DUPONT™ TYNEX® A

THE FINISHING TOUCH.

For more than 70 years, DuPont has been pioneering innovative synthetic filaments to enable brush manufacturers to address emerging trends and meet evolving consumer expectations.

Whether you manufacture cosmetic brushes, toothbrushes, industrial brushes or paintbrushes, DuPont Filaments has a reliable, high-performance solution to meet your product design requirements. In addition to offering a broad range of innovative synthetic filaments, we understand the importance of providing you with the technical data you need to make design decisions. In this document, you will find a wealth of technical data concerning brushes made with synthetic filaments.

Tynex®, Tynex® A, Chinex®, Herox® and Orel® are DuPont registered trademarks for its filaments that are used in premium quality brushes.

Applications are:

- Tynex® 612 Nylon level filaments for toothbrushes
- Tynex® 612 Nylon fine filaments for cosmetic brushes
- Tynex® 612 Nylon tapered filaments for paintbrushes
- Tynex® A 612 Nylon abrasive filaments for floor care and industrial brushes
- Chinex® 612 Nylon synthetic bristle for paintbrushes
- Herox® 610 Nylon level filaments for toothbrushes
- Orel® polyester tapered filaments for paintbrushes

Much of the data presented in this bulletin is pertinent to a variety of brushes and brush filaments. But particular emphasis is placed on DuPont filaments that are now manufactured in ISO 9001-qualified plants worldwide.

The information to follow is intended to help designers and engineers become familiar with the unique characteristics of the DuPont Filaments' business family of filaments and how these characteristics are affected by environment and stress. With this knowledge, and the information provided in the "Filament Performance in Brushes," it is hoped that proper filament selection coupled with good design practice will result in the development of a successful brush product.

The data contained in this module falls within the normal range of product properties, but should not be used to establish specification limits or used alone as the basis for design; they are not intended to substitute for any testing you may need to conduct to determine for yourself the suitability of a specific material for your particular purposes. Because DuPont Filaments can make no guarantee of results and therefore assumes no liability in connection with the use of this information, confirmation of its validity and suitability should be obtained independently.

WHAT IS TYNEX® A?

Tynex® A is an abrasive filament made by extruding a mixture of nylon and abrasive grit. The grit is uniformly dispersed throughout the resulting filament (*see Figure 1*). This abrasive filament is unique because the sharp cutting edges of the grit are randomly positioned and can be held firmly against any work surface no matter what its shape. As the brush moves against the work surface, the flexible filaments bend at all angles to fit the contours of the piece being worked, so the cutting edges of the grit can make contact. Abrasive pads, belts, and wheels do not have this degree of conformity.

Figure 1. Magnified Picture of Grit Containing Tynex® A

Background

From the time that DuPont invented nylon in the 1930s, monofilaments have been a continuous downstream business. The development and commercialization of Tynex® A abrasive nylon filaments in 1968 were a result of this continuous investment in research and development. The market has grown steadily, first in the United States and then quickly in other industrialized areas around the world. Currently, Tynex® A is in use in all major markets, including Western Europe, Japan, China and the Americas.

The balance of this brochure is intended to provide basic product, application, and design information.

MAJOR INGREDIENTS

Nylon

The primary ingredients of abrasive filaments are nylon polymer and abrasive grit. Nylon has several characteristics that make it attractive for abrasive filaments. Nylon is tougher and more durable than common alternative polymers. It is also resistant to abrasion, a fact that helps extend its useful life.

Nylon is resistant to most chemicals. Hydrocarbons, oils, and most organic solvents have no lasting effects. Basic pH solutions (alkalies) have no effect at temperatures under 38°C (100°F); gradual deterioration will occur at higher temperatures. Food acids like vinegar (acetic acid) and short exposure to weak solutions of hydrochloric acid have very little effect. Strong acidic solutions will degrade and embrittle nylon filaments. Exposure time and temperature are key factors in determining how well nylon will tolerate various solutions.

The rate of nylon polymer degradation is roughly a factor of 2 for every 5°C (10°F) increase in exposure temperature. Therefore, the difference in the rate of polymer breakdown at 50°C (122°F) and 80°C (176°F) is a factor of 64.

Nylon filaments offer superior memory or bend recovery. This is the tendency of the deflected filament to return to its original shape. *Figure 2* shows the differences in bend recovery for several different types of filaments. The bend recovery for nylon is over 90%. Over time, all filaments will take a set, and unless the filament recovers, the brush tool will become "soft" and lose its effectiveness. Bend recovery will be affected by filament size, relaxation time, strain, deflection time, and environmental conditions. Among the synthetic filaments, nylon inherently offers the best recovery over an extended period.

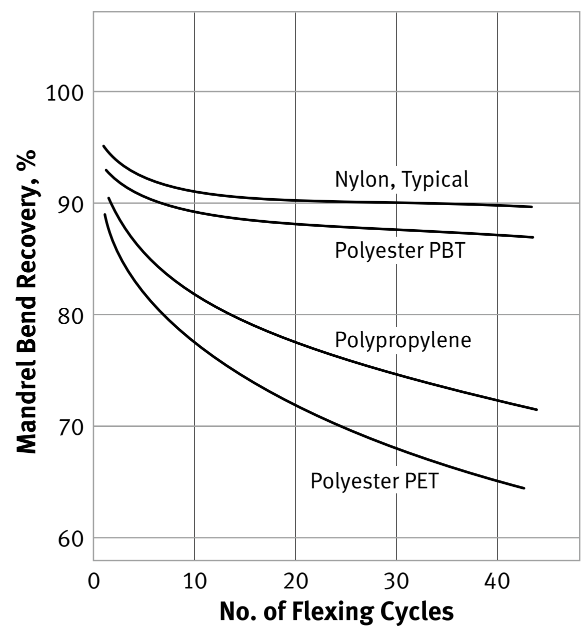


Figure 2. Bend Recovery for Various Monofilaments

Nylon Choices

Filament performance in a brush can be directly related to the ingredients used to make the filament. The basic polymer used in Tynex® A is type 612 nylon. Other types of nylon can be used, but type 612 nylon polymer offers:

- lower moisture absorption
- greater stiffness when wet
- lower density

Abrasive filaments made from nylon types 6, 66, and 610 are available, but after reviewing the key properties, type 612 nylon appears to be a superior choice for brushes.

