The Influence of the Expansion Process on Pore Size

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Abstract:

The Influence of the Expansion Process on Pore Size

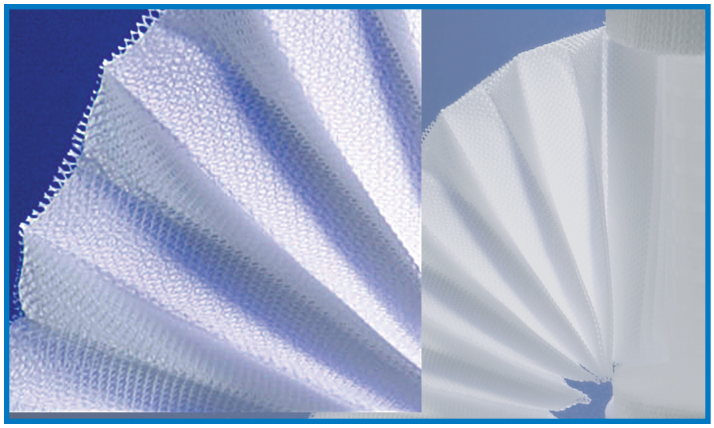
PolyGrid™ precision-expanded plastics from Dexmet are used in filtration applications requiring membrane support, purification and separation. Designing a precision expanded plastic material with unique characteristics such as pore size, resin type and thickness are critical factors in selecting filter media. Dexmet's proprietary expand process is capable of expanding all fluoroplastics, polyamides, polyesters and many other types of high temperature resins in film thickness of .001" - .090"; with pore sizes extending to 25 microns.

An introduction to Dexmet's expand process, clean room capabilities and product range will be presented along with test and measurement data encompassing two types of resins materials. A capillary flow test method will be used to determine how the pore size is affected when the short way of the opening (SWO) and film thickness is decreased by a constant value using identical tooling.

1. Introduction

Expanded Metal has been a part of the manufacturing environment for over 100 years. From what is known; the process was originated in Europe for a wide variety of commercial and industrial security applications such as storefront protectors, stairway and warehouse enclosures, safety guards, furniture etc. Dexmet Corporation (formally Exmet and Delker Corporation) originated in 1948 manufacturing these large mesh designs primarily for the satellite, safety guard, grilles and resistor/load bank industries. In 1951, Dexmet introduced MicroGrid®/ Fine Mesh globally for the first time to meet the growing needs of many battery technologies.

During this period, many other applications evolved as the demand for fine mesh increased, particularly in shielding (consumer and military applications), filtration



(industrial air and liquid), lightning strike protection for composite aircraft and wind turbines and automotive (acoustic protection, bearings, vents, filtration) among others.

This paper will provide an overview of the expansion process, developing a configuration for a specific requirement and review two test methods to determine how the pore size is affected when the strand width and film thickness is decreased by a constant percentage using identical tooling.

2. Fine Mesh Expansion Process

MicroGrid®, Micro Mesh, Fine Mesh and PolyGrid™ are all terms used to describe a unique material that is produced using thin foils and polymer films. The expand process which begins with a solid foil or film, in thicknesses of 0.010" (.254 mm) or below, simultaneously slits and stretches the raw material using precision shaped tools which determine the form and the number of openings per square inch. The shaped openings are uniform in size and regularity, and typically range from 0.020" (.508 mm) to 0.500" (12.70 mm).

In figure 1, coiled material (or sheet) is mechanically advanced beyond the face of a lower die in an amount equal to the strand width. An upper cutting die, then descends and forms an entire row of half diamonds. The upper die then ascends and moves over one half diamond (stroke) to the right while the base material moves forward (based on the strand width dimension). The upper die descends, slits and forms another full row of half diamonds completing a row of full diamonds in two strokes. The die ascends and returns to the original position and the process begins again until the coil or sheet has been fully expanded (Expanded Metal Manufacturers Association, EMMA).

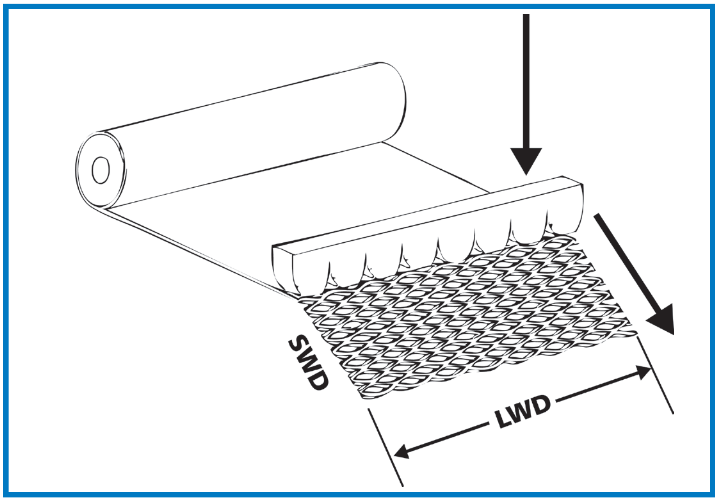


Figure. 1

3. Application Considerations

Expanded MicroGrid® and PolyGrid™ are engineered materials that come in contact with every major industry. Design engineering takes advantage of metal and film properties and tool design to yield a product best suited for a particular application. Common variables for defining a configuration are as follows:

