North American MDF Blending Technology

Presented at the
Composite Panel Association
Resin & Blending Seminar

October 29-30, 1998 and December 10-11, 1998
Portland, Oregon Charlotte, North Carolina

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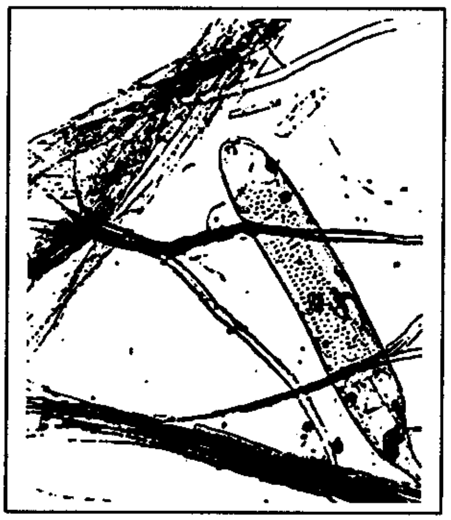
Introduction

One of the major questions faced by those involved with the original development of the MDF process was how to efficiently and effectively blend liquid resin binders with dry, low density fiber. The MDF process arose as an out-growth of dry process hardboard and particleboard technology. The relatively heavy fiber and particle furnishes used to make these products was, at the time, often blended with an atomized spray applied while the material was mixed in either rolling drum or paddle-wheel mixers. When this same technique was used with MDF fiber with a bulk density of 1-2 #/cf (Figure 1), the tack of the resin and the mechanical action would cause the fiber to aggregate into balls. In the early production plants the blended fiber was then passed through a high-speed, air-evacuated attrition mill to disintegrate the balls and fluff the fiber so it could be felted into a mat. This technique worked quite well; resulting in board with smooth, tight surfaces and uniform physical properties. But it was plagued with a highly freckled appearance of both the surface and the machined core.

Figure 1: MDF Fiber, 200x



To combat this cosmetic defect, new blending devices were developed. Grenco and Keystone introduced air suspension blenders that used high speed paddles and short retention time to blend the fiber by blowing it through an agitated fog of resin. These blenders worked well to avoid the formation of fiber balls, but the resin freckles were still a problem.

In the mid `70s, operators of the Holly Hill and Medco plants, with assistance from Borden, began experimenting with the blowline blending concept. This radical idea utilized the turbulence of the refiner blowline to mix resin and wet fiber prior to drying. This placed extra demands on the resin, since it was exposed to the heat of the dryer. Although this resulted in a higher resin requirement, the technique very effectively eliminated resin freckling, and so gained acceptance.

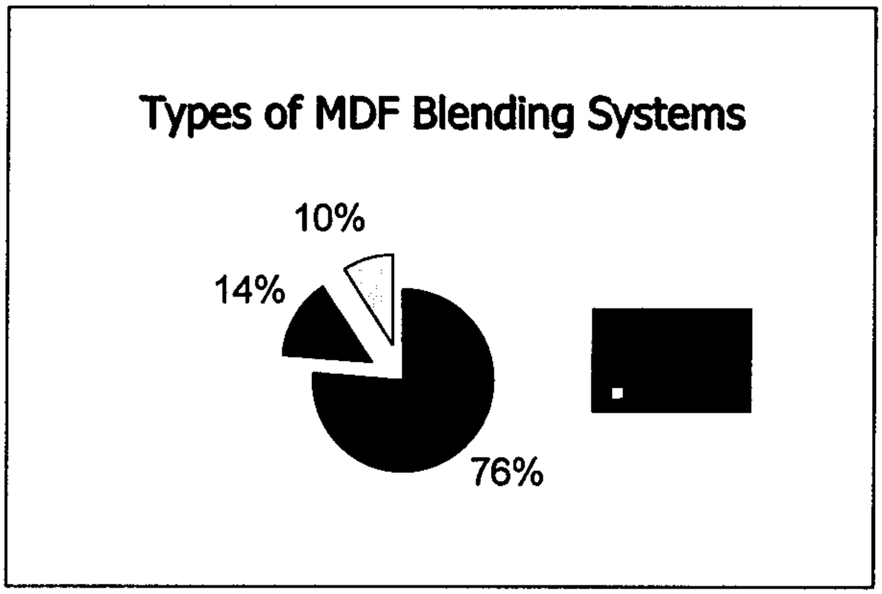
So where has MDF blending technology evolved to today? To address that question, a survey was recently conducted of all 29 of the operating MDF plants in the United States and Canada. The mills were quizzed about how they apply resin to the fiber, how their refiner system operates, the kind of metering and control equipment used, how the system is configured, and how well it all works. Twenty-one of the mills responded to the survey, an excellent return, and only one declined to answer.