Low Moisture Absorption Increases Stiffness

Brushes or brush tools that work well under all conditions generally contain filaments that maintain their stiffness even when wet. Because stiffness is directly related to the amount of moisture that filaments can absorb, *Table 1* reflects that type 612 nylon filaments should be the most aggressive. Even the small apparent difference (16%) between types 610 and 612 is enough to be significant in filament stiffness. Filament stiffness is frequently referred to as aggressiveness in brush terms, although there are other factors that affect brush aggressiveness when using abrasive filaments.

Table 1. Absorption Rates

	Moisture Absorbed, %	
	50% RH	100% RH
Nylon 6	2.7	9.5
Nylon 66	2.5	8.5
Nylon 610	1.5	3.5
Nylon 612	1.3	3.0

Changing Stiffness Affects Brush Performance

Modulus (stiffness) is a physical property of a material that can be defined as the resistance to bending and is an inherent characteristic of a material. The modulus will vary from dry to wet environments.

The resulting aggressiveness of an abrasive filament brush can also change considerably from dry to wet environments. *Table 2* shows how the modulus changes from dry to wet environments for the four types of nylon considered. Nylon 6 filaments are typically limp (low modulus) and are usually used for fishline, where limpness is an asset. Nylon 66 filaments are very stiff in a dry environment; however, brush performance can change considerably as nylon 66 loses 65% of its stiffness as the humidity rises from 50% to 100%.

Table 2. Modulus Comparison

	Modulus, Mpsi		Ratio
	Dry*	Wet	Wet/Dry
Nylon 6	280	140	0.50
Nylon 66	650	230	0.35
Nylon 610	533	333	0.63
Nylon 612	580	420	0.72

*At 50% RH

Source: *Nylon Plastics*, M. I. Kohan, John Wiley & Sons, 1973, page 451.

Tynex® A, made from nylon 612, offers the most consistent performance dry to wet because the modulus is high at 50% RH and only loses 28% in 100% wet environments.

Polymer Consistency Improves Quality

Nylon types 6, 66, 610, and 612 are different variations of the polyamide molecule. The manufacturing processes and ingredients are different, and this can affect the resulting filament performance in brushes. Nylon 6, for example, contains the ingredient caprolactam, which is frequently not completely bonded to the molecule. Nylon 6 filaments in an aggressive brush tool can leave a residue on the part.

Nylon 610 is made from extracts of the castor bean plant. The base sebacic acid will contain some impurities and can vary in quality.

Nylon 66 and 612 are synthesized polymers made from 100% petrochemical derivatives, so the quality is carefully controlled to ensure consistent quality. This is another reason why nylon 612 has been chosen as the base polymer for Tynex® A filaments.

Lower Density Reduces Cost

Because brush products are typically filled by volume, the weight (density or specific gravity) of the filaments is a cost consideration. *Table 3* shows that nylon 612 is the lightest polymer considered: about 2% lighter than type 610 nylon, the next lightest polymer. The specific gravity or bulk density of the filament will directly affect the weight of the material in the brush. If filament pricing is equal, a filament with lower bulk density will result in a lower brush cost.

Table 3. Specific Gravity Comparison

	Specific Gravity
Nylon 6	1.13
Nylon 66	1.14
Nylon 610	1.09
Nylon 612	1.07

Best Choice

The above points demonstrate that Nylon 612 is the best polymer available for Tynex® A filaments. Tynex® A filaments will be stiffer (more aggressive) over a wider range of conditions than other filaments.

Grit

Abrasive monofilaments generally contain 20% to 40% abrasive grit by weight. Most abrasive grit is synthetic mineral that is produced in an electric furnace operation, reduced in size by crushing, then sorted through mesh screens of various sizes.

The grit used for abrasive filaments is cube-shaped (*see Figure 3*), so the cutting effectiveness of the filaments is not affected by the random orientation of the grit. The grit number refers to a specific size: finer grits are assigned higher numbers. *Table 4* shows the variety of abrasive filament sizes and grit combinations that are available in Tynex® A. Grit sizes normally used in abrasive filaments range from large 36 grit to very small 600 grit. Tynex® A is available with silicon carbide, aluminum oxide and ceramic grits.

Figure 3. Magnified View of Abrasive Grit Particles

Table 4. Typical Nylon Abrasive Monofilaments

Filament Size			
Product Code Designation	Actual Metric Caliper (mm)	Grit size	Load, %
12-mil	0.307	600	20
18-mil	0.483	500	30
21-mil	0.559	500	30
22-mil	0.612	120, 240, 320	30
28-mil	0.711	120	30
29-mil	0.736	240	30
30-mil	0.914	240	30
35-mil	1.029	180	30
40-mil	1.13	80, 120	30-40
45-mil	1.219	60	30
50-mil	1.397	80	30-40
60-mil	1.651	46	30
70-mil	1.854	36	25
86-mil	2.183	36	30

The mineral used is normally selected based on cost, hardness, toughness, and the task to be performed. Most abrasive filament brush tools are made from filaments loaded with silicon carbide grit. Silicon carbide grit provides the best combination of hardness, sharpness, and toughness available.

