, 1988).

It is worth mentioning that the Engineering Department stated that the welding standard to be applied was ISO 15609-1 Specification and approval of welding procedures for metallic materials, Part 1: arc welding; and the welders should be certified under ISO 9601-1:1994 Approval testing of welders, Fusion Welding, Part 1: steels. This information was obtained verbally from the department head.

8.3.3.1 SMAW

As its name indicates, this welding method is based upon an electrical arc that is created between the rod and the base metal. The arc itself is a sustained electrical discharge that can generate temperatures from of 2 800°C or ten times greater depending on the particular conditions. In the SMAW process, the welding rod is gradually melted by the arc. The melted metal must be isolated from the air so the rods are covered by a coating that chemically reacts with the heat and produce a protective gas cloud that keeps the melted metal from spontaneous oxidation (Doyle, 1988).

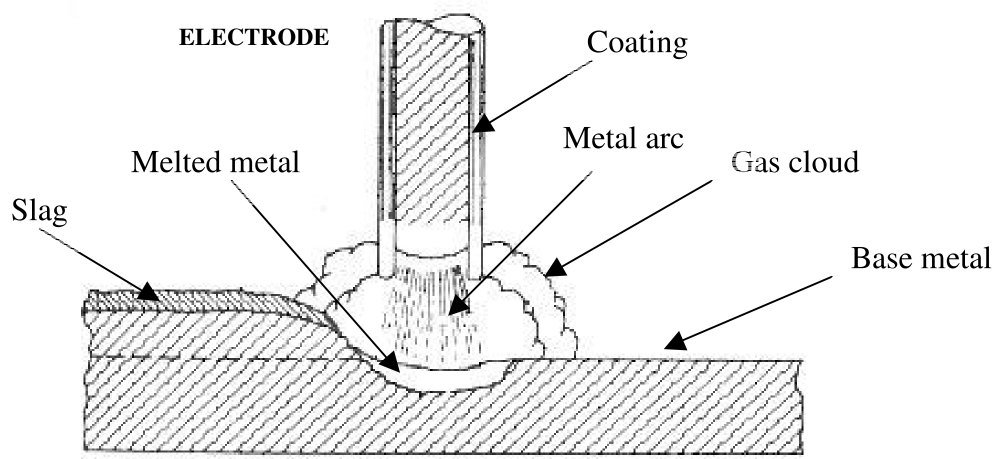

Fig. 8.6 SMAW Process

Several chemical compounds make up the coating: SiO_2, TiO_2, FeO, MgO, Al_2O_3, etc. They are supposed to:

1) aid in stabilizing and directing the arc for an effective penetration

2) provide the gaseous protection to avoid environmental contamination
3) control the surface tension of the melted metal pool to influence the rim's shape once the metal cools down
4) behave as a depurator to reduce the oxides
5) add up alloy elements to the welding
6) promote the build-up of slag to carry away the impurities, protect the hot metal and reduce the cooling speed.
7) electrically isolate the electrode
8) minimize the splashing of the soldered metal

One of the main factors affecting the quality of a soldered joint is the penetration of the welding. The penetration (P) is proportional to the quantity of energy supplied and it is expressed in mm. This energy is a function of I^2R, where I is the intensity of the current expressed in amperes and R is the resistance expressed in ohms. R is provided by the electrode and I is determined by the electrical source. The deepness of the penetration determines the size and strength of the welding seam that will keep the pieces together. Another factor that determines the deepness of penetration is the distance between the electrode tip and the metal base. This distance affects the voltage of the electrical arc (E). The following equation clearly states this relationships:

$$P = \sqrt[3]{k \frac{I^2 A}{E^2}} \quad \text{[mm]} \qquad \text{Ec. 8.5 (Doyle, 1988)}$$

There is a proper rod size for each type of work and an ideal range of current for each rod. The penetration and fusion are not good at all when there is too little current passing through a thick rod and on the opposite for a detailed work a thin rod with little current is needed. This SMAW process rarely is used with currents exceeding 400 A.

