
Executive Summary

Non-destructive testing (NDT) relates to the examination of materials for flaws without harming the object being tested. As an industrial test method, NDT provides a cost effective means of testing while protecting the object’s usability for its designed purpose.

The ability to inspect castings, weldments, wall thicknesses and roll shells in an accurate and comprehensive manner is critical; and even more important when the machine has been in use for several years, possibly with changes made to the original framework, and operating conditions that are now placing more stress on the equipment than original design allowed.

NDT uses several methods, including: visual inspection, ultrasonic, dye penetrant, magnetic particle, acoustic emission, electromagnetic and radiography. Common tools used include: trained expert’s eyes, caliper micrometers, ultrasonic wall thickness gauges, and portable grinders in addition to the specific tools used for more complex testing methods. The white paper reviews the NDT process as performed by skilled Valmet personnel, with examples of problems found and actions taken to resolve these issues.
Non-destructive testing, also known as non-destructive examination and known by its acronyms of NDT or NDE, relates to the examination of materials for flaws without harming the object being tested. As an industrial test method, NDT provides a cost effective means of testing while protecting the object’s usability for its designed purpose.

**Why use Non-Destructive Testing?**

Knowing when and how to apply NDT methodology is important. In the manufacture of massive, high speed paper machines, the ability to inspect castings, weldments, wall thicknesses and roll shells in an accurate and comprehensive manner is a critical need. This is even more important when the machine has been in use for several years, possibly with changes made to the original framework, and operating conditions that are now placing more stress on the equipment than original design allowed.

Methods of non-destructive testing have been in use for centuries, with the easiest form – visual inspection – being the oldest. Other ancient methods of NDT include weighing, perhaps to determine whether an object is solid gold as opposed to some inexpensive base metal, or a simple leak test to find out if a vessel will hold a fluid successfully. None of these testing methods damage the object being tested.

Unfortunately, with modern, massive, complex equipment occupying the space of a football field, the old methods no longer allow accurate measurement within a relatively short period of time, such as a machine shutdown. Nor do they measure things that the human eye, aided or otherwise, cannot detect. Access to every point on the machine to be inspected may be impossible. Disassembly for the purpose of testing is rarely a cost effective option. At this point more modern methods are needed. This is when non-destructive testing becomes a vital maintenance tool.

**When is Non-Destructive Testing performed?**

One common reason papermakers undertake non-destructive testing is when operators or maintenance personnel become concerned about surface rust, flaking, or corrosion and want to know if the machine is still fit for its current use. In this case, measurement of current wall thicknesses and comparison to the original drawings is in order.

For example, in the former section if rust drops into the process wire there will probably be a sheet break which can damage the press rolls. So if there’s a sheet break at the former, and the mill suspects rust, they will need an NDT expert to come onsite and determine if the corroded cross beams are structurally sound.

A second reason for onsite non-destructive testing is vibration in the machine line. Vibration is a very complex issue, requiring an experienced vibration analyst to determine possible causes. NDT can be extremely helpful in pinpointing the locations on the machine where the vibration might be generated. In
many cases a rusted bolt, corroded washer (Figure 12), or non-flat mating surface (Figure 14) is causing the vibration.

Another typical call for non-destructive testing is when production wishes to operate the machine beyond its original design specifications. Perhaps they wish to speed up the machine beyond its original design speed. Other possibilities include an increase in loading, or some other projected increased stress to the framework. In these cases, in addition to NDT, Valmet would also recommend a finite element analysis (FEA) and probably an onsite machine audit. These would help insure all critical plates are within the right dimensions to support the speed increase, increased load, etc. and are still at their original OEM specification. Coordinating the NDT and FEA processes allows mill personnel to see if they can safely and cost-effectively speed up the machine.

**What are the methods of Non-Destructive Testing?**

As mentioned previously, visual inspection and leak testing are powerful and easy NDT methods. In addition, modern equipment and materials allow for these other, more accurate and rapid testing methods:

- Ultrasonic,
- Dye Penetrant,
- Magnetic Particle,
- Acoustic Emission,
- Eddy Current (electromagnetic), and
- Radiography.