Table 5 shows the relative hardness of various materials that could be used as abrasive grits. Abrasive filaments containing aluminum oxide are also available. Aluminum oxide grit is tougher and less likely to fracture than silicon carbide. It is used generally for finishing softer metals. Ceramic grit fractures easily to create sharp edges. It is the most aggressive grit of the three.

Table 5. Hardness Ratings

Material	Modified Mohs Scale	Knoop Scale
Gypsum	2	32
Garnet	10	1360
Fused Alumina (Ceramic Aluminum Oxide)	12	2100
Silicon Carbide	13	2480
Boron Carbide	14	2750
Diamond	15	7000

Filaments with other grits have been considered. But the cost of filaments with harder grits like boron carbide and diamond would be much more expensive than filament made with silicon carbide due to the higher grit cost and damage hard grits may do to the extrusion equipment. For more precise surface finishes, DuPont has developed milder abrasive filaments with smaller diameters and with smaller grit particles.

The actual number of grit particles in a unit volume can be estimated, but the key factor is the number of cutting surfaces on the edge of the filament. A smaller grit can provide considerably more cutting surfaces for the same composition and configuration. The surface finish will also be smoother with a small grit because the depth of cut will be less.

Most silicon carbide grit is made under controlled conditions with specific quality requirements. There is less than 0.1% iron oxide and no free iron in the grit, according to the suppliers. Brush tools made with silicon carbide-loaded filaments can be safely used on aluminum parts without risk of causing corrosion from iron contamination.

In brush tools, the difference in metal removal rates between tools made with filaments containing silicon carbide versus aluminum oxide grit is not clear (diameter and grit size being the same). Some tests of short duration have shown that filaments with aluminum oxide grit are very effective even on steel parts. But generally, silicon carbide grit filament is used because it is harder and is thought to be more durable.

ENVIRONMENTAL FACTORS THAT AFFECT FILAMENT PERFORMANCE

Environmental factors such as humidity and temperature can have a significant effect on filament performance. Many of these are discussed in the DuPont bulletin "Filament Performance in Brushes." The most important are addressed here.

Temperature

All filaments are less stiff at elevated temperatures than they are at room temperature. *Figure 4* shows the typical effect of temperature. Nylon filaments are about twice as stiff

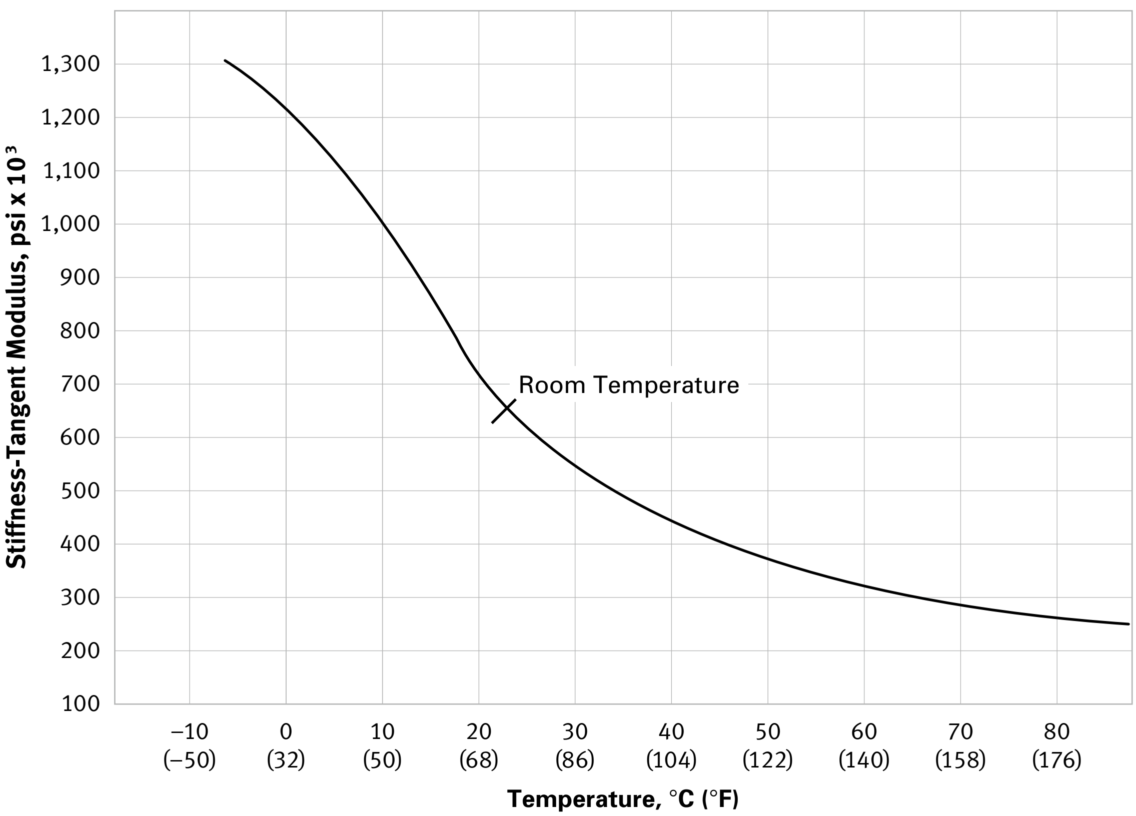


Figure 4. Stiffness versus Temperature for Nylon Filament (Humidity Controlled)

at 0°C (32°F) as they are at room temperature. The change in stiffness is much less above room temperature than it is below room temperature. It should be pointed out that even though nylon filaments become stiff at low temperatures, they do not become brittle. In abrasive filament brushes, temperature effects can be minimized by controlling brush speed and pressure, by using water or oil coolants, and by using abrasive filaments made with nylons that are more stable at higher temperatures. Chemical additives, used with most abrasive nylon filaments, help to retard thermal degradation, but they do not affect the melt point.