This welding process is one of the most attractive ones in terms of versatility and cost. Obviously, the person doing the welding job must be certified to do so in order to guarantee the quality and safety of his job.

8.3.3.2 Suction Box Defect

In one of the new suction boxes that help out extracting water from the felt, there was a major failure in the welding along one of its edges. The problem was not identified during the production stage but during the pre start-up one, when all of a sudden, the water it was extracting was being poured all the around the device. Water was leaking at several thousands of liters per minute and it was necessary to stop the tests, pull it out with an incredible maneuver, then fix it and finally put it back in. This problem alone caused a delay of nearly 24 hours in the testing phase.

The results of the investigation showed that the welding seam quality had not been the best one for the particular arrangement that was made:

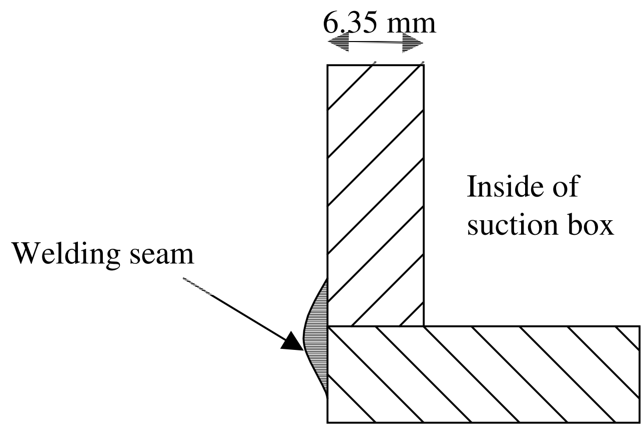

Fig 8.7 Cross-section of the Suction Box Welding Arrangement

An external welding seam was put along around 3 m and when it was polished out to leave a smooth surface a tiny fraction of the welded edges was exposed (as a consequence of the SMAW process chosen). When the suction box filled in, the tiny opening grew bigger and propagated itself lineally along 75% of the seam. The penetration was not deep enough, so when the emery stone was used to smooth out the seam, the edges were left almost exposed back again. This added up to the tremendous pressure that the suction box walls are subjected to in operation, made the failure an expected outcome.

The recommendation issued for this particular problem is to use an weld seam along a chamfer made on both ends of the metal plates (the plate's thickness al lows it) and this would confine completely the water inside the suction. The suction box geometry perfectly allows this and the additional cost does not add up to more than 150 USD so there is no reason why this couldn't be done. The following figure shows the suggested arrangement:

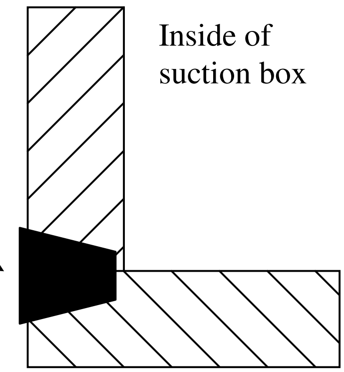

Fig 8.8 Suggested Cross-section of the Suction Box Welding Arrangement

8.3.3.3 Pipelines Defects

One issue that caused severe headaches to the project team was the terrible quality of the welding, particularly in big diameter pipelines (10" and more). Their very aspect was not precisely very professionally looking but the construction team wasn't really expecting all the leakages that would occur all along the pipelines, most of which, due to their size, are not extruded but rolled and welded in one side all along the length of the line.

From the IWS standpoint, this was a major source of contamination that really delayed the start-up of the machine because every pipeline had to be followed along its length to try and identify the defective points which had to be repaired. A small army of workers had to spend two days in this task. The risks involved with this issue were enormous: people had to climb up to 7 m to check the lines and fix them, then, many of these leaks were falling over motors. Luckily, no safety incidents arose from this quality defect, for which, of course, the supplier is fully accountable. By the way, the supplier was the Italian company.

