

# Roller Alignment - Mechanics

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## ABSTRACT

This paper describes a number of instruments and techniques that can be used in the roller alignment process ranging from simple observation, to hand tools and finally to gyroscopes, lasers and optical tooling. This paper shows how these instruments can be used to measure roller level, square, parallelism as well as set common centerline locations. Finally, this paper describes design and maintenance techniques to speed up the costly alignment process.

## INTRODUCTION

Most of the rollers in our web industries need to be aligned, or more specifically, realigned. This maintenance process can be quite expensive so we need to first determine *if and when* rollers need to be moved. This first question is answered in a companion paper written entitled Roller Alignment - Standards [1]. It is a second question that will be answered or at least outlined in this paper. That is *how* do we actually move the rollers. Both questions must be considered carefully because the costs of either excessive or inadequate alignment could, in the long-term, approach that of the rollers themselves. Both questions must be considered in tandem. If, for example, rollers needed to be aligned frequently then that need should be reflected in details of design as well as of maintenance. Conversely, the costs of realignment may in turn affect how tight we set our alignment standards so that some economic balance is achieved. Due to the enormous range of web applications, in this paper we can only outline some of the more common roller alignment tools and techniques.

## GETTING STARTED – DEFINITION, MEASUREMENT, CORRECTION

First, we need to define misalignment. Misalignment is the geometrical error between the axes of two or more nominally parallel rollers. (We will consider the case of offset centerlines separately.) Moreover, misalignment must be specified in two different directions that need not necessarily be perpendicular. As we show in the Roller Alignment Standards paper, the coordinate system that makes sense in web handling is the directions that correspond to in-plane and out-of-plane bending. There we showed that tolerance to out-of-plane bending could be 100X that of in-plane bending. This knowledge of the night and day difference in tolerance between the two is essential to understanding the design of all web guides and some spreaders. However, this knowledge can also reduce the costs of machine design and maintenance in ways covered in the companion paper on Standards.

Unfortunately, this web handling view of misalignment, while essential knowledge for anyone working with web machines and a view that is solidly backed by both science and experience, is a very very awkward coordinate system. It is awkward if for no other reason than the coordinate system moves with every span in the machine. It is also awkward because it is span centric instead of roller centric. So in practice, we use a much more convenient coordinate system of level and square. Level being with respect to gravity. Square is usually with respect to a datum called an 'offset centerline' that we will describe later. Unfortunately, this measurement centric view of misalignment also has severe limitations. It will treat in-plane and out-of-plane problems the same, yet we know without any doubt that the resulting issues are quite different in both character and magnitude. Also, insisting every roller in a machine be level may not solve any problems whatsoever if, for example, EVERY roller in the machine was out-of-level by precisely

the same amount. This situation can be approximated if, for example, you had an extremely stiff frame mounted on a crooked floor or when a foundation settles somewhat evenly on the back side.

How we *measure* and move rollers into closer alignment depends on many factors. Suffice it to say that we have many measurement tools to choose from and that often several are used in combination to achieve an overall machine alignment. These tools range from simple observation, to hand tools to gyroscopes, lasers and optical tooling. We *move* rollers by loosening bolts and then shifting them over, but here again there are many techniques that might be employed depending on the design details of that section of the machine.

## WHEN ARE WEB MACHINES TYPICALLY ALIGNED?

The alignment history of machines varies enormously. Many machines, particularly small ones, are merely assembled without any alignment whatsoever. Some machines are assembled into a unit (or module) and that unit is merely leveled in two planes upon installation in a plant with a precision level. Small machines might have adjustable feet to achieve level on an unlevel foundation (typically an industrial 6" thick slab of concrete). The challenge here is most machines are designed with four feet and there will be the inevitable rock or twist of the frame or both. Designers note: small machines could be designed with extremely stout frames with a three-leg support to avoid both frame rocking and twisting. Bigger machines might be set on footings or even baseplates with level achieved by shimming between the feet and the foundation. If the machine is made up of more than one module, each may be roughed in on a common centerline, the leveled in two planes and finally made parallel to each other. In all of these cases, however, individual rollers are not moved. Whether any of these approaches are adequate in reducing misalignment related waste and delay issues will be discussed later. It is possible that match-drilled side-frames give adequate internal alignment for some/many/most rollers and webs. Here, however, **we will define alignment to mean to move each roller individually in two planes** and thus none of the above approaches qualifies by that definition.

