Quick break is also known as fast break or controlled break and is the sudden ending or stopping (quick break) of magnetizing current. This breaking of the current results in a transient (eddy) current induced into the part. The functionality of the quick break process can be defined as the measurement of how fast the magnetic field collapses in an induced (coil) shot.

Quick break was discovered in the late 1950s when it was found that, when a direct current is shut off, the field around the conductor falls rapidly to zero. This rapid change of energy generates a voltage and a current that is in the opposite direction of that in the circuit. This sudden breaking of the direct current at the end of magnetization resulted in a transient current being induced into the part. This resulting current was greatly increased when using quick break on ferromagnetic material. This increase in the residual magnetic field inside of the part resulted in a better field for inspection. For more information, refer to outside work (Falk, 2011).

The original magnetic particle units that had the quick break feature did this by opening the direct current coil circuit and drawing an arc across the contact. This ensured that the current decayed rapidly enough to zero to induce the transient current. However, this technique caused significant wear and tear on the contacts.

In later models (Figure 1), researchers incorporated silicon-controlled rectifiers (SCRs), making quick break much easier to achieve. Using the turnoff time of the SCR at the zero current crossing, along with a secondary high voltage transformer and an open circuit voltage, researchers developed controlled break. Controlled break is the main technique used in producing quick break in the magnetic particle units used today.

In magnetic particle testing (MT), the quick break technique is used to generate a transient current.
transient current within a part for finding transverse discontinuities in the ends of longitudinally magnetized bars. These types of discontinuities are often concealed by the strong polarity at the bar ends. With the use of the quick break technique, the resultant transient current makes certain that the field stays true to the end of the bar, enabling the inspection of transverse discontinuities.

Figure 2 shows a bar that is magnetized longitudinally (Betz, 1967). Notice in Figure 2a, which shows the bar without quick break, the two ends become poles and the lines of flux enter and leave near the bar at 90° to the surface. Therefore, the very ends of the bar are not truly longitudinally magnetized and any transverse indications in this area may not be reliably detected.

In Figure 2b, it can be noted that when the same part is longitudinally magnetized and the current is closed rapidly via a quick break process a transient current is generated, which flows inside the bar resulting in a near surface field, allowing the part to be truly longitudinally magnetized to the very ends of the bar. This allows transverse indications to be found at the very end of the bar.

As with most techniques used in MT or any other form of nondestructive testing, there are standards or specifications that must be followed. The first standards were military specifications and have since been incorporated into ASTM International specifications. The quick break technique is no different. ASTM E 1444 and ASTM E 709 call for a quick break check to be conducted on a magnetic particle unit with the quick break feature every six months (ASTM, 2008; ASTM, 2012). The ASTM standard only requires the headshot to be checked if the technician is attaching cables and wrapping them into a coil. For this check to be made, ASTM allows for a unit to be checked using an oscilloscope or other applicable technique as specified by the equipment manufacturer. Prior to 1970, units were checked with an oscilloscope where one actually watched the
sine wave collapse rapidly to zero. However, in the 1970s magnetic particle manufacturers introduced quick break testers. These testers were small, handheld devices that gave a go/no go readout. The tester was composed of a small bulb and inductive coil. The technician would place the tester in the coil, and at the end of the mag shot the bulb would light up if quick break were functioning. These instruments are still very much in use today as they are a simple verification of a machine’s quick break function (Figure 3).

There have been new designs of the quick break tester in the last couple of years, resulting in testers that give a digital readout of the quick break value. These testers actually give the value of the voltage induced by quick break. The ability to obtain an actual voltage leads to the ability to provide a quantitative way to detect and track the satisfactory performance or possible degradation of the quick break feature on magnetic particle units. This quantitative ability is a preferred system process check for those technicians that audit MT facilities.

Quick break is used in other applications besides the aforementioned transverse cracking at the end of bars. Quick break serves as a primary function of the induced current technique. The induced current technique is a noncontact MT technique used primarily on ring-shaped parts. However, this is another topic unto itself. The quick break process is not applicable when performing testing using prods or yokes because the test article is part of the magnetic circuit. More information on this topic can be found in other work (ASNT, 2008).

Another application of the quick break magnetization technique is when dealing with articles with structural changes that can create a high internal flux density, resulting in an external polarity that can produce a magnetic indication. Examples of such changes are internal splines, keyways or holes in the article. The problem with these types of non-relevant indications is that they may mask a relevant indication. The quick break process can help minimize, if not eliminate, the indication from the structural change.