The primary focus of this paper is to present the results of the survey. We will also explore recent research and blending theory, and then discuss how this theory applies to everyday mill operation. The paper concludes with a discussion of common problems with MDF blending, and a look at ideas on how they might be solved.

Current Technology, The Results of the Survey

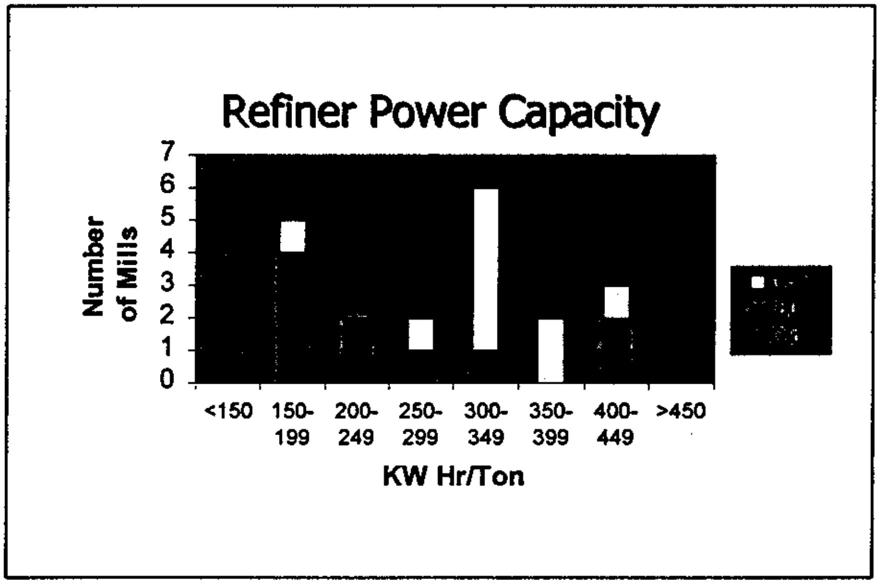
One of the first questions asked of the survey respondents was the type of blending system they used. Figure 2 shows that blowline blending dominates the industry. Over 85% of the mills employ some blowline blending, and three-quarters use it exclusively. It is well known that the MDF industry has been going through a bit of a revolution in recent years. Many new plants have been built in the `90s, and quite a few of the older ones have undergone major remodeling. 100% of these new and modernized facilities use blowline blending.