There could be four or more times in a machine's history when alignment (e.g., moving every roller individually in two planes) might take place. The first time a machine would likely be aligned would be in the machine builder's shop. Here, every single roller may be moved into hairsbreadth tolerances. This is not so much to prevent runnability problems *after* startup. Instead, it is to prevent problems *during* startup. If a roller needed to be moved more than, for example, what the bolt hole clearance allowed, the hole might need to be bored out bigger. Redrilling a hole is much easier to do and usually more accurately done in the very shop that made the hole in the first place than on the customer's floor. In some cases, this shop alignment might be the only one a machine might get.

However, it is usually a good idea to check every single roller for misalignment after it has been bolted to the floor and fully assembled. One reason might be that the machine might get warped if it were, for example, mounted to a crooked floor. Another reason might be that the bolted joints might shift slightly on the long and bouncy truck ride from the machine builder's shop to the customer's plant. However, there is another reason that only some of the most skilled builders would know. That is, metal will stress relieve itself due to vibration; quite possibly on the same truck ride we just referred to. This can happen despite best efforts to stress relieve parts after machining, usually by heating them locally with flame or entirety in an oven, or by giant shakers. In addition to individual parts, you can run into similar situations for assemblies composed of already stress-relieved parts if they get warped and twisted during the assembly.

The next alignment might take place a year or so after startup. It is during this time that much of the last stress relaxation of the frame and much of the initial foundation settling will take place. You will also likely uncover a few design weaknesses such as mountings that are not stiff enough, particularly in regard to both bolted joints and cantilevering. How much rollers move during the period between startup and a year or so later will give you some sense as to how often future realignment checks might be needed.

Let me now roughly outline what might happen during these alignment events. Sometimes it could be merely a survey to better plan a more extensive maintenance event or determine *if* one is even needed. A survey may or may not check every single roller, even though there might be good motivation to do so. It

would certainly involve major process rollers and should include the transport rollers leading into and out of them. Sometimes the call is made on the spot just after the measurements have been made whether or not to move rollers, even though there is a great risk of just guessing. Sometimes the realignment will only be done on a section of a machine, a situation not uncommon for large machines where there may not be enough downtime available to do everything at once. Sometimes the intent is to move every single roller into standard. I say 'intent' because sometimes the mechanics run into situations that are too difficult or too expensive to address at that time and they may just do the best they can or sometimes make no move whatsoever on a particularly problematic roller.

Finally, any time a roller is removed for maintenance it *should* be put back into alignment with precision tooling. My experience indicates that the **greatest source of misalignment** (presuming that the roller had been aligned at one time) **is maintenance**. Process rollers are frequently reground/replaced and small rebuilds or roller moves are sometimes done by the plant's mechanics. If these are done with typical hand tools, pi tapes and levels, you can bet that some of the rollers will end up crooked; quite possibly/likely causing runnability problems. It is ironic that the very department that is charged with returning a machine to a like-new condition may be very same that ruins a like-new condition because they have not been taught best practices; rollers (may) need to be realigned whenever/wherever bolts are loosened.

To this best practices general guideline of realigning rollers that have been taken out I might offer just a couple of practical exceptions. The first is if the same roller is returned to the same place. Here, IF we dowel prior to removal AND we mark and save the shim pack, we can get the roller back pretty close to where it was in the first place, perhaps even close enough. The second is when precision alignment equipment is not available at that time. Here, we can paint the front side bearing housing yellow as a warning for operators to keep an eye on sudden changes in runnability at that location and be ready with a speed-dial number in our cell phone to a contract alignment crew. It is possible, but seldom done, to allow interchangeable rollers by cutting precision keyways into both the bearing housing and frame mount. The problem here, aside from cost, is that it is next to impossible to get the frame mount precise initially and stay that way for years or decades.

## INDICATIONS FOR THE NEED FOR AN ALIGNMENT

Alignment, as are most things in this business world, a matter of economics. Understanding economics will help us make better maintenance calls. The two costs areas to consider; the costs of alignment and the costs of misalignment. Alignment costs would include the alignment crew, usually two people, that do the measuring. To this we add the costs of the mechanics, again often two people, who move rollers. If these are outside contractors we will be also paying for their travel expenses, equipment and so on. However, it is likely that the much greater cost in many situations will not be these people, but rather the **biggest cost of alignment may be machine downtime**. There are exceptions when downtime costs little or nothing so that all we incur is labor for a few people. The first exception might be a new machine startup or a major rebuild because the alignment work can often be done concurrently with some other activities such as electrical work, if it can be planned and coordinated. Second, downtime costs are not accrued for machines that are not fully utilized provided that the alignment can be so conveniently scheduled for nights, weekends or whenever the machine is slack. One implication of this economics is that THERE IS LITTLE EXCUSE FOR NOT ALIGNING NEW MACHINES because they don't accrue the much larger cost of downtime. You will never have the opportunity for a cheaper and more timely alignment than during machine installation.