- Material Type and Gauge Thickness
- Expanded Pattern
- Strand Width, Unit of Weight, Pore Size, Percent Open Area
- Overall (Final) Thickness
- Coil or Piece Size

Because of the infinite number of variability in the expand process, the Engineer or user must know the critical parameters that are required for each application. For example, material consideration is key with regards to mechanical factors such as fatigue, tensile, compressive strengths, hardness, thermal expansion and dimensional stability. With regards to chemical characteristics of plastics, there is no general rule for chemical resistance. Plastics must be tested in the chemical environment of their actual use. Fluorocarbons, chlorinated polyethers and polyolefins are among the most chemical-resistant materials (Richardson & Lokensgard). Metals such as Stainless Steel (300 series), are used in a variety of corrosive atmospheres. Nickel, Copper, and Silver are used in many types of small battery grids or EMI/RFI shielding applications. Other materials such as Titanium, Platinum and Zirconium may be expanded for special electrochemical and fuel cell applications (EMMA). (See Figure 2 for list of ductile expandable raw materials)

The expanded pattern or LWD dimension usually follows the material selection. The strength and rigidity of expanded material is determined by the Long Way of the Diamond. However, if other critical parameters are presented for a specific application, such as percent open area, pore size, final thickness or unit area of weight, both the LWD and SWD are evaluated together, along with the Strand Width. Finally, how the product will be supplied in either coil or piece form is reviewed. In some instances, the expand process is limited by raw material availability and other options are suggested.

Figure. 2

List of Ductile Raw Materials	
Typical Metals	**Plastics / Films**
Aluminum	Polypropylene
Copper	Polyethylene
Stainless Steel	Mylar
Nickel	PEEK
Silver	Nylon
Titanium	PTFE
Zirconium	Tefzel
Niobium	PFA
Kanthal	FEP

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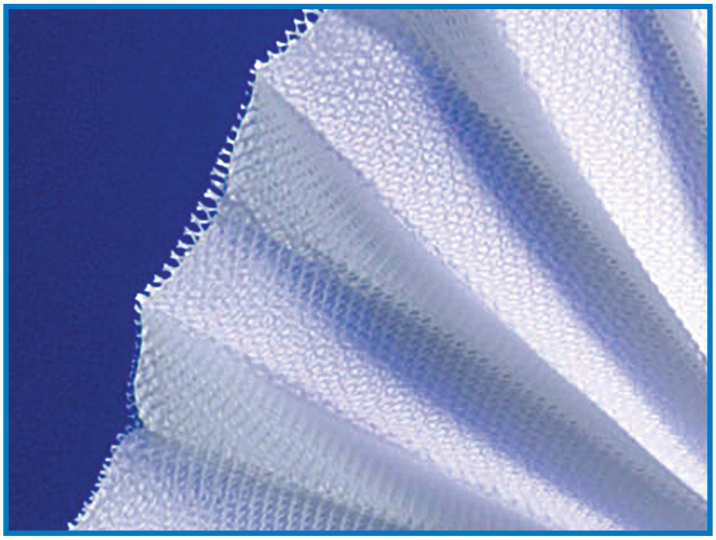
List of Ductile Raw Materials	
Typical Metals	**Plastics / Films**
Low Carbon Steel	PVDF
Zinc	ETFE
Brass	PVC
Gold	CPET
Inconel	Polysulfone
Phosphor Bronze	Polyesters
Etc.	Etc.



4. Defining a Configuration

Each application is unique in itself. Critical parameters or suggested requirements for specific applications are reviewed by the Engineering Department at Dexmet and thus the configuration(s) are originated for the application. A list of die configurations and tolerances can be found in Figure 3 below.