8.3.4 Motors Capacity

Motors for this project were bought from ABB, Baldor and Siemens. Over in Siemens, when a couple of the motors were ordered, apparently someone forgot to consider the altitude at which they were going to be operating. The two motors, one for 125 HP and the other for 100 HP were to provide power to a couple of non-vital pumps that would re-circulate the stock at a low consistency between two tanks in the approach stage. The mistake was made by the motors supplier who sent the same motor frame as was requested but with a different power rating as a result of the altitude at which they would have to work. The power output of a motor depends on the altitude because the higher it operates, the less efficient the air is as a coolant, thus, a 125 HP motor at sea level (0 ft) will provide 100% of its power while at 2380 m (7850 ft) above it it will lose 10% of it according to information provided by Siemens:

Altitude above sea level	**Derating factor**
0-3299 ft	1.0
3300-5000 ft	0.97
5001-6600 ft	0.94
6601-8300 ft	0.90
8301-9900 ft	0.86
9901-11500 ft	0.82

Table 8.2 Derating Factors for Electric Motors According to Altitude above Sea Level (Siemens, 2003)

The obvious result was that the two pumps didn't have sufficient capacity to meet the pressure and flow requirements particularly considering the fact that the recirculation between tanks would take place in two floor levels with a difference of over 15 m.

Siemens accepted full responsibility for the mistake and delivered two new motors in a matter of one week and a half from the complaint. Under the corporate contract that is signed between A&B and Siemens, there are no penalty fees stated, Siemens agreed only to pay for the additional shipping and handling fees for the first motors and the replacement ones. This lost time required that the project schedule was altered, resources were allocated into different tasks and then tried to put back in the pumps installation activities once the right motors came to the plant. Valuable time that could have been devoted to IWS activities was lost.

8.3.5 Electrical Misunderstanding

Some of the first discussions that arose when the Italian team got to A&B's facilities in Tlaxcala were regarding the electrical circuits for the pneumatic and hydraulic control systems. The main problem was miscommunication. The Italian crew didn't understand that this site uses 4-20 mA signals instead of 0-20 mA ones.

The drawing reviews that were sent back and forth at some point got messed up and the final drawings that were released for construction by Pastra were issued based on 0-20 mA analog signals. When the contractors working on the controls part started tending the new wiring system and plugging each cable where their drawings stated to the Italian supervisor realized that the drawings that each party had didn't match.

Although this wasn't disastrous, there was a lot of time invested in recalibrating the drives, valves and flow, consistency and pressure transmitters. Luckily, they both use a 24 V input, so there was no need to modify the transformers. This kind of signals that are used in the distributed control system (DCS) allow a proportional control of valves and drives, one can send a signal to open a certain water valve to 67% or 89% this is what the amperage range is for, unlike digital signals in which there is either a 1 or a 0 signal, let's say on/off valves which are either open or closed.

Examples such as the previous ones do not seem very serious now that the crisis is over, but at the time, they required fast decisions to be made to minimize the damages to the integrity of the project, the equipment and even the people in some cases. Not one single of the mentioned examples should have ever had existed, they were all design flaws which could have been prevented.

The company has to understand how this happened and develop action plans that can be helpful in preventing this kind of things. Maybe it will require sending people to the suppliers' facilities to inspect and supervise that everything is compliant with the requirements of the project, otherwise, the surprises that may pop up once the equipment and machinery is already on the site can be disastrous.

Mainly technical factors affect IWS standards implementation by taking time out of people's hands that could be used for IWS purposes, for training, for visu al controls implementation, for CIL charts development, etc. The good thing about it is that problems like these can be eliminated from their root causes, which mainly are a lack of communication, lack of high quality standards from the supplier and lack of interest in the ergonomical performance of a certain machine or equipment. Once these issues have been identified, surely they won't show up in future projects because through IWS and based upon the PVP, the strategies to be taken will be totally effective.