Now for the costs of misalignment. Here, the situation varies enormously with the application. However, one widely recognized penalty for misalignment is diagonal wrinkling caused by rollers that are not mutually parallel. Any good web handler will recognize this risk as a diagonal trough pointing to the narrow side of the downstream roller. While a trough in the open web span is seldom rejectable, it should never be ignored. Misalignment models indicate that you are half way to throwing a wrinkle across a roller as a bulge when the web first shows diagonal troughing in the web span. A wrinkle crossing a roller is seldom tolerable in any industry because causes it to get narrower, marks the web and may even break the

web. However, a trough in the open web span might also be rejectable in some cases, such as when the web is in the forming zone because the troughs or their memory would also be formed in.

Another cost of misalignment is that it greatly increases web break rates on brittle materials such as paper and foil. Even an invisibly small misalignment (one that does not cause one edge to go slack), doubles the tension on the other side which in turn can increase break rates by 4-8X in that span as predicated by runnability models for paper [2].

A final example of misalignment waste is the costs of loss of web path control. Even on tolerant processes, the web could move far enough sideways to run off a coater head or even roller. Even on tolerant process, poor path control could increase the size of trim that might need to be taken. However, with intolerant processes such as printing, the tiniest path control error could result in reject due to misregistration; often the number one cause of waste on a printing machine. True, not all misregistration is caused by misalignment. Even so, crooked rollers are a major reason for loss of registration. Finally, poor path control leads to poor wound roll edge quality.

To any product waste exacerbated by misalignment we also add maintenance and downtime. Examples here are abundant. Some are machine specific such as increasing wire life by a factor of four and in the process saving \$1.5 million per year after aligning the wet end of a paper machine [3]. Just downstream in the dryer section, credible claims can be made for a half-dozen maintenance troubles associated with misalignment [4]. Others are more universal, such as a finding that 50-70% of ALL rotating equipment failure was directly attributable to shaft misalignment [5].

So, when does economics indicate the need for a realignment? It might be justified IF a portion of the annual costs of misalignment related waste and delay costs exceeded the costs of alignment itself. I say a proportion because not all diagonal wrinkles and not all brittle web and not all misregistered images are caused solely by misalignment. Also, just a little bit of common sense as well as web handling knowledge, can reduce the costs of alignment. What we will say here is that you don't necessarily have to align the whole machine. Instead, **you might only need to align the local area to where these specific misalignment related waste and delay issues are initiated.** How many rollers need to be moved depends entirely on the situation. Similarly, how long it takes to move rollers depends on the situation. Here, however, we can at least offer a very ballpark guess; allow about an hour or two for setup and about an hour per roller. Obviously, some rollers may not even need to be moved (because they are already in spec) or may be moved quickly (if the design allows for it). However, there may well be the problematic roller that takes longer than a dozen of its neighbors. There is another big factor in the alignment time required; that is the primary measurement system. For example, measuring with optical tooling is truly tedious compared to gyroscopic methods that can read and report just about as fast as you can place the instrument/sensor on the roller. Even so, the move will take longest and is not made much faster with fast measurement.

## PREPARING FOR AN ALIGNMENT

There is no better time to perform TLC (Tender Loving Care) on your rollers than before an alignment. If we grind and/or replace damaged rollers first, then align, we only align once. However, if we align a roller then sometime later want to do service on it, we may have to align it again, in other words twice. Because we define the axis of a roller by measuring its surface (gyroscopic methods excepted), there are two types of error that need to be checked for and (best) corrected before alignment. The first is radial runout. While it is possible for the shell to have some runout when purchased, most rollers are ground so that this would be minimal (less than alignment tolerances) when the roller was first installed. However, wear and particularly accidents that bend journals can take the roller out-of-round. Another error is diametral profile variation. Again, most new rollers are ground so that this would be minimal. However, wear usually occurs in bands or lanes so that if you set a target there you will read differently than if you set it on a high spot. Other PM (Preventative Maintenance) that would make sense at this time, such as replacing bearings that are worn and balance, are not strictly needed for the alignment process but would often be most practically done before hand.