Items made with a ferrous metal with high retentivity can benefit from the quick break process. The magnetic field produced in these materials when subjected to the quick break process produces a very strong residual field. This strong residual field is beneficial if the residual technique is to be used to perform the MT. An example of the application of this aspect is the inspection of a bearing race.

A few final things should be remembered. First, quick break is only found on three-phase, full-wave direct current machines. Second, machines are typically only tested on the coil circuit unless cables are connected to the head shot and wrapped to form a coil. Next, quick break is primarily used to enable the capability to find transverse discontinuities at the ends of a part that has been longitudinally magnetized. Finally, quick break is used as a function of the induced current fixture.

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References
INTRODUCTION

Laser ultrasonics is rapidly becoming a well-known industrial technique for inspecting composites that provides large benefits over conventional systems in the inspection of complex contoured carbon-fiber reinforced polymer (CFRP) components (Osterkamp and Kaiser, 2008). The advantages of laser ultrasound over conventional systems for the inspection of complex shaped CFRP are multi-fold. Systems are typically able to rapidly scan the laser beam across the surface of the part with no knowledge of the part curvature, no special tooling or fixtures, and no contour following. Teaching procedures are quick and simple and there is minimal recurring setup time. Typical laser ultrasonic systems use a robot manipulator to move a scan head around a complex shape from a standoff distance of approximately 1.8 m (6 ft). A fast, two-axis galvanometer scanner is used to scan the laser beams across the surface, thereby covering large areas of complex shaped parts in a rapid fashion. These types of system characteristics make laser ultrasound extremely versatile for rapidly testing a large variety of part types. In addition, the variety of system configurations available provides the flexibility needed for all types of factory environments and requirements.

Laser generation of ultrasound in CFRP materials occurs due to the absorption of the laser wavelength in the top 10 to 100 µm of the surface layer. This surface layer is generally an organic matrix such as an epoxy resin, bismaleimide or thermoplastic, although other surfaces such as paint topcoats can also provide excellent generation. The size of the laser spot hitting the target is approximately 5 mm (0.2 in.) in diameter. This provides an absorption volume that efficiently directs the bulk of the ultrasonic energy in a longitudinal mode normal to the material surface regardless of the laser angle of incidence. A short pulse laser, often CO₂ (10.6 µm) or Nd:YAG (1.064 µm), is used as the generation laser. Laser energies are kept below the damage threshold, and the generation mechanism is therefore a thermo-elastic process in which the material returns to its prior state and the laser leaves no lasting effect. The rapid expansion of the material due to heating causes a stress wave in the material, which is the ultrasound.

In general, ultrasound generated by a laser is similar to that from conventional ultrasonic devices with the exception that laser-generated ultrasound typically contains a much broader frequency spectrum. To some degree, both frequency and mode content are dependent on the generation laser spot size. Although the laser generates several types of spatial modes, as the spot size increases, a higher percentage of the energy is shifted to the longitudinal mode (a more piston-like source) and less is available for other modes such as shear or lamb modes. In addition, a higher percentage of the total energy tends to shift to the lower frequency domain as the spot size is increased. This is analogous to transducer diameters increasing as their center frequency decreases.

For detection, a second laser is directed to the same point on the material under test. The detection pulse (typically an Nd:YAG at 1.064 µm) is a long pulse laser of 50 to 100 µs in length. This pulse must illuminate the surface of the material long enough for the ultrasound to reverberate several times in the material thickness. The ultrasonic vibrations on the surface modulate the phase and frequency of the light scattered from the surface and collected by the system optics. This light is sent to a discriminating device where these phase and frequency modulations are converted to amplitude.
modulations and in turn are converted to electrical signals. During the scanning process all data acquisition, system timing and laser light intensity are automatically controlled by the system. There are no user parameters to input or adjust. Optional user defined filter parameters and techniques are available in the post-processing and data analysis phase to optimize the detection of anomalies.