Figure 2: Types of MDF Blending Systems



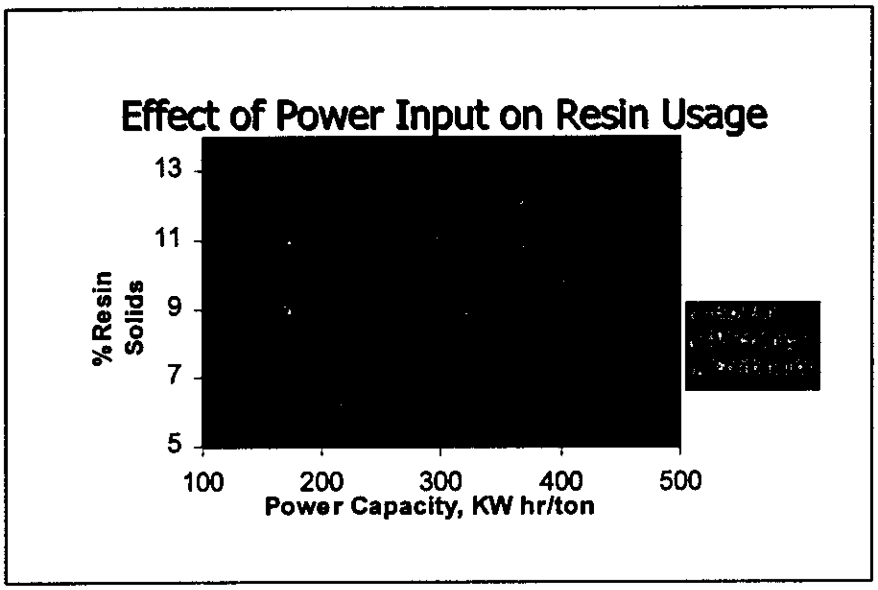
One the biggest recent changes in MDF technology has been the move to high intensity refining to produce very fine, shive-free fiber. Figure 3 shows that refiner energy capacity is moving from the conventional 200 kW hr/ton range to well over 300 kW hr/ton.

Figure 3: Refiner Power Capacity



As fiber size decreases, the relative surface area of the fiber furnish increases. Conventional blending theory tells us that resin requirement is dictated by the surface area of the furnish. If our objective is to coat all fiber surfaces with a thin layer of resin, then it follows that highly refined furnishes will require more resin than coarser fibers. To see if high intensity refining has lead to an increase in resin usage, the plants were asked how much resin they use to make their standard ¾" premium industrial grade product. They were also asked about the size of the refiner motors, and typical fiber production rates. In Figure 4, we see, somewhat surprisingly, no apparent relationship between the amount of refiner energy available and resin usage reported by the plants.

Figure 4: Effect of Power Input on Resin Usage



One thing that is apparent from Figure 4 is that the plants using combination or mechanical blending do use the least resin. This confirms, the conventional thinking about the impact of blowline blending on resin demand. Also apparent from Figure 4 is a fairly wide spread in reported resin usage amongst the plants using blowline blending. Does something other than refiner power, and therefore fiber surface area, influence the demand for resin with blowline blending?

A closer look at how these blowline blending systems are configured is in order. Although the system simply involves pumping resin and additives into the refiner discharge pipe to take advantage of steam turbulence to mix it with the wet fiber before entering the dryer, the survey, and Figure 5, shows there are many ways to configure the system.

Figure 5: Blowline Blending System Configurations

Blowline Blending System Configuration

% of BL Blending Mills with...

BL Length		Configuration		No. of Nozzles		Nozzle Location	
<30'	0%	Straight	13%	1	59%	Near BV	19%
30' - 60'	19%	Gentle	33%	2	12%	BV + 5'	19%
60' - 100'	63%	Crooked	53%	3	24%	BV +20'	31%
>100'	19%			>3	6%	Near Dryer	31%

Atomizing		Nozzle Size		Nozzle Angle		Nozzle Position	
Self	88%	<1/8"	13%	90	38%	Top	15%
Air	13%	1/8"- 1/4"	33%	With Flow	44%	Bottom	8%
		1/4"-1/2"	27%	Into Flow	19%	Side	38%
		1/2"-3/4"	7%			Mid-dia.	8%
		>3/4"	27%			Multiple	31%

While some commonality exists between plants, most blowline lengths are in the 60' to 100' range for instance, some surprising differences are apparent. More than half of the plants describe their blowlines as crooked, with multiple 90 degree bends, rather than straight or gently sweeping. Do these extra bends enhance turbulence and mixing efficiency? While nearly 60% of the mills apply the resin through a single nozzle, the rest are using multiple addition points. The kind of nozzles used to deliver the resin also are quite different. While only a couple of plants use compressed air to atomize the resin, the size of the injection orifice varies widely from under 1/8" to over 1" in diameter. There is far from a consensus about the best location for the resin injection point. On this the responding plants were nearly equally divided between close to the blow valve, about 20' down the pipe, and close to the dryer inlet. These configuration differences stimulate a variety of questions about what is going on in the blowline. Can the system design be optimized to minimize the resin usage requirement?