The other major area of alignment compromise is looseness. Here we can be guided by the best practices of alignment of the front end of an automobile in a garage. No reputable shop would align the front wheels if, for example, you had a loose tie-rod end or steering box play. So if your roller is loosely mounted so that it can go dink-donk-dink within its mounts, how do you align it? To the dink, to the donk, or half way in between? Looseness is common in slides, pivots and other moving elements. Beware, however, that often looseness is a design rather than maintenance problem. If so, a good designer will need to look at options for upgrading those components so that the investment in alignment will not be quickly lost.

Lastly we can have flimsy frames. Most often this involves a bolted joint rather than the flexibility of the metal frame itself, though they often go hand in hand. The biggest single design error is excessive cantilevering where an extension is bolted rather than welded to the frame. Often a simple gusset, strategically placed, might reduce this problem by an order of magnitude.

Two final preparations will speed up the alignment process. The first is to do a thorough cleaning of the area starting with clutter and then dealing with dirt. Clutter gets in the way of maintenance and operation. Dirt can get in between mounting surfaces so that shimming is compromised. The other is to have a web threading path 'circle' diagram with all rollers labeled. Process rollers are usually named by the process, transport rollers can be numbered sequentially. The reason for this will be that best documentation practices annotates this threading diagram with before and after alignment position reports for every roller.

## **ALIGNMENT BY VISUAL OBSERVATION**

There are very special circumstances when it is possible to align rollers reasonable well without any measurement tools besides your own eyes. The circumstances include: just one principle axis of misalignment as well as web paths entering and leaving that roll that are pure horizontal and/or pure vertical as well as being able to safely move the roller while the machine is running as well as the observation of diagonal wrinkles as well as an understanding of web handling. This quite restrictive case is described in the companion paper [1] and illustrated in Figure 1.

## **ALIGNMENT BY HAND TOOLS**

The most common hand tools are the precision level and a squaring method such as Pi tapes or trammig sticks as illustrated in Figure 2. The level is the simplest to understand. You put the **precision level** on the top of the roller and make sure the bubble is in the middle of the sight glass. To make sure the reading is 'good', flip the level end-for-end to see if you get the same reading. This not only checks for setup errors (such as not getting the level square on the top of the roll), but also checks for calibration errors (the level being out of level) and can sometimes detect errors of the surface of the roller. Best practices would have you put the level in the exact center of the roller (required with bowed rollers), but this is usually unnecessary for rollers that comply with decent standards for deflection. However, the biggest limitation of precision levels is that they are not all that precise. The best you will typically find is accuracies/resolutions of 0.001" per foot, or 100 microradians. While this is a tighter tolerance than most rollers in the wider web industry, it is an order of magnitude cruder than suggested by many machine builders in the paper industry. Furthermore, this best case level is literally kept in a velvet lined case locked in the maintenance foreman's instrument cabinet; a quality something few maintenance departments outside of paper mills even aspire to, much less possess.

We have no squaring tool in our hand tools box. Instead, the best we have is the ability to bring rollers into parallel. This can be done with decent precision provided that you use either a precision Pi tape (as opposed to just a flat tape) or a trammig stick with a dial indicator that can read to better than 0.001" In the hands of an experienced craftsman (and the occasional maintenance mechanic or engineer), you can approach the precisions demanded by the paper industry, but only with regards to parallelism.

There are, however, extreme limitations to setting rollers parallel with these methods as given in Table 1.

**Table 1 – Limitations for Setting Parallel Using Hand Tools**

1. No ability to square rollers (a problem for spans that are mostly vertical)
2. Accumulation of errors as one moves down the machine
3. Requires the tangents on both sides of the roller pair to be accessible
4. Tends to encourage sloppiness

It is with irony that I conclude (in general) that while hand tools are great for *detecting* misalignment, they are often terrible at *correcting* misalignment. Even so, there are places where hand tools are the best and perhaps the *only* method (not to be confused with *adequate* method). I was with two wide format printer builders where parallelism needed to be better than 0.001” to avoid web path oscillation/walking and the confines gave little room but for inside micrometers.

## LASERS AND GYROSCOPES

While lasers were invented a half-century ago, laser alignment is much more recent and quite limited in application for aligning rollers. Even so, more than a decade ago lasers began replacing the cumbersome dual dial indicator method for aligning two shafts, such as between an electric motor and its driven roller as seen in Figure 3 [6]. Misalignment here tears up motor/gearbox bearings, roller bearings and especially couplings and is a major cause of rotating machinery failure as discussed previously. A different type of laser setup can also be used for conventional roller-roller alignment as seen in Figure 4 [7]. While I know that major alignment companies have studied lasers (as a replacement/supplement to optical tooling), few have adopted them for routine use for web rollers. Since textbook sensor accuracy of 0.0001” is not limiting, I can only conclude some possible reasons for limited adoption: real system accuracy might not be anywhere near what the sensor is capable of, or it is slower to set up and use or cultural inertia.

