

The effects of improved ultrasonic technology on continuous bonding of nonwoven fabrics

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ABSTRACT: Recent advances in ultrasonic power supply technology can greatly improve the quality of ultrasonically bonded nonwoven fabrics. This paper examines amplitude control to determine its effect on performance enhancements. The authors relate the benefits of a new type A power supply to significance in rotary drum bonding, laminating, and converting of nonwovens.

KEYWORDS: Bonding, nonwovens, power supply, technology, ultrasonic frequencies.

It is essential to understand both the basic theory of ultrasonic bonding and the dynamics involved in the process and equipment to appreciate fully the recent advances in power supply technology as they apply to nonwoven bonding.

Theory

Ultrasonic energy is mechanical vibratory energy operating at frequencies beyond audible sound. When bonding textile fibers, the most common frequency is 20 kHz, although there is some use of 40 kHz. **Figure 1** shows that this energy transmits to the material for joining through a

tool known as a horn¹. For textile or film applications, the typical amplitude at the horn face is 0.075–0.100 μm (0.003–0.004 in.) at 20 kHz. Amplitude is the peak-to-peak displacement of the ultrasonic horn at its work face. It is this motion that generates frictional heat required for ultrasonic bonding. Ultrasonic vibrations and pressure apply at the bonding area to create intermolecular mechanical stress within the fibers. Melting occurs at the points of con-

¹Jacke, S. E., *Proceedings of 1st International Symposium on High Power Ultrasonics*, Branson Sonic Power Co., Danbury, 1969.

tact where the stress is at a maximum. Bonding then takes place there. Because heat occurs selectively within the fibers and does not conduct through them, there is no thermal degradation of the material. The tooling therefore remains relatively cool².

Figure 2 shows the process of passing one or more layers of material between a rotating, patterned drum and an array of ultrasonic tools to create wide web products. The material bonds in the pattern engraved on the drum with the possibility of bonding point densities up to 24%. It is possible to process webs ranging from 1 oz to 10 oz per yard or even higher without the need for chemical binders. Most materials can process at rates of 122.9–152.4 surface meters (75–500 surface ft) per min depending on the material.

People often confuse ultrasonic bonding and laminating with thermal bonding, although there are clear differences between the processes. The primary difference involves the manner of application of thermal energy at the fiber crossover points or fiber surfaces in ultrasonic bonding. The resulting fabric qualities for the two processes are quite distinctive.

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²Flood, G. N., *Nonwovens World*, 1(3): (86)1986.

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The confusion may arise because of the similarity in equipment configuration. The source and application of thermal energy of ultrasonic bonders and thermal bonders are quite different, however. Thermal bonding applies hot tools directly to the web surface to overcome the poor thermal conductivity of typical materials or fibers for bonding. Ultrasonic bonding uses mechanical vibrations to create stress at fiber interfaces within the web structure which results in bonding heat. Chemical binders are not necessary and, unlike thermal bonding, no apparent heat-up time is necessary.

The result of ultrasonic bonding is a nonwoven with virtually no fiber degradation, a soft hand, and high loft. This is because bonding confines totally to the bond site with no adjacent tacking as might occur from the heated drums used in thermal bonding.

Characteristics of textiles & films

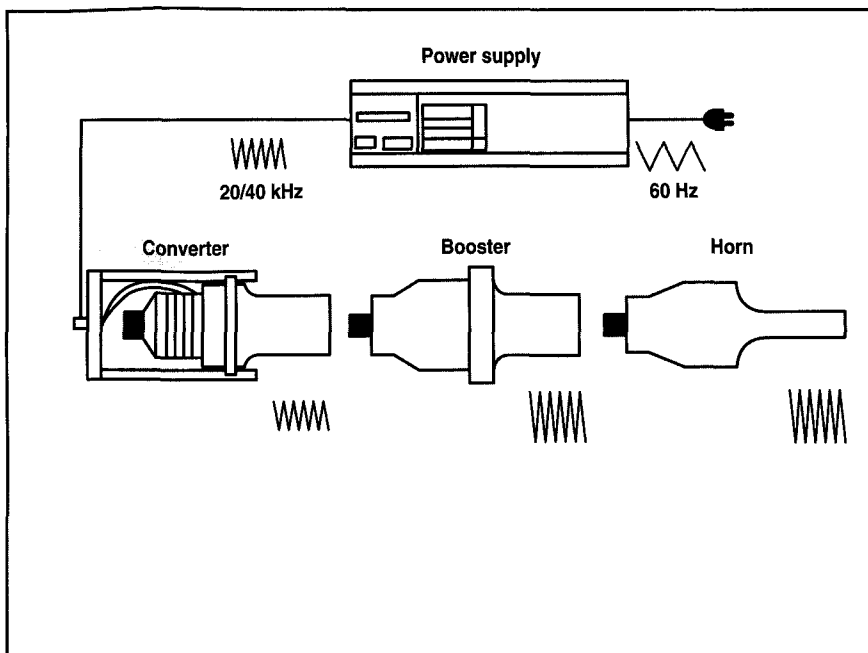
The textiles and films best suited to ultrasonic bonding are thermoplastic materials with similar melt temperatures and like molecular structures. Materials may be 100% thermoplastic products such as nylon, polyester, polypropylene, modified acrylics, some vinyls, and urethanes. They may also be synthetic blends with up to 35–50% nonthermoplastic fiber content depending on strength requirements.

