Ceramic Doctors and Yankee Metallization

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Abstract:

The traditional creping process has in principle changed little in the past decades; however the evolution of technique and new materials has steadily improved productivity and product quality. Some of the most significant advancements have been the development of ceramic creping blades, of the hardened surfaces applied to Yankee cylinders and of coating chemicals. In this paper we will focus on the former two: ceramic blades and Yankee metallization.

Both of these products individually offer the tissue maker the opportunity to improve the creping process by reducing downtime. Many tissue makers have in fact redefined their production economics with only one of these new products. There is, however, an even greater potential in the synergy that exists when these two materials are properly used together as a system. The behavior of materials under high specific pressure and high temperatures, such as those that exist at the blade/Yankee interface, dictates the everyday operating conditions such as blade change frequency, Yankee grinding requirements and product quality [1) 3)].

In this paper the behavior of different materials will be explored, and the mechanism of wear will be reviewed as it pertains to the creping process.

Beyond these academics, a case study will be presented of the SCA tissue mill in Mannheim, Germany. This mill has quite a long history of using BTG ceramic creping blades on Infinikote Yankee surfaces.

Product quality, blade change frequency, blade- and surface wear characteristics, production output and finishing characteristics will be presented.

Introduction

The creping of tissue on a Yankee cylinder is an extremely violent process. During this operation, there are forces at work that would perhaps predict that it would not be possible to make a fine consumer product in this way. As with many aspects in the paper industry, the technology strives forward out of necessity as the myriad of process variables holds back the precise science and explanations of what we are really doing. In this paper we hope to expose you to new technology as well as give you a glimpse and an understanding of the science responsible for it. And as we are all pragmatists in these days of cost-cutting, asset maximization and productivity improvement, we will also present a case study of the implementation of a new "technology package" in an actual tissue mill.

Ceramic creping blades

BTG introduced the DUROBLADE line of ceramic blades to the tissue industry in 1990. Acceptance was quite slow as a very conservative industry eyed this new "ultrahard" product with suspicion. Fear of Yankee surface damage limited the trials and eventual use to only a few intrepid and forward-thinking souls.

However, things have changed. From the figures gathered in 2001, the use of ceramic creping blades is established in 40 countries and the users are represented by all the major tissue producers. It is estimated that in 2001 over one million hours of tissue production was made with ceramic blades. In this same year, there are no reported damages attributed to, or caused by, the blade. There is no statistical evidence that shows ceramic blades to accelerate wear on the Yankee surface. There is, however, evidence to the contrary, with longer time periods between regrinds being established on many Yankees. There is in fact "science" behind this. The sliding wear between two surfaces is the result of several phenomena. In our case, i.e. the blade tip against the Yankee surface, we consider friction and abrasion to be the most interesting to study. In the case of friction, two surfaces under high specific pressure and temperature tend to microweld the asperities of the surfaces to one another. These contacts then break free resulting in material transfer which we casually call wear. The more chemically similar the materials are on the two surfaces in contact, the greater the tendency[2)]. In the case of steel blades against a metallic Yankee surface this tendency is high, meaning that there is potentially a great deal of frictional wear to both surfaces. In the case of ceramic against cast iron their dissimilarity drastically reduces this phenomenon. Hence, there is far less friction-related wear on both the blade- and Yankee surfaces. The component of wear that is due to abrasion can be thought of as the “cutting” of one surface by the other. The degree to which this mechanism occurs depends on the roughness of the two surfaces, the hardness of the materials and the “fracture toughness” of the materials. This latter term is the least familiar to most people but actually the most critical when it comes to the nature of abrasive blade wear against the Yankee cylinder.

Fracture toughness is a metallurgical term expressed as K_{IC} with the units ($\text{MPa}\sqrt{m}$), perhaps most easily conceptualized by thinking of it as “brittleness”. And as you would expect, a brittle material such as ceramic has quite a low K_{IC} value. (Fig. 1 shows some key values of toughness and hardness). Therefore, whereas one would think that a material such as ceramic, which is much harder than a cast iron surface, would cause high abrasive wear, the low toughness values of the ceramic prevent this damage. Also, from reviewing the values in fig. 1, it would be a reasonable assumption that the abrasive wear between a cast iron surface and a steel blade would be quite high. However, it must be understood that the hardness of steel is much lower at elevated temperatures. In the operating condition, the sliding surface of the steel blade tip reaches very high local temperatures [3], much higher than the Yankee surface, resulting in plastic flow of any of the asperities that would abrade the cast iron surface. This argument again points the primary wear mechanism to being friction.