Blowline Blending Theory

Until recently, few attempts had been made to characterize the actions and forces occurring in the MDF blowline. However in the past few years, David Robson, Jamie Hague and others at the BioComposites Centre at The University of Wales in Bangor have been studying the subject, and have published their theories and experimental measurements made in pilot scale equipment at the Centre. The following theoretical discussion is based heavily on their published work and recent discussions with them.

The first consideration of blowline blending theory is identification of those factors affecting resin efficiency. If the system is to be optimized, we must first understand what influences these resin efficiency factors, and then look for ways to optimize their impacts. The three primary efficiency factors identified by Robson are (1) resin drop size, (2) mixing and turbulence, and (3) precure. Clearly, precure, or premature advancement of the thermosetting resin, should be minimized, but what is the optimum resin drop size, and how much turbulence is enough?

The question of optimum drop size is a critical one. Large resin drops will obviously not disperse well over the vast surface area of the fiber, but if the drops are too small the resin may over-absorb into the fiber wall and be effectively lost as an adhesive. Robson speculates that the optimum resin drop size is in the range of fiber diameter, about 40 microns. While this may be, the actual dimension is of little consequence since its impossible to determine in an operating facility. What is important is understanding how process conditions influence drop size, then experimenting with those conditions to evaluate their impact on resin performance.

Figure 6: Factors Effecting Drop Size

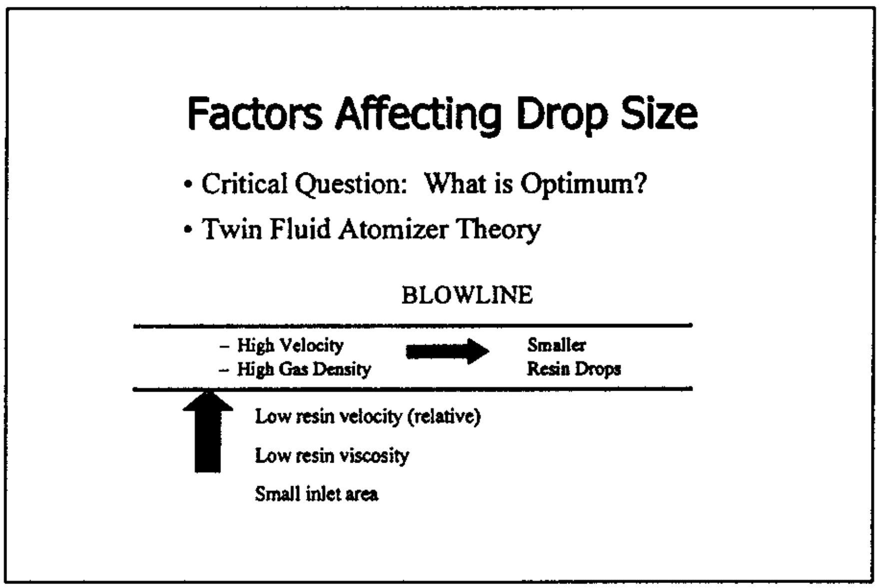


Figure 6 shows that resin injection into a blowline follows the theory of "twin fluid atomization". The action is akin to the formation of spray when strong winds blow across large bodies of water and strip droplets off the tops of waves. The size of the drops decreases as the resin viscosity and relative velocity decrease and the velocity and density of the steam and fiber in the blowline increase.

How well these drops of resin mix with the fiber in the blowline is a function of turbulence. As the steam leaves the refiner under high pressure it races through the blowline at near sonic velocity. While doing so, the pressure in the blowline drops rapidly and the relative steam volume increases enormously. This creates a highly turbulent environment. Sharp bends in the blowline, along with higher steam flow rates, and higher velocities created by narrower blowlines all increase turbulence, and therefore the mixing action between resin and fiber.