The most common methods used by Valmet are visual, ultrasonic, and dye penetrant, with magnetic particle and acoustic emission being used only in special circumstances.

**Visual inspection**

Valmet NDT experts are trained to visually check for many types of problems (Figure 2) including surface rust, scaling (paint lifting away, showing a rough not-clean surface), and signs of cladding buckling (bumps when looking down a straight line or putting a straight edge up to the headbox apron). Testing is needed not just on cast iron surfaces but also on stainless steel. If a stainless part is not kept clean there will eventually be some visible surface corrosion and pitting. Fortunately corroded stainless only requires surface cleaning and conditioning to be renewed.

Other important aspects to notice during a visual inspection include missing or corroded-away washers (Figure 12), and the condition of bolts. Bolts made of mild steel will delaminate over time. Attention must also be paid to those parts of the machine that are only used in special circumstances, such as changing machine clothing. Removable block finished surfaces may not mate properly when installed (Figure 14), resulting in vibration. Cantilever beams have rods going to supports. These rods are typically mild steel.
and may become corroded. This can be disastrous because when changing a fabric, these rods are all that hold up the section.

**Tools Used**

In addition to the expert’s eyes, the next most important tool is the caliper micrometer (Figure 3). As long as the technician can access both sides of the surface, its thickness may be measured. This can occur at an edge or a convenient hole. The micrometer is typically used for measuring the thickness of exposed ribs. However, sometimes it can be as simple as pulling a bolt out and checking the thickness of a beam at the bolt location.

In the case of mild steel, an ultrasonic wall thickness gauge is used (Figure 5). This measures the wall thickness without needing to tear the beam apart. First the diagnostician must grind down a quarter sized patch to a flat shiny surface. He will typically bring a portable grinder (Figure 4) for this purpose. On a smooth painted surface, the thickness gauge will work well, but some hand sanding may still be required to get it completely flat so the gauge doesn’t rock back and forth, producing an incorrect reading.

Many times the cladding can look OK, cloaking a problem with the underlying framework. This is typically what causes the cladding to bulge, i.e. a straightedge rocks on the cladding. For cladding that is showing signs of buckling, it may be necessary for mill maintenance to use the appropriate tools to cut a piece of cladding out. This will allow the NDT technician to measure the framework mild steel plate thickness underneath. Then the cladding must be patched to a watertight condition.

**Magnetic Particle Testing**

This method of determining surface discontinuities has been around since 1868 when it was used to inspect cannon barrels using a compass needle. It is only usable on ferromagnetic compounds, and uses magnetic fields and iron filings to detect component flaws. Magnetic particle testing is commonly used to inspect castings, forgings and weldments for fitness. The ferrous structure is magnetized and iron particles are spread on the structure. The particles would normally only cluster at the magnetic North and South poles of the structure. If they cluster elsewhere, there is a discontinuity in the magnetic field that may indicate a crack in the structure.
Ultrasonic Testing

The ultrasonic method uses equipment (Figure 5) that produces an electrical pulse which sends a high frequency sound pulse into the structure. If this sound pulse hits a crack or void in the structure - or the other side of a wall, when used to measure thickness - part of the pulse will be reflected. These reflections are transformed back into an electrical signal by a transducer, and the results displayed on screen. The results are instantaneous, and the technician only needs access to one side of the structure.

Liquid penetrant testing

This method uses capillary action to detect discontinuities, and is commonly used in fatigue testing to find cracks in roll shells. Liquid penetrant has been used at least as far back as the late 1800s, for things such as detecting cracks in pottery and railway locomotive wheels. Since that time, advances in liquid penetrant materials have been made which make the results easier to see. Essentially, a liquid is applied to the surface and penetrates into the flaws in the surface. After a dwell time to ensure sufficient penetration, the excess penetrant is removed. Then a developer is applied to the surface in order to draw the remaining penetrant from the cracks up to the surface. The penetrant is typically either a high contrast color, such as red, or is a UV fluorescent dye that will show up under black light (Figure 6). While this method is slower to perform than the ultrasonic method, the results are very clearly visible to the technician.