	Toughness K_{IC} ($\text{MPa}\sqrt{m}$)	**Hardness** **HRC**
Steel blade	50	50 - 55
Cast Iron	6 – 20 [4]	20 - 35
Infinikote	3 - 10	55 - 65
Ceramic Blade	2 - 3	65 - 68

Fig.1 Toughness and hardness for key materials (at room temperature)

Metallized Yankee surfaces

The traditional construction of a Yankee cylinder is of course cast iron. The size and shear mass of this piece of equipment prohibits construction from perhaps better or more sophisticated metals. The frictional wear of this surface, as discussed previously, is only one factor that affects the surface and eventual service life. Corrosion is the other very significant aspect. Iron is a very chemically reactive material. Chemical attack, and even simple oxidation from moist air, dictate frequent grinding of the surface to achieve levelness and smoothness.

In the early 1970’s, Bender applied the first full-faced thermal-sprayed coatings to Yankee cylinders. The material used at that time was an AS-400 stainless steel. While certainly achieving some of the objectives of corrosion-resistance and better wear properties there was a sacrifice in heat transfer. To address the heat transfer limitation, other materials were adapted and by 1985 a product known as PS-500, based on molybdenum and nickel, was in use. This solved a great deal of the thermal heat transfer problem and the material seemed to be acceptable for a while. However, serious sacrifices in chemical corrosion-resistance were experienced once mill water systems began closing up and residual chemical concentrations escalated.

In the early 1990’s, Bender dedicated significant time to developing a new product, one to address all of the issues: corrosion-resistance, heat transfer and abrasion-resistance. An extremely hard stainless steel with very high levels of chromium seemed to be the answer. Once the metallurgy of this material was identified an application technique needed to be developed as well. The method of application was also extremely critical in determining the final surface properties of this material. A process called “high-velocity arc jet thermal spraying” was adapted and the parameters developed to create not only a uniform full-face coating with good heat transfer properties, but also to produce the surface texture needed for holding an organic chemistry. All these developments came together in a process called “Infinikote”. The Infinikote surface has been demonstrated to keep heat transfer properties virtually unchanged and, in most cases, to actually improve on organic coating acceptance. This type of surface is now in operation on 100 Yankees around the world.

The “Package”

With the two technologies of ceramic blades and ultrahard sprayed surfaces both growing in popularity it was inevitable that the combination of the two would be tested. While many tissue mills were understandably nervous to do so for fear of damaging their newly metallized Yankee surface with these hard blades, a few went ahead on their own to use DUROBLADE ceramic blades on the Infinikote surface.
Under closely observed preliminary trials and subsequent months of operations, it became clear that the marriage of these worked very well. It was decided by both BTG and Bender that it would be a good thing to try to better understand the interaction of these products through some designed experiments.

Experimental procedure

At Bender’s facility in the UK a pilot scale Yankee surface was prepared with half its surface coated with Infinikote and the other half left as cast iron. The blades run on the surface for this experiment were both steel and ceramic. To accelerate any observable results, the test was run with no lubrication at all between the blade and Yankee. The speed of the Yankee was 500 m/min and the loading of the blade was 48 kg/meter. In each case the run-time was 1 hour. Mechanical drive limitations prevented higher speed or loading. However, with no lubricating or protective layer between the Yankee and the blade we were confident that we would generate plenty of wear.

The results

The most notable result of these trials were the differences in the amount of wear of steel blades vs. ceramic blades. The cross-sectional wearing pad for both cases can be seen in fig. 2 and 3.