Materials that respond well to ultrasonic processing possess many of the following characteristics:

- Broad melting range
- High coefficient of friction
- High content of thermoplastic material
- Uniform thickness

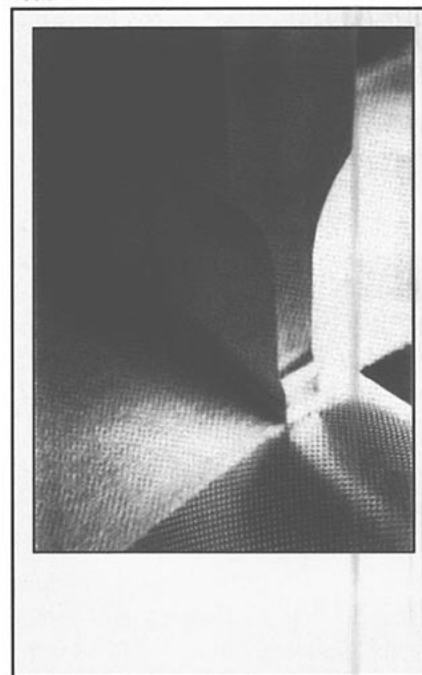
³Anon., *Ultrasonic Plastics Assembly*, Branson Sonic Power Co., Danbury, 1979.

1. Conversion sequence



- Sufficient rigidity and thickness to accept energy at the material interface—at least 0.013 mm (0.0005 in.) thick³.

2. Photograph showing ultrasonic bonding head



Rotary drum bonding

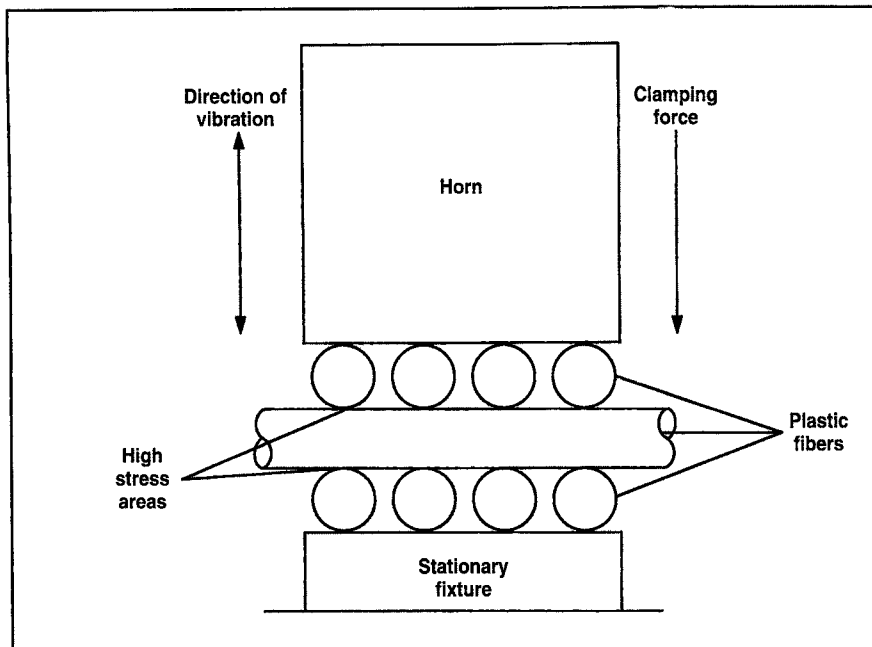
Ultrasonic bonding of woven and nonwoven goods in both wide rolls and individual products has been a commercial production process for many years. The use of ultrasonic technology in fabric and fiber bonding is over 25 years old. The textile industry uses it extensively. Ultrasonically laminated mattress pads and bedspreads use a process that has been the basis for ultrasonic bonding and laminating of woven and nonwoven products and fabrics.