For production components, material integrity is of the utmost importance. Nondestructive testing (NDT) is by definition nondestructive. To that end, the laser pulse energies and spot sizes used in laser ultrasonics are designed to keep the energy density below the damage threshold of the CFRP matrix. Different materials may have different damage thresholds and can react differently to the laser wavelengths. Material testing to determine the characteristic damage threshold is needed prior to production use. For a number of years, laser ultrasonics has been used on the factory floor at a military aircraft manufacturing facility in Fort Worth, Texas and more recently at a military and commercial aircraft manufacturing facility in Winnipeg, Canada to inspect production composites parts for military aircraft (Drake et al., 1998; Yawn et al., 1999). The technology has been approved and implemented on an array of programs such as the F-16, F-22, F-2 and F-35. To date, the systems installed in the Fort Worth facility have tested in excess of 40 000 flyaway production parts.

Carbon-fiber Reinforced Polymer Inspection Difficulties

As the use of composites in the aerospace industry continues to expand, more complex and difficult to inspect components are becoming common. Part diversity can range from small brackets and clips, floor panels, stringer sections and complex inlet ducts up to large wing and fuselage skins. In commercial aircraft, very large barrel structures for the fuselage and large flat floor panels are commonplace. The amount of square footage of CFRP that must be tested daily to meet production rates can be enormous. Throughput of this magnitude and of such a wide variety of components often requires companies to purchase and maintain a number of different machine configurations for ultrasonic inspection alone. Often, these systems are dedicated to inspecting only one type of part configuration such as floor panels and still may require extensive setup time when parts are changed in the system. Laser ultrasound has the potential to alleviate many of those difficulties. Often, inspections of large complex contoured parts with tight radii, ply drops and drilled holes can be accomplished on the same machine as a large batch of small clips and brackets. Setup time and machine configuration changes between parts are simple or virtually nonexistent. The next section will describe two common production testing problems and their laser ultrasonic solutions.

Two Inspection Problems and Their Solutions

Two specific examples of difficult inspection scenarios will now be detailed. In the first example, consider a set of small brackets approximately 152.4 mm (6 in.) in length, each of a slightly different configuration and size. These brackets typically have two or three sides oriented at 90° to each other with the corners having approximately 6.4 mm (0.25 in.) radii. Production rates may require on the order of 2000 of these various brackets to be tested each month. Inspection of large numbers of small, complex shaped brackets such as these create two main difficulties: part transfer and setup for each bracket would be extremely time consuming, and the subsequent inspection of that number of brackets in a month would swamp any system. On the other hand, the inspection of individual brackets with a laser ultrasonic system is easily accomplished with little setup, and the inspection of a three-sided bracket can be completed from a single inspection view of the part. In addition, a laser ultrasonic system could easily be designed with automated ingress and egress to the inspection cell of a rack loaded with many brackets at one time, all tested from a single inspection view. Figure 1 shows an amplitude C-scan of a two-sided bracket scanned from a single view. The angle of incidence of the laser beams to the bracket faces is approximately 45°. Figure 2 shows a B-scan cut across the

![Figure 1. High-resolution amplitude C-scan of areas around drilled holes and porosity on a two-sided angle bracket (angle of incidence of laser beam to surface is approximately 45°).](image1)

![Figure 2. High-resolution B-scan of areas around drilled holes and porosity on a two-sided angle bracket (angle of incidence of laser beam to surface is approximately 45°).](image2)
(four) drilled holes in the two-sided bracket. The image clearly shows the four holes by the absence of a back wall signal. (The front wall signal inside the holes is the result of the generation laser interacting with the floor behind the bracket.) The front surface of the part together with the back wall is noted in the figure.

The three-sided bracket of this material (shown in Figure 3) can also be tested from a single view with an angle of incidence of over 65°. In principle, this would allow a single, simply designed rack to hold many different styles of brackets at one angle convenient for the system to scan with minimal adjustment to the scan head angle or position. The rack could be designed to move in and out of the inspection cell in an automated fashion. The only manual task at that point would be placing the brackets on the rack and removing them after inspection.

The second example is of a hat stringer section. In commercial aircraft production these types of stringer section can be upwards of 10 m (32.8 ft) in length and of varying widths and curvatures. These types of stringers can present many difficulties for conventional systems. Part loading and unloading into fixtures, system setup and calibration can all be time consuming and difficult to get correct, producing results that are frequently dependent upon the skill of the system operator.