Alternatively, gyroscopic methods are even more recent but are rapidly gaining market share [8-10]. One motivation is that it addresses one of the biggest costs of alignment; downtime. The time to set up and especially to measure roller position is faster and much faster respectively than optical tooling. Nonetheless, there are a couple of downsides. The first is that real accuracy (perhaps 0.002-0.005”) may not be good enough for some machines and even whole industries such as paper mills (at least as specified by the big machine builders). The second is even more limiting; you can not buy the equipment. It is only available as a contracting service that includes the instrument and a factory trained technician. This contractor service only option hardly does you any good at 10 PM when your machine suddenly goes down for an unplanned major roller servicing and reinstalling requires better precisions than hand tools would allow.

A final limitation with any technique is the concept of gage length. A small optical target is subject to rocking on an inevitably poor roller surface. The spirit level or gyroscope are wider, so errors in the surface are less important. The gage length of optical tooling, described below, is as wide as possible: the width of the rollers. So while lasers and gyroscopes are both quite interesting and useful for many situations and that their usage is growing, they are still uncommon with respect to the use of optical tooling and especially hand tools.

## OPTICAL TOOLING

By optical tooling we mean instruments *resembling* the surveyor’s precision sight level and theodolite that you often seen on building construction sites, lot mapping and roadways. However, there are a few distinctions. The first is that while precision levels and theodolites can be used, the primary tool that the web alignment crew will use for squaring rollers to an offset centerline is the TTS (Telescopic Transit Square). These instruments are depicted in Figure 5. Second, while surveyors often use lasers, these are

not so common with web alignment crews as discussed above. Third and perhaps most important, that is the equipment used by the web alignment crews may be more or much more accurate than those used by surveyors. While the origin of this equipment was surveying, it was greatly improved on by companies such as Brunson Instrument Co., Keuffel & Esser, Kern, Wild and Leica around WWII for a variety of aerospace, marine and industrial applications [11]. The improvement results in “first order” accuracy of one second of angle (0.001” over 17 feet or 5 miliradians) that is an order of magnitude or better than mere surveyor’s equipment that could be as sloppy as one minute of angle. This best practice accuracy was comfortably below the specifications of paper machine builders such as Beloit Corporation and Valmet (now Metso). Both companies quickly adopted the instruments and incorporated them into roller design and maintenance standards in the 1970’s and other web machine builders from other industries followed [12].

As with most methods, leveling and squaring are distinct and sequential steps. The first step is to level all rollers with respect to gravity using a precision sight level or machinist’s level. The physical move would be to first remove all shims under both ends and then shim under the low end by the difference of the front and back readings as read/calculated by the level/sight-level. Alternatively, jack screws or a temporary shear ledge is installed to allow a leveling adjustment but to preserve the level when in the next step the bearing housing is again loosened, but this time for squaring.

Squaring requires a datum and a squaring tool set as seen in Figure 6. The datum could be a roller that would be difficult to move, such as a CI (Central Impression) drum. That roller could serve as the reference for all others. However, a much better practice is to use that roller(s) to define what is called an ‘offset centerline’. This centerline is usually located in the walkway and is defined by two or more ‘monuments’ that are brass plugs with a pinprick in them. A pair of TTS (Telescopic Transit Squares) is set above the imaginary line connecting these two monuments. The optical square magnifies the scale that is held on the 3 or 9 o’clock position on a roller and the difference between the front and back readings indicates the horizontal move that is needed to bring that roller into square with respect to the datum. The need for line-of-sight access to one side or another of a roller is one major limitation of the optical method, especially with closed frames.

## **CENTERLINE SURVEY**

While most people think only of level and square when thinking about alignment, there is a third coordinate that is neglected and one that can cause immense runnability issues for the life of a machine. That is a machine where all rollers (or modules) do not sit on a common centerline. As seen in Figure 7, it is quite possible to have a machine whose rollers are level and square and yet have the web run off the center of the rollers and possibly off the rollers altogether. While there are web-handling solutions, such as an active displacement guide or the equivalent static geometry, they are clumsy and limiting after the fact. Unfortunately, many machines have modules that are not set in with common centerlines and moving them axially is next to impossible after the fact because of piping and wiring. These machines will often run either the web off center or the guide off center for its entire life. To avoid this one carefully measures the center of a roller (in a module) and drops a plumb bob into a cup of oil. The distance from the wire to the offset centerline (defined above) is measured and made the same on all modules. The centerline is the first move and needs to be only done once, upon installation. Subsequent moves as indicated above are level followed by square.