Rotary drum machines first developed jointly by our organization and James Hunter Machine Co., Inc., bond layers of material to produce quilting 5–10 times faster than conventional methods. For example, when rotary drum machines laminate webs of nonwoven fabric, fiberfill, and woven shell fabric to form mattress pads and bedspreads, the productivity increases ten-fold to

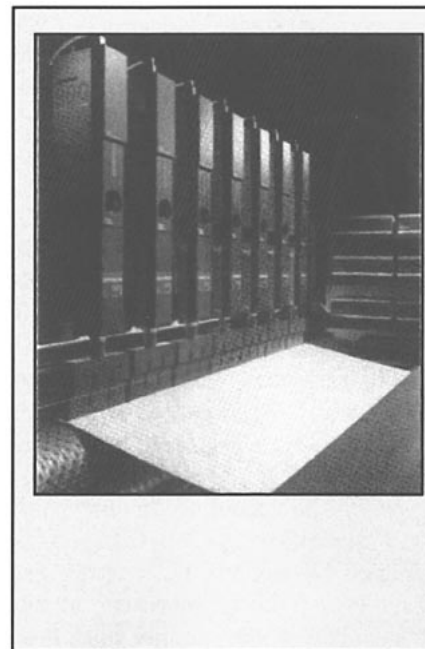
9.14–15.25 meters/min (30–50 ft/min). Today, this process produces over 50% of the mattress pads and bedspreads made in the United States.

The rotary drum sealing process is a continuous bonding process that bonds in the same manner as in single

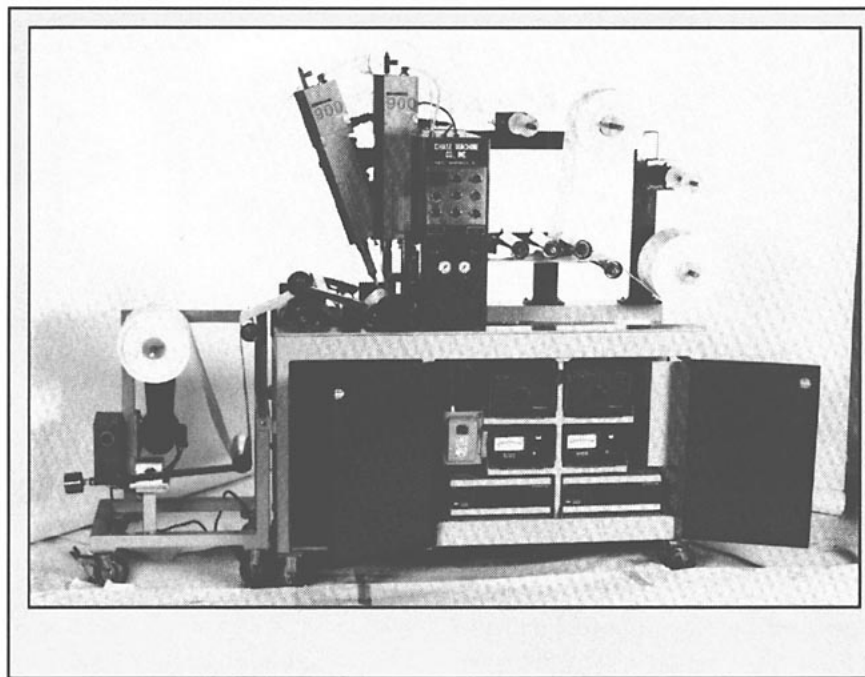
3. Textile joint with melting at high stress areas



4. A typical system for bonding or sealing large-width goods



5. Photograph showing a typical laboratory ultrasonic bonding unit



station ultrasonic sealing. Fibers, webs, and film containing thermoplastic material pass between the horn and the raised surfaces (pattern) on the drum. An applied force compresses the materials. Ultrasonic vibration applies to the compressed

product causing stress development. Figure 3 shows that this stress reaches a maximum at the fiber cross-over points where thermal energy releases. The thermoplastic materials soften, and pressure forces the fibers into one another. As the

fiber passes from under the horn, the horn itself, the drum, and the surrounding unheated fiber absorb energy. This action allows solidification and bonding of the softened fibers. Ultrasonic bonding is economical, because it eliminates mechanisms and costs associated with needle and thread. Since there are no threads to snag or pull, products are more durable. Ultrasonic bonding allows virtually any pattern design without compromising productivity or quality.