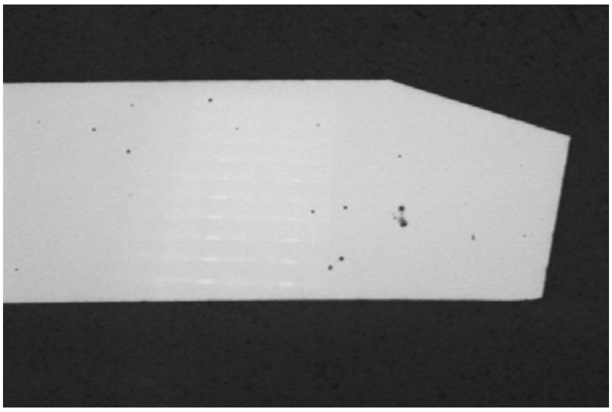

Fig. 2a Steel blade against Infinikote

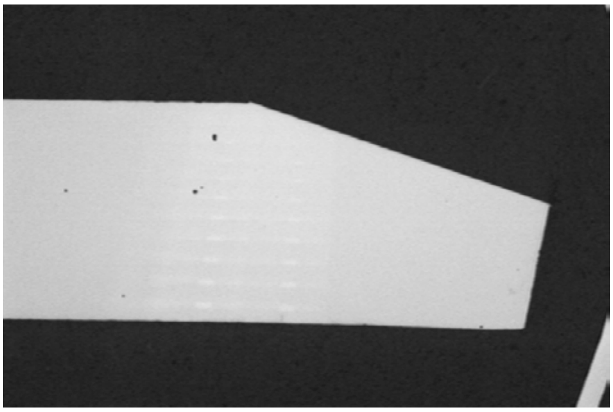

Fig. 2b Steel blade against cast iron

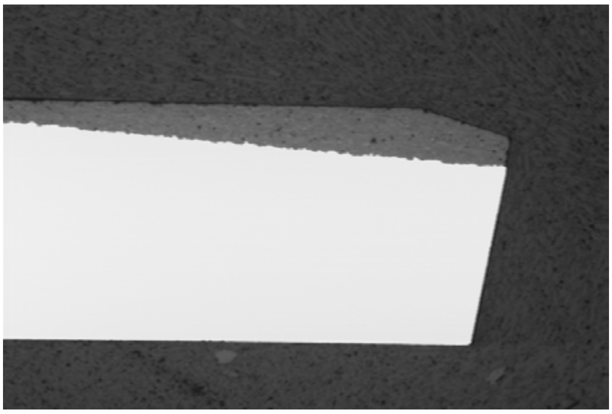

Fig. 3a DUROBLADE against Infinikote

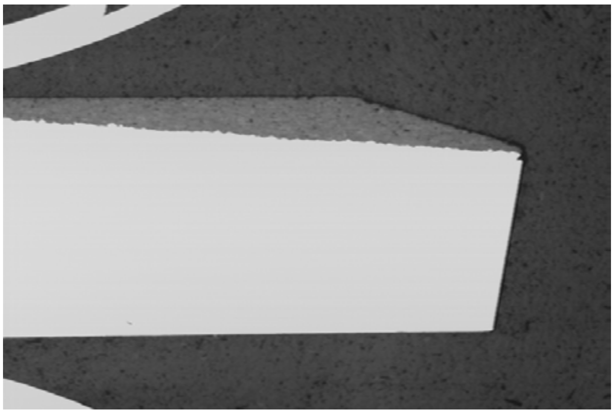

Fig. 3b DUROBLADE against cast iron

In calculating the amount of material worn away, it can be said that the steel blade lost 250% more material during the test period compared to a ceramic blade when run against a cast iron surface, and 460% more on the metallized surface. This is as predicted by arguments on friction presented earlier in this paper. More interesting, perhaps, is the comparison of wear of the ceramic blade against the cast iron compared to the metallized surface.