Figure 4 shows an example of a commercial aircraft stringer section with challenging tight radii. Figure 4a shows a photo of the part taken by the system camera located on the scan head. This is a view from the actual scanning position. From this view the system is able to scan the flange, inside radius, web, outer radius and top of the hat without repositioning. The amplitude C-scan image from such a scan appears in Figure 4b. Only one additional view from a similar orientation on the other side would be required to test the entire part. In laser ultrasound, software controls the entire ultrasound generation and detection process. By removing adjustable parameters, the data quality is consistent from operator to operator.

CONCLUSION

In over 15 years of daily production inspection of complex aerospace composite structures at the Fort Worth and Winnipeg facilities, laser ultrasound has shown itself to be an extremely versatile, adaptable and cost-effective NDT technique. This article has shown two examples of component types that, in a high production rate environment, are very difficult to inspect quickly and easily with conventional NDT. Herein has been demonstrated how laser ultrasound can be used as a simpler, faster and more efficient solution to the inspection of these challenging components while providing results that are less dependent on the skill of the operator running the system. Laser ultrasound, while still a new technology to many in the aerospace community, is rapidly proving itself to be a capable and versatile NDT tool.

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Practitioner Profile
Dale Lynn

NDT runs in the family for Dale Lynn. The following interview shows how the son of a radiologic testing (RT) technician has forged his own path over a period of 11 years in the world of RT and explosive ordnance, keeping up on the latest in technology and “things that go boom.”

Q: How did you first become involved with NDT?
A: Well, I first became involved because, like many people in the NDT world, my dad does it. He’s actually a five-discipline Level III. I did it because he was doing it and I thought it was a good, healthy career, but I didn’t want to be one of those guys that just got the job because his dad was there so I tried to get my foot in the door in a company that didn’t know his name. I wanted to make my own name. I worked for a while until I got audited by a couple of people and then bigger companies wanted to hire me after seeing me work.

Q: How did you get your NDT training?
A: I got my education through work and through George Hopman, who has been a mentor and a friend. He has been able to offer a lot of wisdom and advice for situations I encounter.

Q: You’re a Level III in RT. Do you have any other certifications or training?
A: I could be a Level III in mag particle and penetrant, and have spent classroom time for eddy current and ultrasonic. I just haven’t gotten the hands-on hours for them.

Q: Can you tell us about the work that you do?
A: We do mostly explosive ordnance. We make the initiators or first level for anything from rocket motors to missiles. We’re the key factor. If our product doesn’t work, it never starts to fire. Plus, we also make safe and arm devices, which are just what they sound like: parts that will make certain missile systems not fire if they fall into the wrong hands. I actually work in the building where they do destructive testing and blow them up in special containers. If you’re jumpy, it’s not a good place. I don’t do a lot of offsite work, mostly in our lab. I do daily metrics, document revision, and record what products are there for the day for the test department. I schedule X-ray and N-ray [neutron ray]. I do ATPs [acceptance test procedures]. And then I watch over the Level IIs and help train them. I know some people get stuck where they are, but I’m always trying to grow and so I encourage that in the people around me.

Q: Do destructive testing and nondestructive testing go hand in hand with the work that you’re doing?
A: They do. Where I am now, it’s more of an assembly check for X-ray. So we’re making sure all the components are put together properly, without gaps, and all the powder loads are where they should be. Being in the same building is very helpful. When something doesn’t function the way it should during one of the destructive tests, they come right back to the X-ray and it shows a big part of any failure investigation mode. We also get the unique opportunity to read N-rays. We send a lot of our products out for neutron radiography so we can help build a class for that to provide insight on how to read the film.

Q: Is there an ongoing safety concern in the workplace?
A: Our workplace is very focused on safety; we do audits almost weekly. For the film badges, we use a new type of dosimeter that a lot of people don’t know. They use them in Fukushima and in the medical world. It’s a quick, permanent log of your dosage, and it’s an instant read: you plug it into a USB port, sign onto a website from anywhere and you can get your dose instantly.

Q: What is the most rewarding aspect of your job?
A: Just to know I’m saving lives is kind of why I got into it.
Q: You are helping to switch over all the company’s systems from film to digital radiography, correct?
A: That’s correct. Our goal is to become completely filmless by the end of 2014. We’ve been prepping to get a lot of our customers onboard. We did a lot of research and ordered our system. They flew me out to different companies so I could research and see which system to go with and for our products what fit our need best.