Moisture

All filaments are affected to some extent by moisture. *Figure 5* shows in graph form the information in *Table 2*—the effect of moisture on modulus for nylon filaments including Tynex® A. As can be seen from *Figure 5*, test results show that 66 nylon is stiffer than Tynex® when dry, but Tynex® is stiffer when wet. This is caused by the lower moisture absorption of Tynex®, which absorbs only 3% moisture when saturated. At about 60% relative humidity, the modulus of Tynex® and 66 nylon are equal. Type 6 nylon becomes very limp when wet and does not make a good brush-filling material.

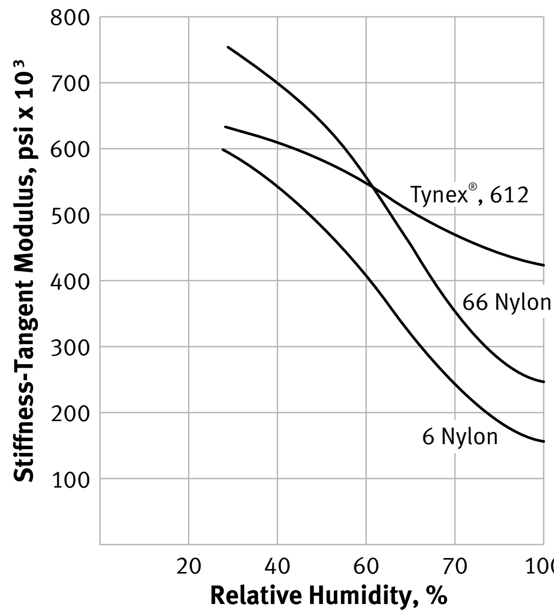
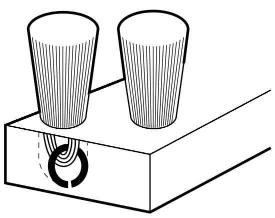


Figure 5. Stiffness versus Relative Humidity: Nylon Filament at 23°C

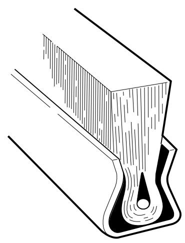
BRUSH CONSTRUCTIONS

There are many ways to produce industrial brushes, and all of the methods described below have been used. Although DuPont does not make brushes, we often consult with brushmakers and the following methods come from these consultations.



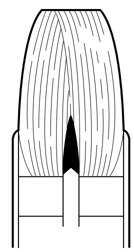
Staple Set

Staple set construction is commonly used for rotary (disk) brushes and cylindrical brushes. Typical uses include the floor care, vegetable and fruit industries, and some industrial brushes. This construction allows for excellent filament flexibility in the brush, but tuft retention can be a problem.



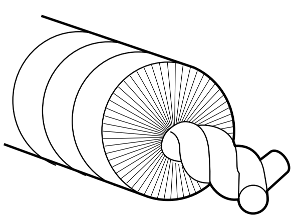
Metal Strip

Metal strip construction is typically found in cylindrical brushes, either wound around a brush core or inserted into extruded aluminum hubs in a straight line lengthwise along the shaft. Typical uses are finishing and cleaning flat metal sheets such as printed circuit boards or aluminum and steel coil. Long trim length brushes are also made in this style. This is a very durable construction.



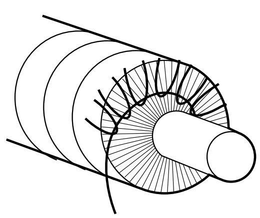
Epoxy Set

Epoxy set construction is found in both rotary (disk) and cylindrical brushes. This method is growing as new techniques are developed. The end uses for this construction include deburring, floor care, and flat metal sheet finishing. This construction also allows for excellent filament flexibility. Aggressive brushes with high filament density are possible.



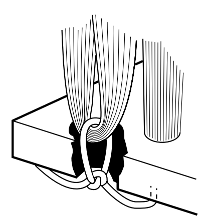
Twisted-in-Wire

Twisted-in-wire construction is almost always used in a power brush application for metal finishing of holes in objects. This construction holds the densely packed filaments very tightly so brushes can be used in very aggressive applications. Filament length can vary from very short to very long.



Wound

Wound construction is typically used in cylindrical brushes wrapped on a core. The filaments can be wound with rope or wire. The most common application for this brush is for cleaning printed circuit boards. This style is not used in very aggressive applications because the filaments are not held as tightly on the brush core as other styles.



Wire Drawn

This is an old method that is still used in some areas around the world. It is simple, does not require sophisticated equipment, and can be set up quickly. Generally, the brushes are flat but can be disk-shaped for use with floor machines or in finishing applications.

APPLICATIONS

The applications for brushes made with Tynex® A are broad and growing. The applications (*Table 6*) range from aggressive scrubbing of steel coil to wood finishing. The benefits (*Table 7*) of using abrasive filament brushes versus other methods (*Table 8*) usually makes the decision to adopt this product very easy. For example, from a total cost standpoint, long brush life and the flexible abrasive filaments result in a product for aggressive cleaning of steel coil that reduces downtime and increases productivity. Also, longer brush life and faster machine movement provide dramatic savings for floor care applications.

Descriptions of several common applications follow. However, many applications require some development trials in order to achieve the precise result desired. This is best done with an industrial or floor care brushmaker. Although DuPont does not make brushes, we often consult with brushmakers and users to suggest which Tynex® A product may work best.