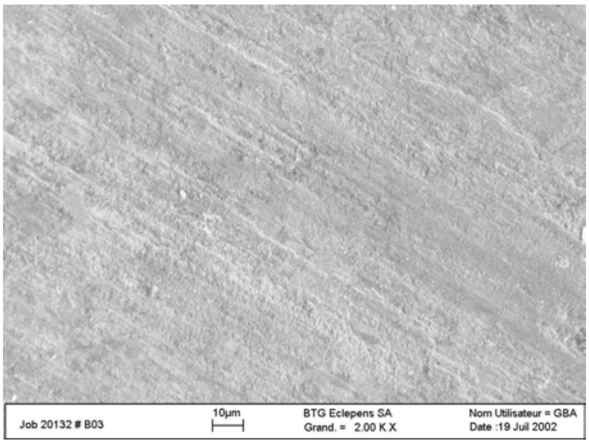

Fig. 4a DUROBLADE on Infinikote

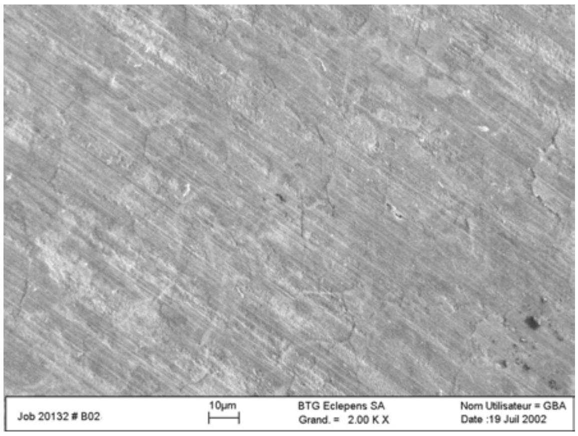

Fig. 4b DUROBLADE on cast iron

In fig. 4 you can see the typical wear pad of both cases. When calculating the average amount of material lost over several sample points, it can be said that the ceramic blade lost 360% more material when run against the cast iron surface compared to the metallized surface. Now, comparing old technology to new, this being the extreme cases of steel blades against cast iron and ceramic blades against the metallized surface, there is 900% less wear in the combination of these two enhanced materials.

	Cast iron	**Infinikote**
Steel blade	152	144
DUROBLADE	131	108

Fig. 5 Chart of temperature comparison (°C)

In fig. 5, the chart shows the average temperature of the blades as they were running on the Yankee surface for both the cast iron and the metallized side. The steel blade ran 8°C cooler on the metallized surface and the ceramic blade ran 23°C cooler against the metallized surface. And, if you again compare the two extremes, you see a very significant 44°C temperature difference. This fact, combined with the previously discussed lower wear rates, indicates significantly lower friction.

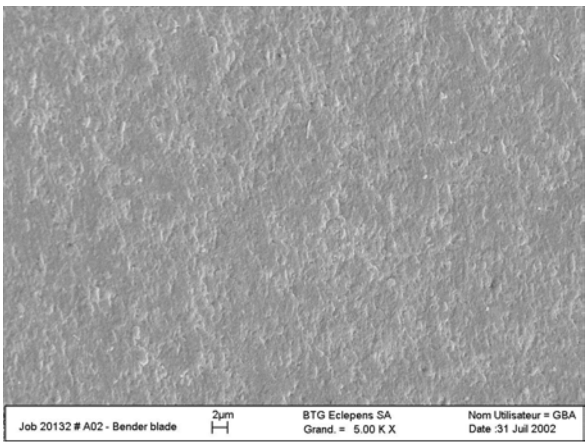

Fig. 6a Steel blade on Infinikote

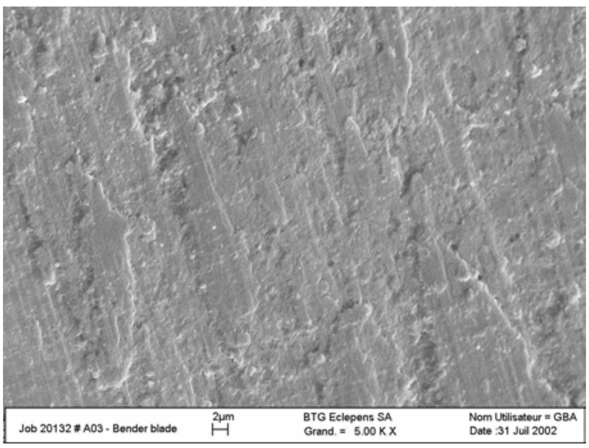

Fig. 6b Steel blade on cast iron

Fig. 6a and 6b show two SEM photomicrographs at 5000 x magnification, one of the worn steel blade bevel having run against the metallized surface (a) and the other of the worn steel blade surface having run against the cast iron surface (b). In the latter, the surface is clearly different in its apparent smoothness. From the pitted irregular surface seen in 6b it is not difficult to visualize the microwelding phenomenon occurring here as a result of friction.