How much turbulence is needed to afford optimum resin blending depends on whether the blending is accomplished more through dispersion of small resin drops onto fiber surfaces, or through the spreading of resin from fiber to fiber as they collide in the blowline. If dispersion is the primary mechanism then we would expect a system that favors small drop size, long retention, and a well dispersed fiber suspension to be optimum. On the other hand, if physical spreading through collisions is the dominant blending mechanism, then a highly turbulent environment will improve performance.

The third factor affecting resin performance is precure. The curing reaction for urea formaldehyde resin is accelerated as the resin is exposed to high temperatures, and the reaction advances quickly over the duration of the high temperature exposure. The conventional thinking is that the more the resin is heated in the blowline, and the longer it remains at high temperature, the greater the loss of bonding effectiveness in the press. Since the steam pressure in the blowline, and therefore its temperature, drops as the blowline approaches the dryer, this tends to argue for resin addition near the discharge end of the blowline. Large resin drop size could also retard precure through the insulating effect the drops perimeter might have on the interior resin. This argues for a resin addition point through a large diameter nozzle, near the discharge of a large diameter blowline, to favor large drop size and short exposure to precure conditions. But will there be enough turbulence and retention time to accomplish good blending? Only careful experimentation and observation can tell.

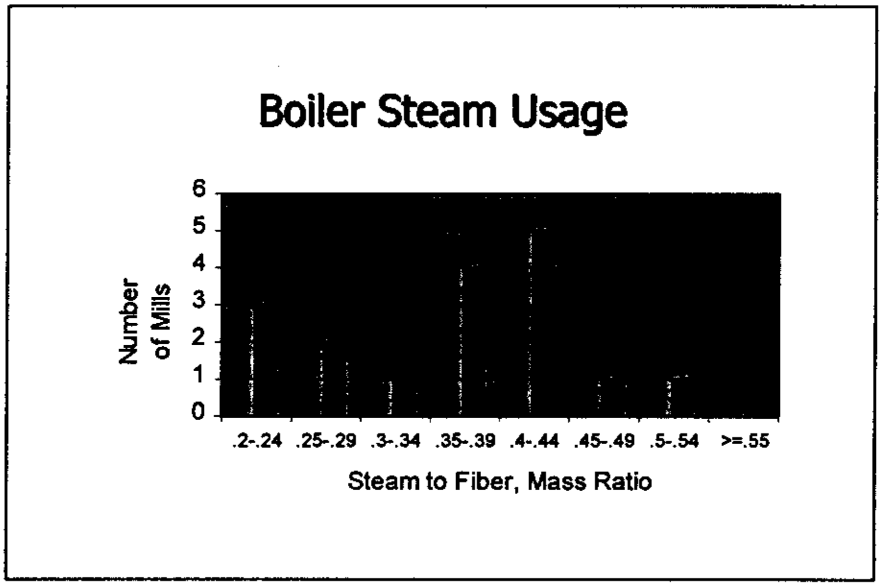
It is important to keep in mind that optimum performance of the resin blending system is only one part of the larger goal of optimizing the entire refining/drying/blending operation. The blending system is highly inter-related with refining and drying, and any steps taken to modify it will have an impact on the other operations as well. In order to achieve optimum performance of the overall operation, plant operators' goals must look to minimize consumption not only of resin, but of steam and dryer energy as well. The simplicity of the system and its maintenance requirements are also important considerations.

The Steam Factor

It is clear from the foregoing discussion that the one element that influences all optimization factors is steam. The mass flow and velocity of steam in the blowline effect all the same things that effect resin efficiency; drop size, turbulence, and precure. Steam consumption is also an important consideration in overall optimization of the refiner and dryer operations, and also impacts equipment maintenance requirements. The inescapable conclusion is that total system optimization requires careful steam management.