Cost savings vary from application to application depending on what finishing method was being used prior to switching to an abrasive brush. Deburring and finishing metal parts using a machine mounted abrasive brush can result in significant labor savings when compared to using a hand file or angle grinder. Many operations will have parts fed by conveyors or presented to the abrasive brush by robotic systems without the need for an operator. In addition, more accurate positioning of the part results in more consistent finishes from part to part.

Floor Care

Floor care brushes made with abrasive filaments are the most cost-effective product for stripping floors and aggressive scrubbing procedures when compared to floor cleaning with pads and abrasive pastes. Abrasive brushes can last for many

Table 6. Applications of Brushes Made with Tynex® A

Common	Specialized
Floor Care	Aesthetic Finishes
Coil Coating	Ceramic Greenware
Steel/Aluminum Mills	Plastic Surface Roughing
Automotive Parts	Car Wash Tire Scrub
Aircraft Parts	
Wood Finishing	

Table 7. Benefits of Using Brushes with Tynex® A

Long Brush Life vs. Other Methods
- Durable Tynex® A filaments
- Flexible filaments conform to irregular surfaces
- Obstructions do not tear brushes apart

Increase Productivity
- Reusable brushes are easy to clean
- Fewer shutdowns to replace abrasive wheels/brushes
- Brushes do not “load up” with residue
- Long-term and consistent abrasiveness

Consistent Quality Finishes with Fewer Rejects

Cleaner and Safer Process than Some Other Methods

Table 8. Competing Methods

Power Grinding Wheels
Metal Wire Brushes
Cloth Wheels and Abrasive Slurries
Nonabrasive Filaments
Abrasive Slurries
Nonwoven Pads
Abrasive Paper/Cloth
Molded Abrasive Wheels and Disks

months while pads and pastes often must be replaced daily. Brushes made with abrasive filaments require less storage, can minimize equipment cleanup, and help reduce inventory cost and inventory supply maintenance.

A key advantage of brushes over pads is the forgiveness of the filaments when they strike an obstacle or uneven floor surface. A brush will glide over obstacles that can severely damage a pad.

Brushes can be designed for most floor care needs, although most are used in the more aggressive applications, such as stripping floors for new surface treatment and aggressive scrubbing. Brushes made with smaller abrasive filaments mixed with tampico, a natural fiber, are sometimes used for polishing. The Tynex® A filaments used in floor care brushes are shown in *Table 9*.

Table 9. Floor Care Data

	Filament		
Application	**mil**	**mm**	**grit**
Stripping	60	1.5	46
Stripping and Aggressive Scrubbing	50	1.3	80
Scrubbing	45	1.1	60
	40	1.0	120
	30	0.9	180
Cleaning/Buffing	22	0.5	320
	18	0.4	500

Brush Design

Two basic brush designs are used for floor care brushes: disk and cylinder. Both usually are made by tufting the filaments into a plastic block or core. The disk style is frequently used in floor machines for commercial or institutional buildings. The cylinder style is more common in machines designed for industrial cleaning.

A newer brush construction for floor care involves mounting the abrasive filaments in a flexible base. On the side of the base opposite the filaments is one-half of a hook-and-loop fastener. The other half of the fastener is on the machine so the brush can be "peeled" off of the machine for quick removal and replacement.

Application

Floor care applications usually involve wet cleaning solutions at room temperatures. Tynex® A filaments are well suited for this environment. The nylon 612 base material resists moisture and retains the filament stiffness and aggressiveness better than other nylons.

Benefits of Brushes with Tynex® A

- Brushes have long lives
- Residue doesn't accumulate
- Filaments/brushes adapt to uneven surfaces
- Brushes do not tear on obstructions
- Brushes can be used on any surface: wood, stone, brick

Industrial

The industrial category covers everything except floor care and retail consumer brushes. There are many applications. Descriptions of several major ones follow.

Coil Coating and Flat Sheet Metal Finishing

Coil coating plants receive cold-rolled steel from mills around the world. The steel sheet must be scrubbed free of oils and corrosion so final coatings may be applied. Thorough cleaning is critical to the quality of the finished coating.

Brushes made with Tynex® A have been used to clean steel sheet for over 30 years, and Tynex® A is specified by many processors. The results can be impressive and justify initial product cost. Benefits include the following:

- Improvement in metal coil surface cleaning, finish, and paint adhesion.
- Coating rejects are significantly reduced.
- Brushes made with filaments of Tynex® A last longer than nonwoven pads.

Equipment shutdown costs at high-productivity mills can be expensive, so reducing downtime and improving quality are tremendous benefits.

Brush designs such as the one shown in *Figure 6* will vary depending on the surface finish required. *Table 10* gives a summary of the types of filaments most commonly used.

Cylinder brushes similar to those used in coil coating can also be used to finish and deburr flat steel sheet in which cutouts have been made. The flexible filaments contour to the shape of the cutout to remove the rough edges. No machine adjustments are needed.

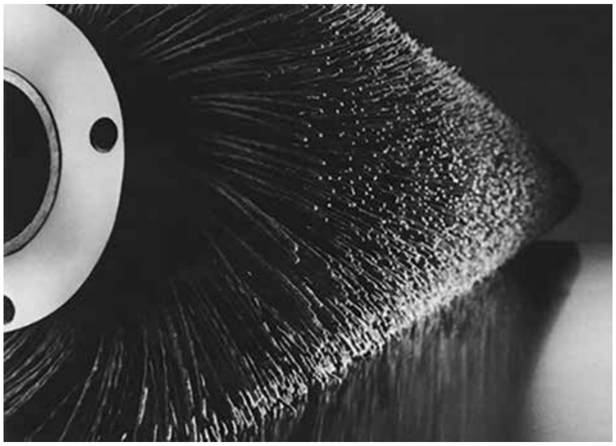


Figure 6. Wide-Faced Cylinder Brush Cleaning Steel Coil Prior to Coating Operation

Table 10. Sheet Metal Finishing

Environment	Hot, up to 85°C (185°F) Caustic chemicals	
	Diameter, mil (mm)	Grit Size
Cleaning	40 (1.02)	80
	40 (1.02)	120
	35 (0.89)	180
Finishing	30 (0.76)	240
	22 (0.56)	120
Filament in Brush Silicon carbide grit Crimp Short trim 30% grit loading Cylinder style Strip construction		

Parts Finishing

The category of parts finishing covers a very broad area of physical dimensions, from parts as small as carbide tool inserts that are clamped in place to milled aircraft parts as long as 40 ft (12 m). The variety of brush tools can be equally diverse, but generally fall into two brush styles—short trim and long trim. Typical filaments used in these brushes are shown in *Table 11*.