Observing the previous photomicrographs you can see very little visible evidence of abrasive wear, which would be detected by heavy scoring lines in the worn blade bevels. The test set-up and procedure used to collect the above data is obviously not well suited for the study of abrasive wear, however, it is valuable to have learned that even in an unprotected state the Infinikote, with its hardened metallic matrix, did not cause any appreciable abrasive blade wear. Because of the hardness of ceramic the Infinikote can not abrade the blade, and due to the much higher toughness of Infinikote, the ceramic can not abrade Infinikote. In the combination of steel blades against a metallized surface the case is not so clear. At the very high temperatures occurring at the blade tip, the hardness of the steel blades is much lower than the metallized Yankee surface. Under these conditions, there should be concern about transfer of material from the blade tip to the Yankee surface. If this occurs, the rugosity of the Infinikote surface could be filled with steel, changing the nature and functioning of this designed surface. Because of this possibility, it should certainly be better to use steel blades with high hardness values. On this point, it can further be said that the mating of a ceramic blade to an Infinikote surface is ideal.

In the actual mill environment there are many other factors to deal with, such as organic coatings, filler materials, inorganic contaminants and of course the tissue sheet itself, impacting on the blade's creping shelf. All of these factors tend to make anything but production experience somewhat theoretical or, at best, idealistic. For this reason, actual mill production experience is critical for complete satisfaction.

Mill experience at SCA

The intention of this presentation is to describe the experience, the mill Mannheim of SCA Hygiene Products has had with ceramic doctor blades from BTG in connection with metallized Yankee cylinders from Bender, in the last few years.

SCA's Mill in Mannheim

Mannheim is the biggest tissue mill in Europe with a production capacity of more than 260.000 t of tissue for consumer products per year. The mill has 5 tissue machines whereof 4 are conventional ones and one is a TAD machine. Each machine is dedicated to one tissue quality. That means that 2 machines are producing mainly household towel, two machines toilet tissue and one machine only facial tissue. The last machine was started up in 1999. Fig. 7 gives an overview about the key figures of our 5 machines in Mannheim.

	WM2	**WM 3**	**WM 4**	**WM 5**	**WM 6**
Supplier	Voith	Voith	Valmet/ KMW	Voith	Valmet
Year of start-up/rebuild	1968/82	1971	1980	1986	1999
Type	Twin wire	Single wire	Twin wire	Twin wire	Twin wire
Width (headbox) (m)	5.28	5.40	5.40	5.45	5.59
Construction speed (m/min.)	1,650	1,500	2,200	2,200	1,700
Winder	4-ply	4-ply	2-ply	-	-
Production	Facial	Toilet	Toilet HHT	HHT Toilet	HHT

Fig. 7 Tissue Machines at the SCA Mannheim mill

History of DUROBLADE and Infinikote in Mannheim

In the meantime, four of our machines were metallized with Infinikote from Bender. Machine No. 5 was the last one, which changed over from metallization to Infinikote in November 2001. Our experience with BTG's ceramic blades, DUROBLADE, started about three years ago on our machine No. 2.
No. 3 started to use DUROBLADE in May 2000, No. 4 in April 2001 and No. 5, finally, in July 2001.

The main purpose of using ceramic blades was to increase the time-efficiency of the machines by reducing the time needed for blade changes. By this means, the broke would be reduced, which meant improved productivity. Another issue was the quality of the tissue. By changing the blade material there was the hope of achieving a better softness of the base tissue. But we didn't have the same experience on all of the machines.

Our experience

The following charts show the trend of the softness of base tissue on two of our machines over a longer period of time. The change of type of doctor blade is marked with a red line. The softness stated in the charts is measured by a panel of specialists in a SCA-specific scale, where 100 is the best and 0 the worst.