It is appropriate at this point to return to the survey and examine how steam is managed by the MDF plants. The mills were asked if they measured steam flow from the boiler to the refiners, and if so what its typical consumption was on a pounds per hour basis. A steam usage to fiber production mass ratio was then calculated. This is displayed in Figure 7.

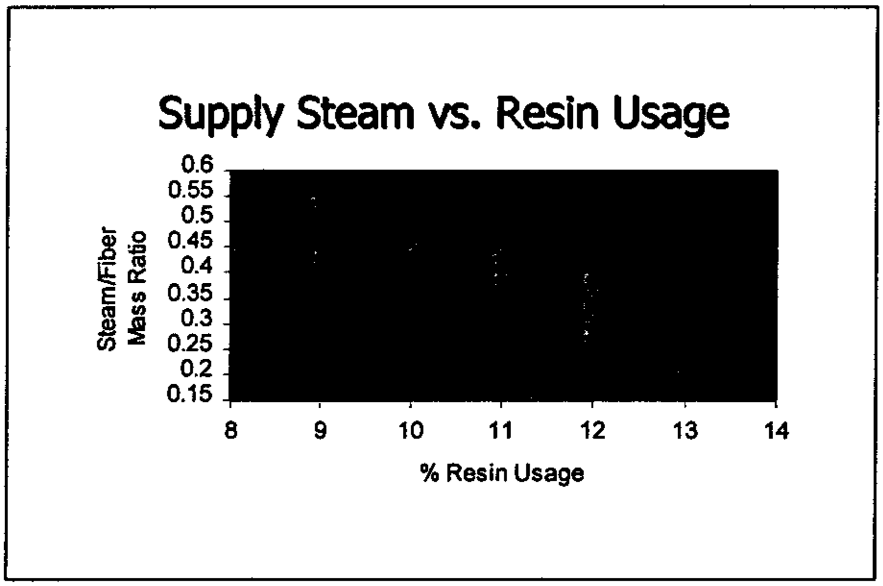
Figure 7: Boiler Steam Usage



It should be noted that the mass ratio values shown in Figure 7 do not tell the whole story of steam flow in the blowline. Some of the supplied steam is used to heat the incoming raw material. This may be off-set, and even supplemented by the creation of additional steam in the refiner as motor power is converted to heat. Models have been developed that can be applied to the refiner system to more accurately predict the steam flow in the blowline, but they were not available for this analysis. However, if we can accept that the boiler steam to fiber production mass ratios depicted in Figure 7 reasonably approximates the blowline condition, we can use this information to examine the impact of steam on resin efficiency.

In Figure 8, steam to fiber ratio has been plotted against resin usage. The data is limited because only 13 plants reported both their resin and boiler steam usage. However, the data does indicate a reasonably good correlation (r = -0.812) between high steam flow and low resin usage. Other interactive factors, such blowline size and resin nozzle location, have not been examined. While it may be inappropriate to draw any quantitative conclusions from this, it does seem clear that steam flow plays a major role in blending performance, and so should be closely monitored at all plants.

Figure 8: Supply Steam vs. Resin Usage



MDF Blending System Performance

The final part of the plant survey examined how well current blending technology is working. Plants were asked to report how well they were doing in the areas of resin usage (Figure 9), board appearance (Figure 10), and system problems (Figure 11).