How does Valmet perform a non-destructive test?

Let’s say your mill requests Valmet to come onsite and perform NDT analysis of your machine. Typically, you would have one or more specific problems that necessitate the NDT analysis. These problems would usually be restricted to a particular section of the machine. Valmet follows a straightforward plan of action including preparation, onsite visit, and reporting.

Preparation: What happens before a visit?

During the initial call Valmet will obtain as much information as possible about the problem, suspected location(s) and possible visit time windows. The Valmet NDT technician will then pull the OEM drawings and map out what should be tested. He will make an NDT plan (Figure 7) on the drawings, numbering all of the locations to be tested. A chart (Figure 8) is then made, showing each location #, original plate thickness, and measured plate thickness in columns (and maybe the part #, in order to reference back to a drawing). Typically, this NDT plan is not sent to the mill ahead of time because access to the areas is usually not an issue.
Onsite: What happens during the visit?

NDT analysis is usually done during a machine shutdown, since the NDT process will usually include minor grinding. This way no material will get into the process (fabrics, etc.) during the testing process.

The NDT expert arrives onsite and reviews the plan (Figure 7) with mill personnel. He then does a visual walkthrough of the machine section to see if there are any other areas that need to be checked. For example, if the NDT analyst is looking at a headbox, there may be a shield, and the mill may not have noticed that underneath the shield there is additional corrosion. He would then ask mill maintenance to remove the shields so that he can test those locations. This is also the time when the NDT technician may find he doesn’t have access to some of the locations, and may need to shift location points or add more accessible location points.

<table>
<thead>
<tr>
<th>Location Number</th>
<th>Assembly Print</th>
<th>Description</th>
<th>Location of Measurement</th>
<th>Original Thickness</th>
<th>Measured Thickness</th>
<th>Loss of Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Outside framework</td>
<td>1.000</td>
<td>0.917</td>
<td>8.3%</td>
</tr>
<tr>
<td>2</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Outside framework</td>
<td>1.000</td>
<td>0.863</td>
<td>13.7%</td>
</tr>
<tr>
<td>3</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Inside framework</td>
<td>1.000</td>
<td>0.955</td>
<td>4.5%</td>
</tr>
<tr>
<td>4</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Inside framework</td>
<td>1.000</td>
<td>1.001</td>
<td>0.0%</td>
</tr>
<tr>
<td>5</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Inside framework</td>
<td>1.000</td>
<td>0.844</td>
<td>15.6%</td>
</tr>
<tr>
<td>6</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Inside framework</td>
<td>1.000</td>
<td>0.620</td>
<td>38.0%</td>
</tr>
<tr>
<td>7</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Inside framework</td>
<td>1.000</td>
<td>0.420</td>
<td>58.0%</td>
</tr>
<tr>
<td>8</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Bottom of beam</td>
<td>1.750</td>
<td>1.331</td>
<td>23.9%</td>
</tr>
<tr>
<td>9</td>
<td>4-0907-001</td>
<td>Press framework, tending side main beam</td>
<td>Bottom of beam</td>
<td>1.750</td>
<td>1.283</td>
<td>26.7%</td>
</tr>
</tbody>
</table>

Figure 7. The NDT plan starts with the original drawings, and shows locations where measurements will be taken. In this example, color indicates reading location. Blue and red are outside and inside the framework, respectively. Readings to be taken on the top, bottom or sides of framework are in green.

Figure 8. An NDT location chart, such as the one shown above, is an important element of the final report. It helps guide maintenance personnel in the selection and planning of future repairs. In the example above, there has been significant thickness loss, and framework will either need to be repaired or replaced to regain structural integrity.

One-by-one the Valmet technician will then measure and compare the wall thicknesses to the original drawings and see how much of the material design thickness remains. At each location he will grind a small flat patch, measure the thickness, record data in his chart (Figure 8), and photograph the location.
If less than 90% thickness remains, he will recommend changes in the particular area. Sometimes the measured thickness may actually be larger than the design thickness. This is because a weldment or surface thickness may not have been ground down completely to the exact design thickness.