Table 11. Parts Finishing

Environment	Both Wet and Dry Machining Oil Cleaning Solutions Room Temperature	
Diameter, mil (mm)	Grit Size	Grit Load, %
22 (0.56)	120	30
30 (0.76)	240	30
35 (0.89)	180	30
40 (1.02)	120	30 and 40
Filament in Brush Usually silicon carbide Crimp Short and long trim		

Short-trim brushes were the conventional style when Tynex® A was introduced (*see Figure 7*). Tynex® A was seen as a substitute for wire in basic short-trim brush construction. In this brush, the tips do the work, so the brush wears down gradually from the tips, exposing new grit as it is used. Short-trim brushes usually operate at speeds common for wire brushes. In dry applications, excessive heat can cause the polymer to soften. Lubricants or sprays are sometimes used to minimize this risk.

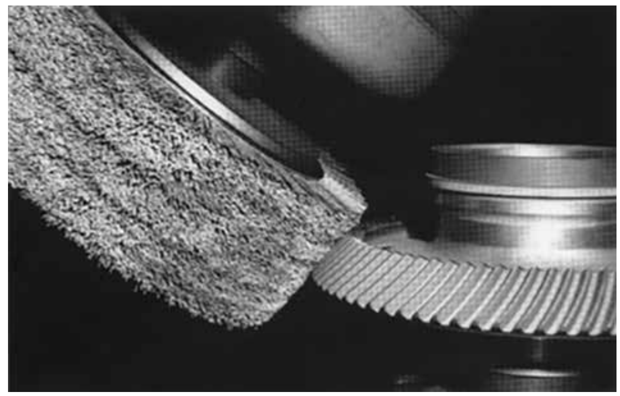


Figure 7. A Short-Trim Brush Is Used to Deburr and Finish a Gear

In the early 1980s, the value of long-string deburring was demonstrated by process developments in the aircraft industry. Because Tynex® A filaments are abrasive on the sides as well as the tips, brushes were designed that used the edges of the filaments to do the work by dragging the filament across the part (*see Figure 8*).

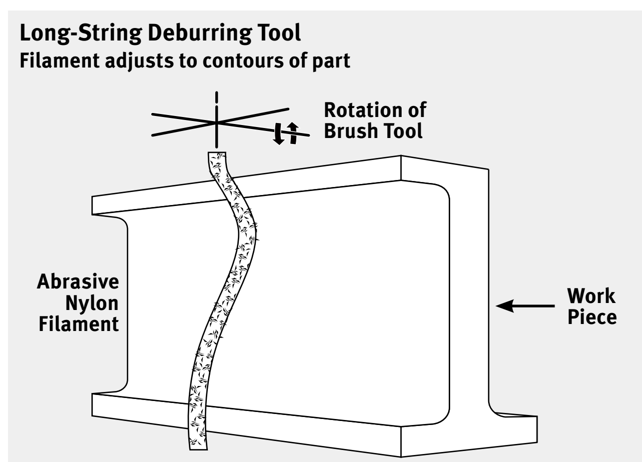


Figure 8. Long Abrasive Filaments Deburr as They Drag Across the Part

These brushes usually run at slow speeds and in dry environments. Brush speeds are adjusted to take advantage of the filament stiffness. Robots as shown in *Figure 9* are frequently used with this style brush.

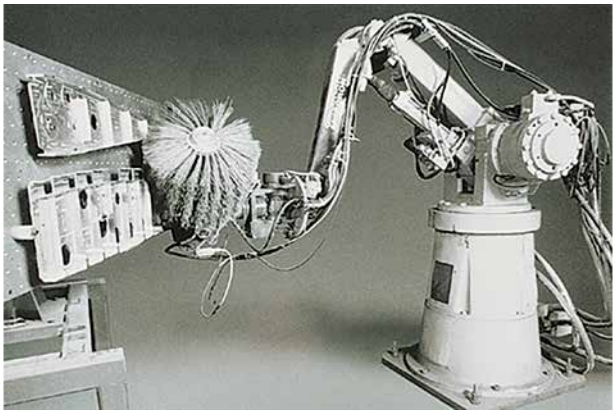


Figure 9. Robotic Deburring Application with a Long-String Brush

Wood Finishing

There are several applications for abrasive filament brushes in the fabrication of wood into paneling, doors, furniture, and flooring. This is one of the older applications for Tynex® A filaments, and it continues to grow as automation enters this industry.

Structuring

This requires a stiff, aggressive brush to remove the softer wood grain and leave the harder grain. A brush with flexible abrasive filaments performs this function well. Sometimes this process is completed by following the rough structuring brush with a finishing brush containing finer abrasive filaments.

Denipping

Sometimes called primer sanding, this technique uses an abrasive filament brush to remove the wood grains or fibers that are raised when the wood finish primer dries.

Finishing

Abrasive filament brushes work particularly well on irregularly shaped cabinet and house doors. The finishes are much more consistent and faster than can be obtained by manual sanding.