Figure 9: Average Resin Usage

Average Resin Usage

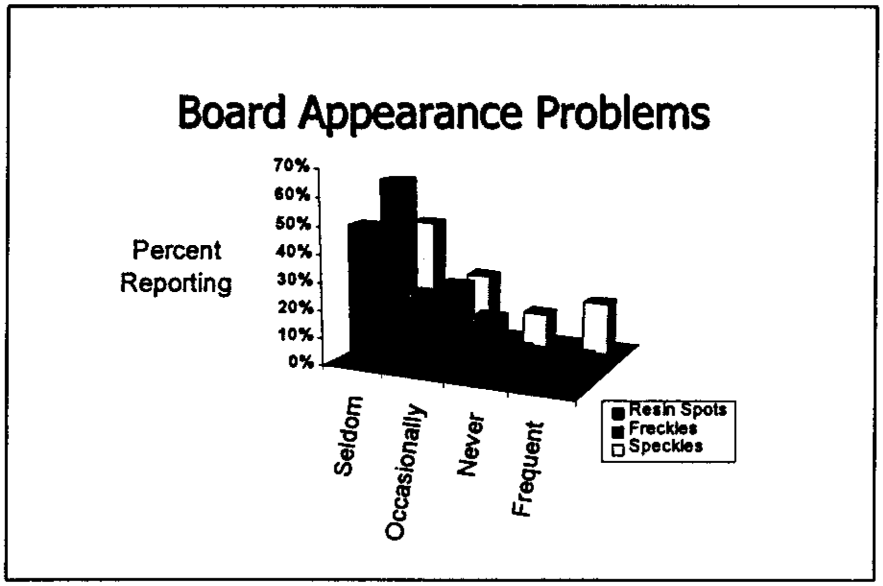
System	Ave. Resin Usage*
Blowline	11
Combination	10
Mechanical	7

* % UF resin solids on a dry fiber basis

The resin usage responses were to the question of UF resin requirement to make standard, ¾" industrial grade board. Some of the respondents reported this value in terms of percent resin solids to dry fiber, and others reported pounds of resin per msf of net production. Values in the latter units were converted to the percent solids basis as depicted in Figure 9. While some error, both in reporting and conversion is certainly present, it does seem clear that the mills pay a price for using blowline blending.

The cost of extra resin is, apparently deemed acceptable, because the blowline blending system does successfully deliver a clean, spot-free board appearance.

Figure 10: Board Appearance Problems

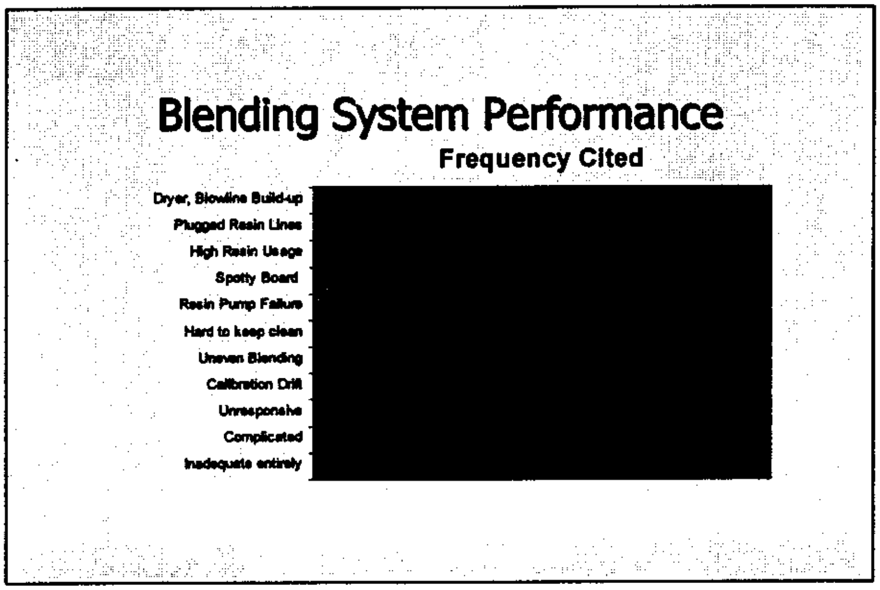


The mills were asked to report the frequency that they experienced appearance problems with the board's surface. They were not asked if the appearance problems were serious enough to cause the board to be down-graded, but only how often they occurred. Three types of defects were defined and queried. "Resin spots" were described as solitary, dark spots greater than ¼" diameter, in contrast to "resin freckles" which are smaller, lighter colored, spots that usually occur in a scattered pattern. The third defect is "resin speckles" which are very small, dark, pepper-like particles dispersed across the board surface.