After all the data is gathered, he will prepare preliminary results and immediate recommendations. He will then meet with mill personnel and discuss the findings.

Typically, one Valmet NDT diagnostician can thoroughly cover one section (headbox, former, press, etc) in a single 8 hour shutdown. If the mill needs more sections processed during a shutdown, Valmet can bring more NDT engineers in and do them simultaneously.

**Reporting: What happens after the visit?**

Upon arrival back at the Valmet office, the engineer prepares a full formal report, including the NDT location plan (Figure 7) and chart (Figure 8) and communicates this to Valmet’s repair, rebuild and spare parts departments as appropriate. The report, including full recommendations for all problem areas noted, is sent to the mill. A meeting or conference call is then scheduled to review the report, discuss the issues found and determine the action plans.

**What actions can be taken after Non-Destructive Testing?**

If the problem is either a surface corroded part or any kind of mild steel plate or cast iron, the best solution may be to grind to bare metal, and then prime and paint (Figure 9).

If there is significant material loss from the design wall thickness (Figure 10), the corrosion must first be ground off to arrest the corroding process. The part may need to be replaced or it might be repaired by adding plates to bring the thickness back to the same or higher level than the design thickness specification.

Then there is the problem of damaged cladding that exposes the mild steel plates underneath to moisture. The mild steel below may need to be repaired first, then the cladding must be repaired or replaced.

A common solution for problematic transition pieces on headboxes and exposed ribs in press sections is to upgrade any mild steel to stainless.
This is a one-time fix. Cutting out the mild steel plate and then replacing it with stainless will not work. The mild steel, in many cases, still holds the component square and true, so cutting it out could result in a sprung framework. Basically, you can laminate by welding a stainless plate next to the mild steel rib and the stainless plate takes the load.

Sometimes there are enclosed box beams or trough-shaped exposed ribs that are holding water or pulp mixture (Figure 11). In these cases, drain holes can be cut into the cavities that are water filled. Each hole is placed and sized so as to effectively drain the cavity but not negatively affect the structural integrity of the component.

Figure 11. These cavities are filled with standing water. Adding drain holes will keep water from collecting in the frame.

Finally, we come to replacement of a structural part, which may be necessary for multiple reasons. Replacement may be called for if the necessary welding would affect the OEM tolerance. For example, too much welding along the length of a beam will thermally bend the beam out of tolerance, so it should be replaced instead. Sometimes you have to replace or repair too much of a part, i.e. 50 or 60% or more, and it is typically more economical to replace the entire part (Figure 13). Downtime might also limit your repair time - you might be able to replace a part quicker than repairing one. Also, the added benefits from the currently available latest technology part or section may make it more financially feasible to replace rather than repair.

Figure 12. In this mill there were lock washers which had corroded away. Any fasteners that have failed should be replaced with stainless steel lubricated if they were mild steel standard fasteners.

Figure 13. The end of this walkway support is entirely corroded through and much of the material is completely gone. There is also delamination in process on other parts of the support. This part will need to be replaced.
Conclusion

This white paper has reviewed non-destructive testing as it is currently performed by Valmet in modern pulp, paper, board and tissue mills. Like all preventive maintenance, there are times when NDT is appropriate and times it is not the best solution. Non-destructive testing can help to solve chronic process problems, as well as avoid catastrophic equipment failures and unsafe operating conditions. Valmet's personnel have performed NDT testing at hundreds of mills worldwide. When this experience is combined with our process know-how and access to original drawings – you receive an unbeatable solution to keep your process up and running.

This white paper combines technical information obtained from Valmet personnel and published Valmet articles and papers. Addition background information was provided by the NDT Resource Center (www.ndt-ed.org).

Valmet provides competitive technologies and services to the pulp, energy and paper industries. Valmet's pulp, paper and power professionals specialize in processes, machinery, equipment, services, paper machine clothing and filter fabrics. Our offering and experience cover the entire process life cycle including new production lines, rebuilds and services.

We are committed to moving our customers' performance forward.