## **SPECIAL CHALLENGES**

There are many challenges you can run into when aligning machines, a few of these are listed in Table 2.

**Table 2 – A Few Challenging Alignment Situations**

1. Poorly maintained or loose rollers or flimsy frames

2. Lack of line of sight through frames (optical tooling)
3. Floors that are not sturdy enough to set a tool on (such as on an elevated platform)
4. Skewable rollers (without a fixed and precision position readout)
5. Pivoting rollers must be checked on both ends of stroke (dancers, turret winders, etc)
6. Translating rollers must be checked along many points in travel (chain or gear rack pitch varies)
7. Bearing housings at an angle
8. Bearing housings that have no shear ledge
9. Bolt bound designs
10. Insufficient time to do all of the planned rollers
11. Lack of guidance on what should be moved (e.g., how close it needs to be to run well)
12. Metal foil or other high modulus webs (may require precisions beyond what is practical)
13. Segmented rollers
14. Curved axis rollers

Since alignment, or more specifically, realignment may be a regular occurrence on some machines it would be great if the machine builder designed a machine for serviceability, i.e., alignability. One of the easiest is to use a frame pad that is machined in two planes, vertical and horizontal for precise shimming. The shear ledge shown in Figure 8 is one way to achieve quick and accurate alignment moves and is especially useful for larger machines. Jack screws are another way that might be better for smaller machines. You might need to paint a mark on these adjustments to make sure maintenance and particularly operators don't move things without supervision.

## AFTER ALIGNMENT

There are two post alignment tasks. The first is to secure the rollers from moving out of position. **Doweling** is the drilling and reaming of a hole through the bearing housing into the frame into which a threaded tapered dowel is driven. The threading at the end is so that it can be more easily removed for service. Doweling of bearing housings is useful for two reasons. First, it can help preserve alignment because the housings would be nearly impossible to shear sideways. Second, it can help preserve alignment when a roller needs to be removed and returned from servicing: mark and save the shims and dowels and the roller will be returned close to where it was before service. The downsides of doweling are two. It takes time. It also can turn the bearing housing into Swiss cheese if you realign regularly, such as is common in the paper industry. You can start with a small tapered dowel, say a #6 and re-drill to a larger #8 for the second alignment. (Note smaller machines would use smaller dowels. Also, I have been taught that no one should use straight dowels or especially rolled dowels.) However, soon you will have to find a place for a new hole and there are only so many places where you can drill holes in the housing without compromising function.

If you want to lock rollers into position but **not dowel**, you simply can't tighten bolts more; unless you change to a higher grade. The reason is that proper bolt torque is fixed once bolt size and grade is selected. However, you can increase the effective COF. The cheap and dirty way to keep bolts from loosening is thread-locking compounds; though this can be inconsistent and unreliable. A slightly better way is lock washers. A much more professional way is to wire nuts and bolts as the aircraft industry does. (Note, most non-aircraft mechanics do not know how to do this properly and should go to school before practicing.) There are even more powerful techniques, such as using the wedge principle, that are best incorporated at the design state. Even so, **pivoting systems** are so hard to align and keep in alignment that it is sometimes best to tack weld the arms to the cross shaft and do the alignment out at the roller.

The second post-alignment task is required for any major service; that is **documentation** of before and after positions of every roller that was serviced. This documentation answers many questions that are likely to arise. Too often I hear that the "machine was aligned". Was this every roller, idlers included? (Recall, aligning modules is not alignment as defined in this paper.) Was this most rollers but they had difficulty or ran out of time on a few. How close did the rollers get moved to? How much did the rollers move since the last alignment (giving an estimate of the frequency of future alignments)? Being able to put



one's hand on an alignment report speaks well of maintenance. Not having a report or not being able to find it immediately calls into question the quality (if not integrity) of the maintenance service.