Q: Do you find that RT is advancing more quickly than the other NDT methods?
A: I think RT has an advantage in that it can go digital. This is a digital world. Ultrasonic does seem to be taking off, and there are some emerging methods that are pretty neat. We had a guest speaker at our local ASNT meeting who made a presentation on vibrothermography. That’s where they vibrate the part and watch its heat signature, because it will heat up the part in various ways and stress crack. There’s a lot of stuff coming out, but RT is definitely progressing very rapidly.

Q: Do you mainly do government contracted work?
A: We do a lot of government work. We do commercial as well, and stuff that is in the oil field. When you think about fracking for oil, we make a delay that drops down a well and has to burn for so long before the output goes to set off the next chain of events to shake some of the shale loose.

Q: I understand you worked on the Mars Rover?
A: We made the bolts that cut the parachutes, and then we actually had the main camera. Before it popped up, the camera was held down by a cable and we made the initiator that cut the cable to spring it into position; it had to have a gas actuator, since it was a cutting device. There was dust on the camera lens from when it landed that no one anticipated, and the gas from the initiator, when it cut the string, cleaned off the camera. It was an accident, but of course everybody liked to say, “We planned that.”

Q: You are the Section Chair for the Arizona Section, correct?
A: Yes, I’ve been acting chair for the past two years now, and I was acting as chair unofficially for a year before that.

Q: What kind of Section events do you help organize?
A: We typically have a speaker make a technical presentation. On average, I’d say this year was probably the best year I’ve seen. We had about 20 to 25 people at each meeting, and we’ve only missed two events this year.

Q: Are you doing any outreach efforts to local schools to get young people involved?
A: Not yet but we do have a Facebook page and we’re trying to bring in younger people. Most young people don’t understand what NDT is or what it’s for and so I’m trying to get that out there.
Q: You’re the responsible Level III for your work: do you mentor people?
A: I’m mentoring a couple of Level IIs and I have a Level I.

Q: What are some of the more challenging aspects of your work?
A: The challenge I see coming is that the Level IIs working under me are older and a couple of them are getting ready to retire. And there are just not a lot of people coming into NDT. In the next 10 to 15 years there’s going to be a huge gap in the number of technicians out there.

Q: What advice would you give to somebody considering the NDT field?
A: It’s a pretty quick career if you’re willing to put in a little bit of hard work. You can see the reward, you can see the products; you’re saving lives, making the world a safer place. You can also kind of shortcut college. I skipped college and was able to advance faster without it and now I’m able to get my college paid for. Everybody learns differently. For some people who struggle with school, just getting in there and getting your hands dirty is a great way to jumpstart your career.

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Across

3. When using coils and calculating amperages, a fill-factor _______ must be considered.
5. Ampere-______ is used to express magnetizing force in longitudinal magnetization.
8. The advantage of a mobile system’s high _______ is its ability to inspect large castings, forgings, welds or any other test object requiring strong magnetizing field intensities.
11. For materials with high magnetic__________, direct current can be applied in the technique known as quick break.
12. Special quick break design considerations are required on _______-powered machines.
13. In magnetic particle testing, the sudden cessation of magnetizing current is known as _____ break.
15. Prods, a yoke or the _____ flow technique make quick break magnetization unnecessary because the test object is part of the magnetic circuit.
16. When structural indications occur, the magnetic lines of force exit the material _______ to the surface, an unfavorable orientation for the detection of discontinuities.
17. For test objects made of soft material, with little retentivity, the _______ technique must be used and the collapsing direct current field technique is not applicable.
18. A rapid change in current produces strong magnetic induction during toroidal magnetization and reduces the disturbing _______ near poles for sensitive testing of the test object’s ends during coil magnetization.

Down

1. The _____ hand rule is a technique for visualizing the relationship between a flowing current and its induced magnetic field.
2. When direct current applied to a coil is quickly turned off, the rapid collapse of the magnetic field creates low frequency eddy currents within the object in a direction favorable for the detection of _______ discontinuities at the ends of the object.
4. The primary concern over _______ indications is their ability to mask relevant discontinuity indications.
6. A quick break test should be conducted at least once every ____ months.
7. Quick break is needed when using three-phase full-wave rectified alternating current during coil or induced current _______.
9. Direct current can be applied in the technique known as quick break and the objects may then be tested by the _______ technique.
10. The _______ field generated by the induced current leaves the test object with a strong residual induction.
14. Alternating current is also known as _____-wave direct current.