It can be seen from Figure 10 that none of these defects are a major problem for the plants. For most mills, they all occur on a "seldom" or "occasional" basis", and certain mills report "never" seeing them. The defect most often described as both "frequent" and "occasional" was resin speckles. Analysis by others has indicated that this common defect is created by build-up of natural and added resins to the walls of the blowline and dryer that subsequently sluff off, break-up, and disperse through the fiber. Its occurrence is best controlled through measures that prevent the build-up from forming in the first place.

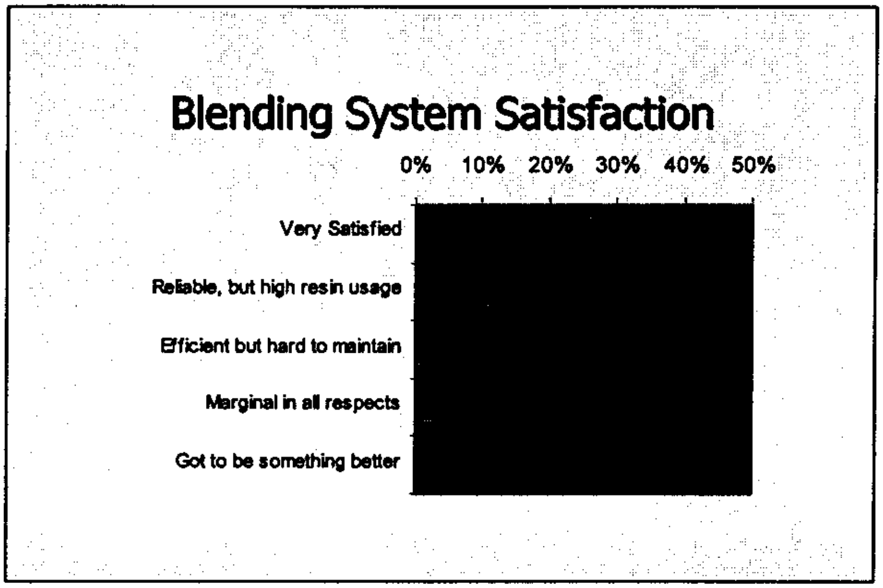
Figure 11 depicts the frequency that mills cited different blending issues being a problem for them. They were presented with the list of performance issues shown, and asked to identify up to three that might be regarded as "problems" in their mill. The two most frequently cited items were build-up problems in the dryer and blowline, and plugging problems in the resin delivery lines. Both of these problems are avoidable through resin delivery system design and addition control logic. Some mills never experience either one. Those that do should take a hard look at their operation and, perhaps with the help of outside consultation, experiment with different configurations and controls to improve their understanding of the causes and origin of the problems.

Figure 11: Blending System Performance Problems



The third frequently cited problem was "high resin usage". It is hoped that the foregoing examination, and the observations that steam usage plays a role in resin performance, and that many different system configurations are possible, will stimulate users of blowline blending to systematically examine their system and experiment with ways to optimize it. Alternatively, it is clear that the price for achieving the benefits of blowline blending is high resin usage. Clearly, an opportunity exists to pursue research into the development of equipment that will allow mechanical blending systems to achieve the appearance and reliability levels of blowline blending.

Figure 12: Blending System Satisfaction



Finally, the plants were asked to rate their overall satisfaction with the blending technology they employ. Figure 12 shows that 40% of the plants are "very satisfied" and another 30% would be as well if only their resin usage was lower. The remaining 30% are apparently experiencing performance and reliability problems at an unacceptably high rate. The good news for this group is that those problems are solvable. The bad news though, for the entire industry, is that less than half of the mills are satisfied with their blending system's performance, and some of them may simply be complacent.

Clearly, the opportunity exists, through research and experimentation to advance the science of blending UF resin with MDF fiber. This survey has complied a wealth of information about what is being done in the industry today, and the analysis presented in the foregoing has simply scratched the surface of the possible insights the data might provide. It is clear that both resin usage and system reliability with blowline blending is influenced by the way the system is configured and controlled. It is also clear that the potential for mechanical techniques should be more deeply explored.

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