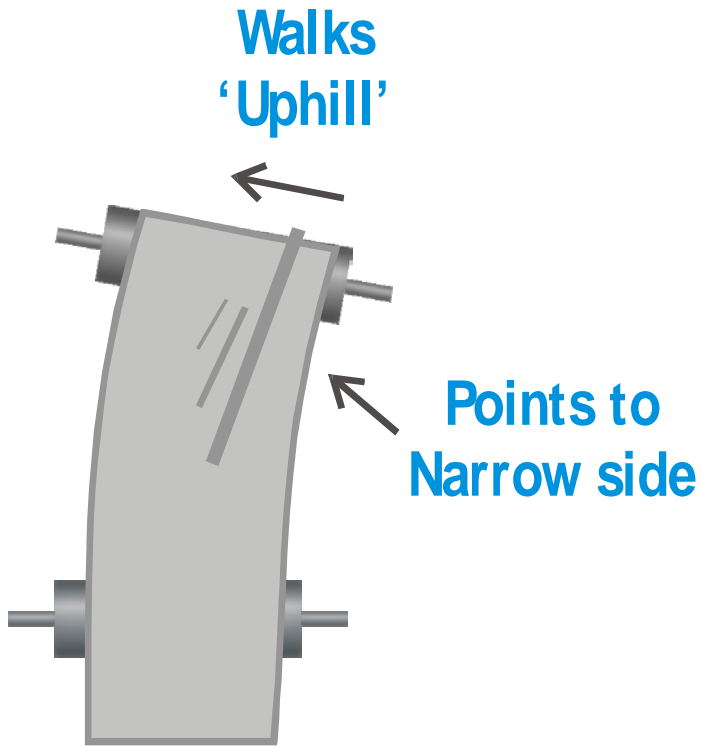
## CONCLUDING REMARKS

Many rollers in many machines may need to be realigned during their lifetimes. Detecting misalignment begins by observing certain runnability issues, most particularly diagonal wrinkling, but also certain path control and web break problems. Verification of a misalignment is easy using hand tools, such as a Pi tape or tramming stick, coupled with a knowledge of web handling. Unfortunately, hand tools are not as useful or as safe to use as their ubiquitous application might indicate. The reasons including the lack of a squaring tool and the great big tendency to sloppiness. Thus, optical tooling is often the gold standard for all but the smallest of machines. Even so, most precision alignments of a single machine may employ a variety of methods and tools that are selected to be adequately accurate and fast enough for each move of every roller in every direction. This is the craft of alignment. The science of alignment is detailed in my companion paper on *Roller Alignment – Standards*.

## BIBLIOGRAPHY

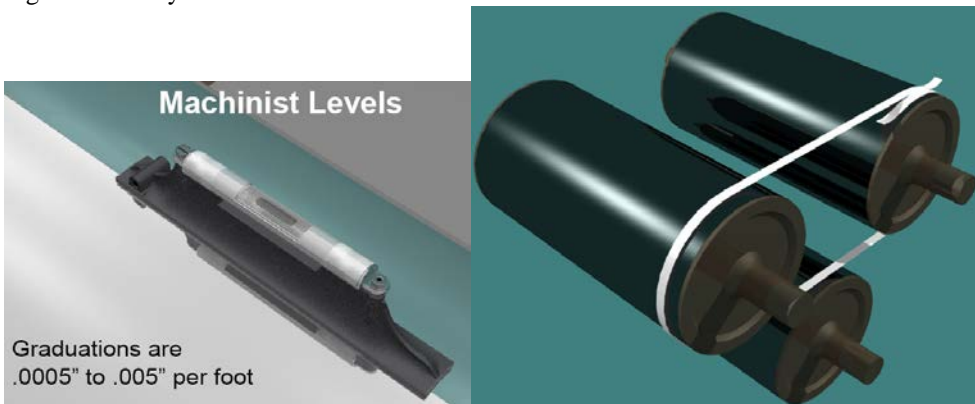
1. Roisum, David R. *Roller Alignment – Standards*. AIMCAL 2012
2. Roisum, David R. *Runnability of Paper, Parts I & II*. Tappi J., vol 73, no 1, pp 97-101, January 1990 and vol 73, no 2, pp 101-106, February 1990.
3. Allen, George Jr. *The bottom line on Press Alignment*. Pulp & Paper Magazine.
4. LeBel, Gary A. *Improving Dryer Section Runnability through Optical Alignment*. Tappi J., vol 77, no 5, pp 285-288, May 1994.
5. Engineers Digest, August 1989.
6. <http://www.damalini.com/Home-622.aspx>
7. <http://www.pinlaser.com/appNotes.html>
8. Busch, Sebastian. *Inertial Measurement of Roller Parallelism - A new approach to solving an old Problem*. TAPPI PLACE Conf, Las Vegas, September 26, 2005.
9. Sasikumar, Arun. *Inertial Roll Alignment for Diagnosing and Preventing Web Handling Problems*. Applied Web Handling Conf, AIMCAL AWEB, Charlotte, May 7-10, 2006.
10. Woo, C. *The Advantages of Inertial Roll Alignment Device in Eliminating Web Handling Issues*. 11th Int'l Conf. on Web Handling Proc., Web Handling Research Center, Oklahoma State Univ, June 13-15, 2011
11. <http://www.brunsonkc.com/p/AboutBIC2.asp>
12. Offerhaus, Douglas. Private communications, 2011.