Large production systems incorporate several actuators mounted over a drum with remotely located continuous-duty power supplies. The system shown in Fig. 4 is typical for bonding or sealing large-width goods. Single actuator systems with small drums produce narrow-width goods.

Test equipment

This study examined power supplies using a laboratory unit consisting of two 2000 W advanced power supplies, a 228.6 millimeter wide x 101.6 millimeter diameter (9 in. wide x 4 in.

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diameter) rotary drum, and two ultrasonic bar horns. **Figure 5** is a photograph of the laboratory ultrasonic bonding unit.

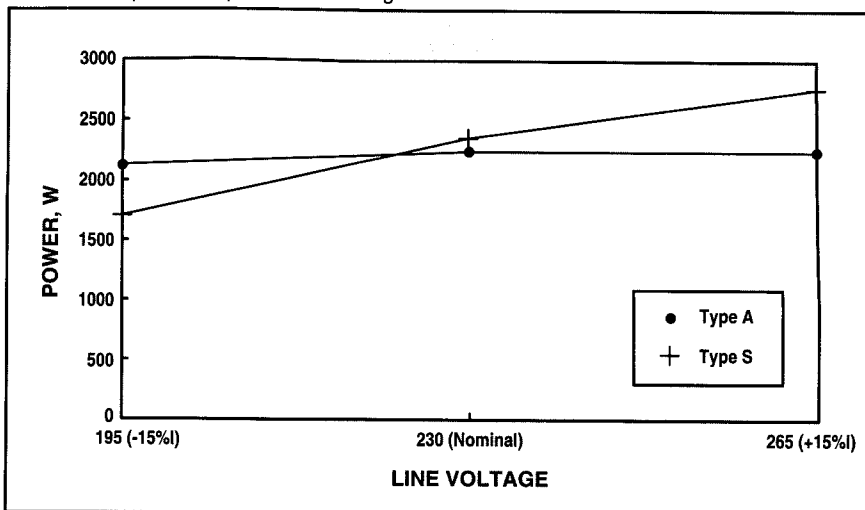
New, advanced power supplies

In this paper, type A refers to new, advanced power supplies and type S to standard power supplies. The type A units used in continuous duty operation provide automatic line and load regulation to compensate for fluctuations in voltage. This keeps the amplitude constant with any changing voltage and load conditions during the welding and sealing process. The power supply "memorizes" and identifies the operating frequency for consistent starting regardless of the temperature of the horn. The power supply also provides infinitely variable amplitude to accommodate varying pattern density or line speed such as might happen on startup.

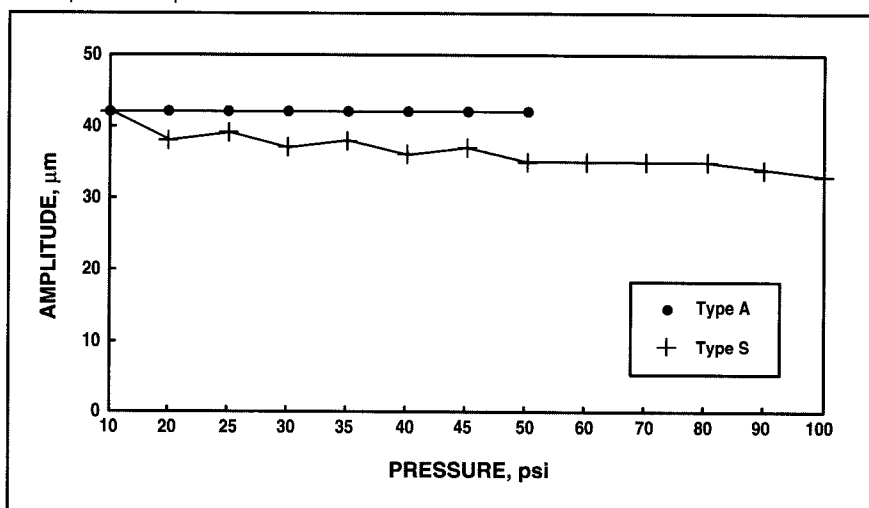
The type A power supply allows external control of the amplitude by a potentiometer or electronic signal to modulate the amplitude and power profile of the weld in a normal working range of 50% to 100% of the amplitude. This feature maintains a direct linear relationship between amplitude and power. Electronic amplitude control allows rapid amplitude change during the weld. This change makes possible a level of control of the process not previously feasible. In rotary drum processing, this capability permits use of a low amplitude setting upon initiation of the bonding operation. As speed increases, amplitude increases to deliver the same energy (power) to every bond site independent of the line speed.