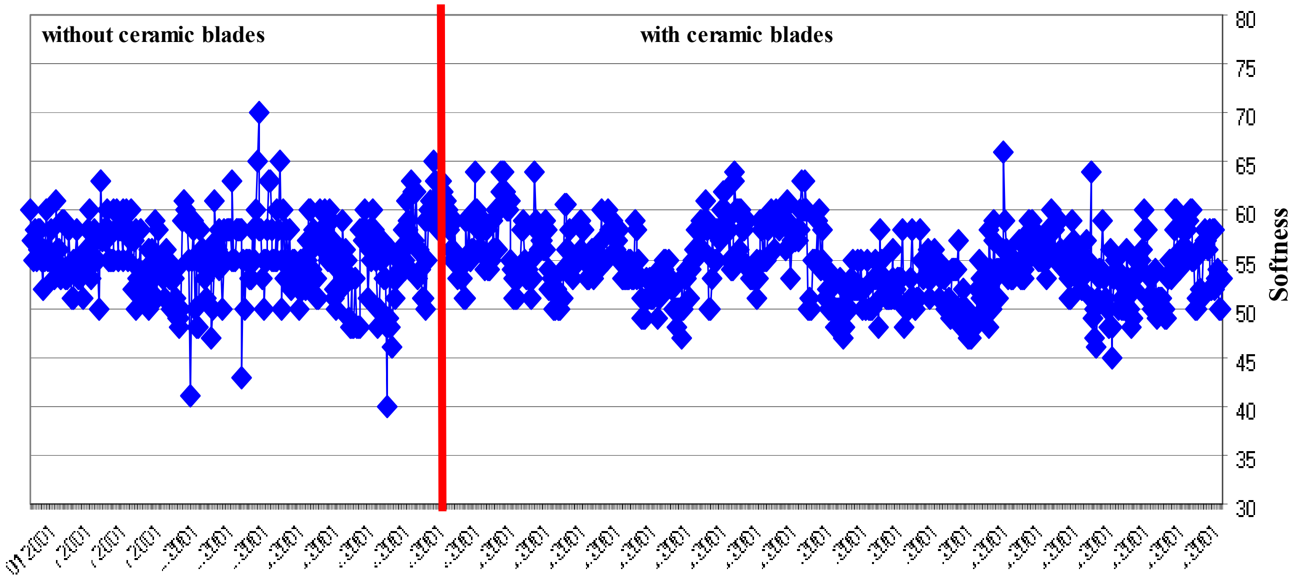

Fig. 8 Softness trend, machine No. 4

The trend of machine No. 4 is representative also for Nos. 2 and 3. As can be seen, the range of softness of the base tissue – in this case toilet paper and facial tissue - didn't change. However, what we noticed was the improved uniformity of the base tissue softness. The softness remained stable for a much longer time than with a steel blade. The creping process shows more stability. Therefore, the quality of the tissue became better.

A different experience was made on tissue machine No. 5. On this machine the softness level of the household towel increased about 5 points in contrast to the other machines after the introduction of ceramic blades and the necessary adaptation of the coating chemicals. An adaptation of the coating package had to be done, more or less, on all machines after the change. A precise explanation about the different softness development, depending on machine, couldn't be found.