**FIGURE 1 –PARALLEL MISALIGNMENT AND THE DIAGONAL WRINKLE**



**FIGURE 2 – LEVEL BY SPIRIT LEVELS AND PARALLEL BY PI TAPE**

Figures courtesy of OASIS



### FIGURE 3 – ALIGNING SHAFTS WITH A LASER

Figure courtesy of OASIS



### FIGURE 4 – ALIGNING ROLLERS WITH A LASER

Figure courtesy of OASIS



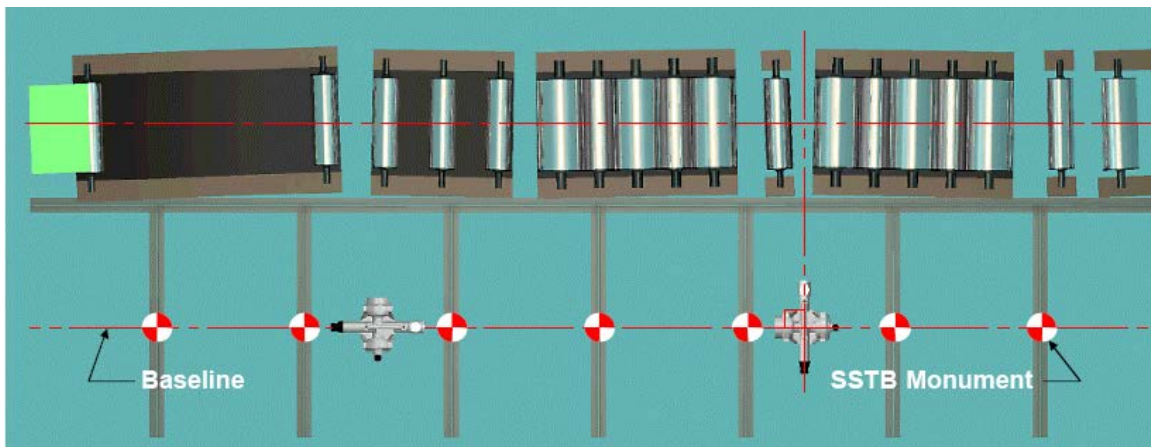
## FIGURE 5 – TELESCOPIC TRANSIT SQUARE AND OTHER OPTICAL TOOLS

Figure courtesy of OASIS



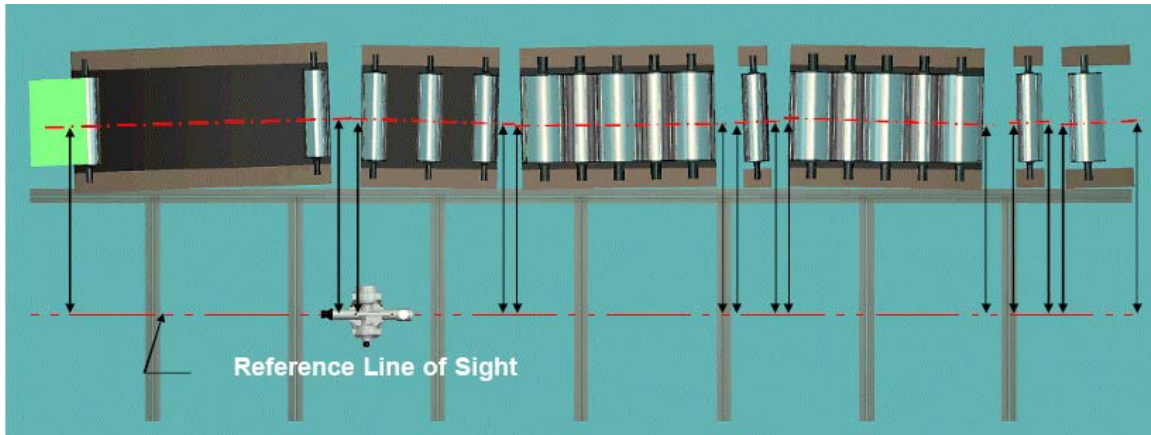
## FIGURE 6 – THE OFFSET CENTERLINE DATUM

Figure courtesy of OASIS



### FIGURE 7 – THE CENTERLINE SURVEY

Figure courtesy of OASIS



### FIGURE 8 – A COMMON DESIGN FOR (RE)ALIGNMENT