Type A power supplies monitor, adjust, and control the system in ways that are not possible with type S units. One must tune type S power supplies manually. In type A units, this is now automatic either on startup or on request during production.

6. Maximum power output vs. line voltage



7. Amplitude vs. pressure



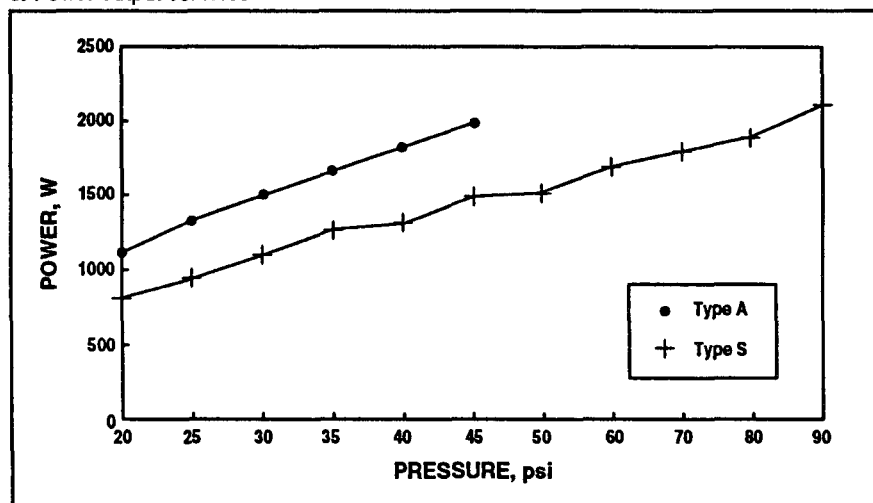
The new power supply has automatic tuning, memory, and automatic seeking. The automatic tuning and memory remember the operating frequency of the ultrasonic stack (converter, booster, and horn) when the machine last stopped. Although the ultrasonic welding tool delivers mechanical energy to the web to produce bonding, some heat conducts to the horn from the melting fibers to raise the horn temperature. This is especially true at high operating speeds and pressures. In turn, there is an increase in the length of the horn which changes its frequency. On starting the machine again, the power supply identifies the fre-

quency and makes tuning adjustments, if necessary. This all happens automatically.

It is possible to activate the automatic seeking function either manually or automatically on a periodic basis. This feature allows checking a system at a low power level of 5–10%, locking onto the frequency, and then storing it in memory. If the horn cools when not operating, the automatic seeking function tracks the changing frequency so the system can restart with no manual adjustment.

Other factors to consider are the regulation of the line and load. The line is the electrical power to the

8. Power output vs. force



system, and the load is the power drawn from the power supply during the process. Figure 6 shows line voltage vs. power for both types of power units. The type A power supply delivers constant power through a range of ± 15 V. Since amplitude is proportional to power, constant power produces constant amplitude. The type A power supply therefore produces a more consistent bonding pattern.

With type S power supplies, however, the maximum power and therefore the amplitude varies with the usual fluctuations in line voltage in a plant. In type S units, a change in voltage could result in an overload. At the least, the varying power could cause the ultrasonic bonding to go beyond the acceptable limits necessary for critical, high-performance nonwovens.

Load regulation is application driven. It depends on factors such as pressure, fabric weight, number and type of webs, etc. If the load varies on a type A power supply, the power supply adjusts to maintain constant amplitude from zero to full load. This means no other manual adjustments are necessary for the system as Fig. 7 indicates.

Compared with type S power supplies, the new type A units deliver a specified power level with considerably less pressure on the horn and the material undergoing bonding. There is also lower amplitude. There may even be a combination of less

pressure and lower amplitude indicated by Fig. 8. Lower pressure reduces drag on the web, wear on the horn, and stress in the mechanical components. Lower amplitude decreases the unfavorable stress in the horn and results in longer tool life.

Type A power supplies produce nonwoven fabric not only with greater bond strength and consistency but also with a more uniform pattern. Equipment for type A power supplies requires much less operating maintenance.

Summary

Recent developments in new ultrasonic technology and equipment controls offer significant improvements for existing nonwoven textile applications. What is more important, these developments provide new concepts to visionaries in the field of nonwoven bonding who can grasp the possible application of these unique capabilities. □

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