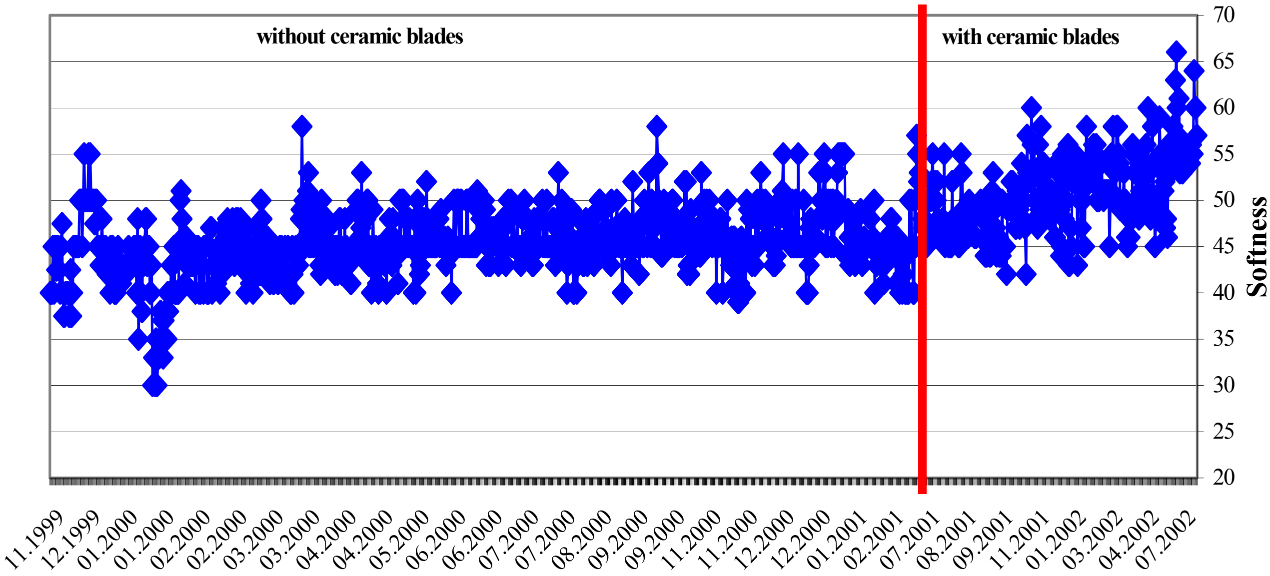

Fig. 9 Softness trend, machine No. 5

The blade change frequency for tissue machine Nos. 4 and 5 can be seen in the next two figures.
On machine No. 4, the average blade lifetime increased from 2.2 h per blade to a maximum of 60 h per blade.

	number of blades	blade performance	
2001	pieces/month	lifetime (h)	to/blade
January	264	2,8	20
February	291	2,3	16
March	273	1,6	9
April	336	2,1	14
May	13	57,2	413
June	12	60,0	421
July	22	33,8	230
August	39	19,1	122
September	14	51,4	343
October	12	57,2	375
November	20	36,0	244
December	28	21,9	134
2002			
January	31	24,0	165
February	20	33,6	221
March	15	49,6	331

Fig. 10 Creping blade performance, machine No. 4

On machine No. 5, the increase went from 2.5 h per blade to a maximum of 53 h per blade.

	number of blades	blade performance	
2001	pieces/month	lifetime (h)	to/blade
January	263	2,8	21
February	318	2,1	15
March	326	2,3	16
April	247	2,9	20
May	237	2,7	20
June	356	2,0	13
July	111	6,7	49
August	37	20,1	137
September	38	14,5	107
October	23	21,4	153
November	35	16,5	103
December	28	18,9	119
2002			
January	14	53,1	370
February	15	39,4	293
March	23	32,3	233

Fig. 11 Creping blade performance, machine No. 5

Due to ongoing optimization processes on the tissue machines, such as blade geometry, coating chemicals and quality requirements of the produced tissue, there is a high variation in the shown lifetime figures of the ceramic blades. Nevertheless, it is obvious that due to the reduced amount of blade changes the production time of the machines was increased by a couple of minutes each day, which improved the time-efficiency of the machines.

Recapitulating, it can be said that the decision to use DUROBLADE was the right one. The expectations were mostly fulfilled. The Infinikote metallization made the application of ceramic blades possible and protects the Yankee surface well. Our regular inspections of the surfaces of all Yankee cylinders showed no increased wear. As already said, the optimization of the whole creping process is ongoing on all tissue machines in Mannheim and also includes DUROBLADE.

Summary/conclusion

The trial work done for this paper along with other independent work by BTG and Bender shows that the theoretical aspects of wear mechanisms are in fact demonstrated experimentally. The superiority of these new materials for the Yankee surface and for creping blades is further proven by a great deal of actual mill experience.

The new generation of metallized Yankee surfaces makes it possible to think of Yankee service lifetime as potentially unlimited. The wear-resistance of the surface will eliminate virtually all of the significant re-grinding outages that are required with cast iron. The ceramic blade will run many times longer than conventional steel blades between changes. The slow wear rate at the tip results in much more consistent specific pressure levels and makes it possible to lower overall blade pressure. Both of these technologies on their own offer the tissue maker huge potential savings. Together in a package, the ceramic blade - unlike metallic-based blades - ensures that there will be virtually no wear on the metallized Yankee surface from frictional interaction. This means that all the time lost for Yankee surface maintenance will be eliminated. The slow-wearing and long-running ceramic blade offers even more savings by eliminating much of the time lost for blade changes. The implications for tissue quality cannot be overlooked. A consistent Yankee surface will result in a more predictable coating chemistry behavior. A more consistent blade tip geometry will always result in less variability over time for tissue properties with benefits cascading from the reel to the finishing room and, ultimately, to the consumer.

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