The types of filaments used are shown in *Table 12*.

Table 12. Wood Treatments

Environment	Dry Room Temperature	
Process	**Diameter, mil (mm)**	**Grit Size**
Structuring	60 (1.52)	46
	50 (1.27)	80
	45 (1.14)	60
Denipping	40 (1.02)	120
	35 (0.89)	180
Finishing	30 (0.76)	240
	22 (0.56)	120, 240
Filament in Brush Silicon carbide Crimp Short and long trim		

DESIGNING EFFECTIVE BRUSHES/ TOOLS

There are several filament properties that can be modified to aid in properly designing or improving brushes for a specific use. For example, a brush tool for radiusing or deburring an irregularly shaped part will differ significantly from a tool for scrubbing flat metal sheet. The filament characteristics that most easily can be modified are:

Diameter	Grit Loading
Length	Crimp
Grit Size	Filament Combination

Diameter and Length

A key fact to remember is that when groups, bundles, or tufts of filaments are combined in a brush, the brush tool stiffness varies with the square of the filament diameter. (Note: For unsupported single filaments, the relationship is that stiffness varies with the fourth power of the diameter.) Therefore, brush tool aggressiveness can be changed significantly by an apparently small change in filament diameter.

It should be obvious that stiffness also varies inversely with the length of a filament. As the brush trim is lengthened, the filament becomes more flexible. Theoretically, brushes of equivalent stiffness can be made from filaments of different diameters by varying the length. The total effect, however, is not likely to be the same because grit variables and filament density in the tool also affect performance. A very aggressive brush can be made with what appears to be a small-diameter, limp filament. Brushes used to deburr flat sheet material contain 18- or 22-mil (0.46- or 0.56-mm) diameter filaments, but with effective filament lengths of less than 0.75 in (19 mm). This design offers a densely packed, aggressive brush.

Grit Size and Grit Loading

Grit sizes and loadings (weight percent of grit in the filament) have become more important in brush design as people have recognized the effectiveness of using the sides of the filaments as well as the tips. During the 1980s, designs of long-string (long filament trim length) deburring tools became popular. Prior to this time, abrasive filaments were treated like wire and other nonabrasive filaments. Large filaments with large grits were selected for demanding jobs and small filaments with finer grits for lighter work.

Now, the numerous grit options offer more choices. *Figure 10* shows two filaments with different grits and grit loadings. The filament on the right contains 30% by weight of a large 46 mesh grit. It is easy to see the grit and the open space between particles.

These filaments are fine for aggressive scrubbing, but are not the best selection for deburring edges or surface finishing. In many cases, it is important to get as much abrasive in touch with the edge or surface as possible. A smaller, more flexible filament with more grit on the surface can do a better job, like the one on the left in *Figure 10*. Increasing the grit loading to 40% by weight can add to the aggressiveness. Smaller filaments will also last longer.

The long-string brush tool is particularly effective in deburring parts. With filaments 8 to 9 inches long, the tool uses the grit on the edge of the filament, not just that on the tip. The filament can wrap around the edge of the part, deburring cutouts as well as external edges.

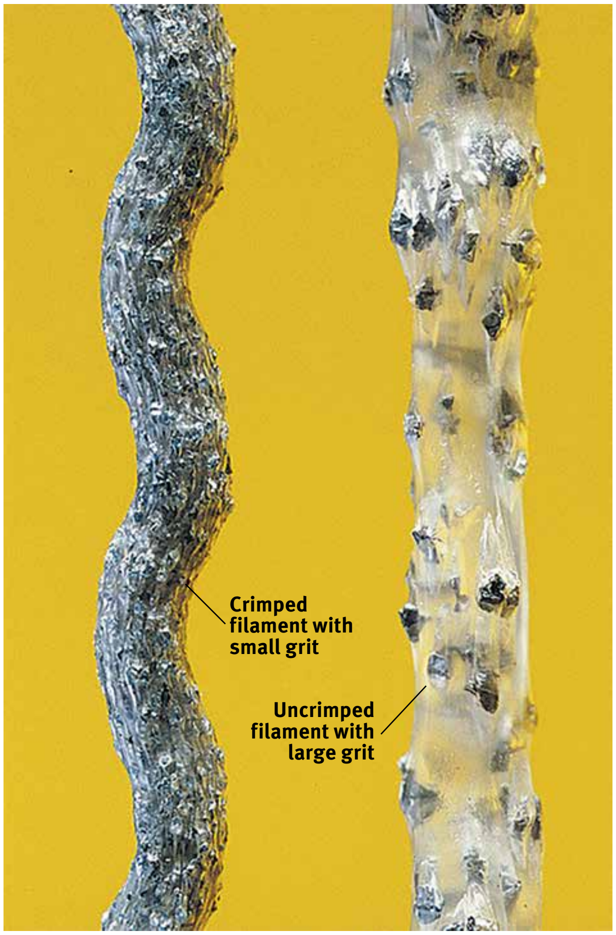


Figure 10. Crimped Filament with Small Grit versus Uncrimped (Straight) Filament with Large Grit

Crimp

Figure 10 also shows the difference between a crimped and uncrimped filament. Brush tools are normally made with crimped filaments. The crimp is the cyclical wave imparted to the filament during production. In a tool, the crimp keeps the filaments separated and generally offers a consistent bushy appearance to the tool. In long-string brushes, the crimp offers an irregular surface that makes the deburring tool more aggressive. However, uncrimped filaments are used when a very aggressive tool is needed. These tools normally are made with short trim lengths and the filaments are densely packed into the tool.

Combining Filaments

Occasionally it is possible to mix abrasive filaments with other types of filaments to get a special effect. For example, fiberglass plus Tynex® A makes a very aggressive brush for cleaning residue from newly rolled steel sheet. At the other extreme, natural tampico fiber can be mixed with 18-mil Tynex® A to make a softer floor brush for buffing.

Summary

The effectiveness of Tynex® A brushes can be changed significantly by changing the filament. The following points have been demonstrated by using different filaments in the same tool and using the tool on similar parts.

- A smaller-diameter filament in the brush tool is often more effective. The filament can adjust to the contour of the part more easily, and more surface area can be exposed to the part. For example, the difference between using a 50-mil and 40-mil filament is 25% in the amount of abrasive filament surface area that can contact the part, given that the tool contains the same volume of filament. A filament that is too large may hit and bounce off the part.
- Filaments with a small grit size can be more effective since there will be more cutting edges on the surface. Using 120 grit versus 80 grit in the same size filament offers about 50% more grit particles on the surface of the filament.
- Increasing the grit loadings from 30%, which was standard for years, to 40% increases grit particles by one-third, offering another level in aggressiveness. Increasing beyond 40% loading is not practical because the filament durability is noticeably reduced.

These variations do not include any changes that can be made in the way that the tool is used, such as tool speed, tool location, part position, or angle of contact.

BRUSH WEAR

Brushes and brush tools eventually wear out. As brush tools wear down, the performance characteristics will change. Adjustments to equipment can be made to maintain performance.

Short-trim brushes wear from the tip. As the filament length shortens, the brush tool will become more aggressive because the filament will be shorter and stiffer. The original filament deflection, usually 1⁄8 inch with proper pressure setting, cannot be maintained without increasing pressure. The greater pressure increases the stress on the filament at the flex point, which is usually where the filament joins the tool base. This added stress eventually can cause the filaments to break.

Brushes with longer filament trim length normally wear out for a different reason. The normal wear pattern for a long-trim brush is a gradual taper of the filament as the nylon and grit wear down. Eventually the filament diameter is reduced, and the tips begin to break off. Of course, the stiffness is reduced as the diameter changes. In continuous operations, these tools are changed regularly to maintain a consistent finish.

Although flex fatigue can occur, brush construction methods have been developed to support the filaments better at the flex point. Filament fatigue, if it occurs, normally results from placing the part too close to the tool core, causing excessive filament flexing. Circulating coolant at the flex point will minimize heat generation and filament fatigue.

MANAGING PROCESS EFFICIENCY

Brush tool performance is a result of many factors; filament selection is just one. Environmental factors such as humidity and temperature, and operating factors such as tool condition, workplace cleanliness, and equipment methods can have a significant effect. A few of these are reviewed below.

Filament and brush stiffness drops as temperature rises (*see Figure 4*). As described earlier, nylon filaments are twice as stiff at 0°C (32°F) as they are at 24°C (75°F). Stiffness drops another 50% at 60°C (140°F). Deburring or finishing metal parts with a brush tool will result in some heat buildup from friction at the point of contact. So the tool's aggressiveness can be affected if the temperature increases significantly.

Heat generation is normally not a problem in long-string deburring where brush tool speeds are slow. However, in short-trim power brushes, the combination of tool pressure on the part plus high speed in a dry environment can generate high temperatures at the brush tips. Cooling liquids are often used to counteract this problem.

Break-In Period

Another point to consider is the time required for the brush tool to reach an equilibrium condition. A new brush may seem very aggressive. Several characteristics contribute to this initial aggressiveness.

First, all of the grit on the filament is new and sharp. As it begins to wear, new sharp grit will blend with the older grit. Another part of the initial aggressiveness can be attributed to the filaments' basic dryness relative to the operating environment. As the filaments absorb moisture either from natural humidity or workplace liquids, the apparent aggressiveness (cutting rate) will drop, then level off as shown in *Figure 11*.

The time required for the brush tool to reach equilibrium performance will vary, but could take from several minutes to several hours.

Brush tools taken out of service, cleaned, and set aside will again require time to become conditioned when placed back on the machine. Of course this period can be minimized if the tool is placed in a closed container when not in use so the filament does not dry out completely.

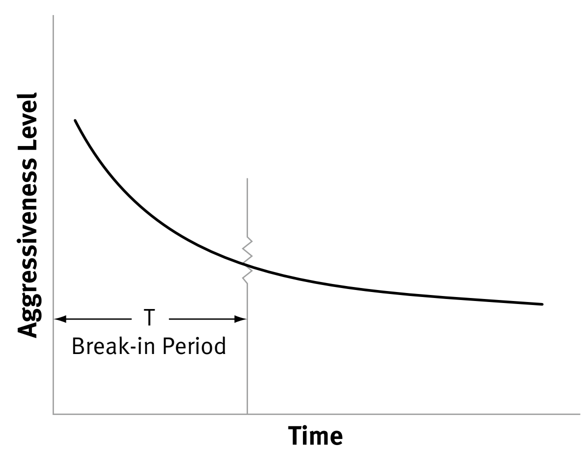


Figure 11. Brush Tool Aggressiveness versus Time

Equipment Operation

Before incorporating a brush tool, the entire operating system should be analyzed to determine what controls are available and how they are to be monitored. Good operating and quality control procedures are very important to satisfactory long-term performance. Many situations can occur that will affect performance.

Increasing brush speed or pressure should be one of the last corrections, not the first.

Product Advances

Over the past few years, the Tynex® A product line has increased to include mild abrasive filaments, rectangular filaments, and more aggressive filaments with heavier grit loadings. Specialty filaments modified to deliver improved resistance to harsh chemicals are one example.

New brush designs made with Tynex® A are continuously changing to meet the needs of industry. DuPont Filaments will continue our efforts to improve Tynex® A abrasive filaments.

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