Tool Code	LWD (mm)	SWD (mm)		Hole Size (mm)		Opening/SQCM		Open Area		Width (mm)	Raw Thickness (mm)	
		Min	Max	Min	Max	Min	Max	Min	Max		Min	Max
020	0.508	0.013	0.011	0.025	0.178	1162.79	1395.35	32%	75%	203.2	0.025	0.051
031	0.787	0.024	0.018	0.038	0.254	410.85	550.39	32%	82%	304.8	0.025	0.127
040	1.016	0.032	0.022	0.051	0.432	271.32	348.84	24%	85%	304.8	0.038	0.152
050	1.270	0.036	0.024	0.076	0.559	173.64	254.26	21%	89%	609.6	0.038	0.203
060	1.524	0.043	0.030	0.076	0.686	120.93	178.29	20%	90%	609.6	0.038	0.229
075	1.905	0.037	0.030	0.084	0.762	111.63	136.43	15%	90%	965.2	0.038	0.229
077	1.956	0.056	0.033	0.102	0.838	73.64	120.16	15%	90%	914.4	0.051	0.305
080	2.032	0.067	0.037	0.178	1.016	58.14	104.65	16%	90%	1219.2	0.051	0.356
090	2.286	0.056	0.045	0.178	1.143	62.02	77.52	16%	90%	609.6	0.051	0.356
100	2.540	0.077	0.040	0.178	1.168	38.76	73.64	16%	90%	965.2	0.051	0.432
105	2.667	0.077	0.050	0.178	1.219	38.76	54.26	20%	90%	609.6	0.051	0.457
125	3.175	0.111	0.050	0.203	1.321	23.26	50.39	20%	90%	1219.2	0.051	0.635
140	3.556	0.125	0.059	0.254	1.651	17.05	38.76	30%	90%	609.6	0.076	0.762
158	4.001	0.125	0.077	0.279	1.905	15.50	27.91	30%	90%	685.8	0.076	0.762
180	4.572	0.111	0.071	0.279	2.032	15.50	23.26	32%	90%	609.6	0.102	0.762
190	4.826	0.100	0.067	0.508	2.235	12.40	20.16	35%	90%	609.6	0.127	0.762
215	5.461	0.143	0.083	0.508	2.413	10.08	17.05	35%	90%	609.6	0.127	0.762
236	5.994	0.143	0.091	0.635	2.540	9.30	13.95	35%	90%	609.6	0.127	0.762
250	6.350	0.167	0.100	0.686	2.794	7.75	12.40	35%	90%	609.6	0.127	0.762
284	7.214	0.143	0.091	0.762	3.302	6.98	12.40	35%	90%	609.6	0.127	0.762
400	10.160	0.333	0.125	0.889	4.572	2.33	6.20	35%	90%	609.6	0.127	0.762

Figure. 3

The key characteristics of manufacturing an expanded product consist of the following:

Long Way of the Diamond (LWD) - This dimension is built into the tool, and is always parallel to the width of the coil. The LWD is measured from the center of the joint to the center of the adjacent joint. Strength and rigidity of expanded metal/plastic is determined by the LWD. (See Figure 4)

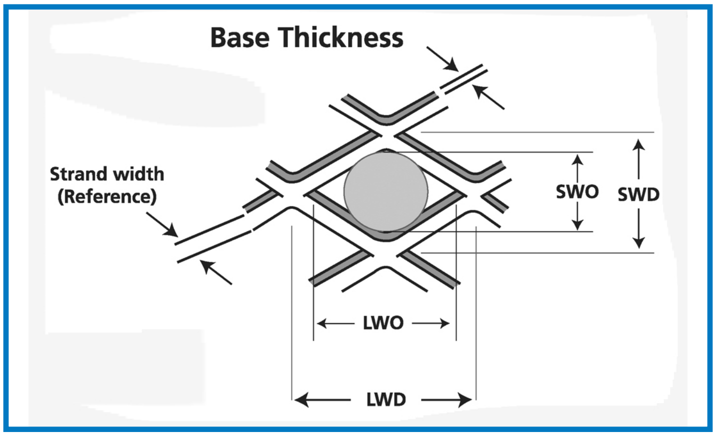


Figure. 4

Short way of the Diamond (SWD) - Short axis of the diamond dimension. This dimension is measured from center to center of the joint and is a reference number only. For each fixed LWD dimension, there is a range of SWD dimensions available (see Figure 4). The SWD will vary with any given die as the degree of expansion is varied. (See Figure 4)

Base (Original) Material Thickness - This is the material thickness before expanding. (See Figure 4)

Strand Width - The amount of metal/plastic slit from the parent raw material in forming each mesh. The strand width is a reference number only. By varying the strand width you will achieve a specified open area, weight and pore size with standard tolerances. (See Figure 4)

Long Way of the Opening (LWO) - A dimension measured from the inside of the Long Way of the Diamond. (See Figure 4)

Short Way of the Opening (SWO) - A dimension measured from the inside of the Short Way of the Diamond, also known as Dexmet's Pore Size Measurement. (See Figure 4)

Raw Material - Any Ductile Metal or Plastic, See Figure 2.

5. Application Parameters

Reviewing what is critical to the application is important in the initial stages of product development. One of the major parameters is percent open area, which controls many aspects of the design.

Percent open area of expanded metal or plastic is a function of the strand width. The strand width is the amount of metal slit from the parent metal/plastic in forming the mesh. By varying the strand width, it will either increase or decrease the open area or pore size. (See Figure 5, on page 5) The strand width is closely controlled and is directly related to the weight and overall thickness as well.

In most aerospace applications, area weight is the most critical aspect of the design (besides the raw material choice) and the configuration must be designed with this in mind.

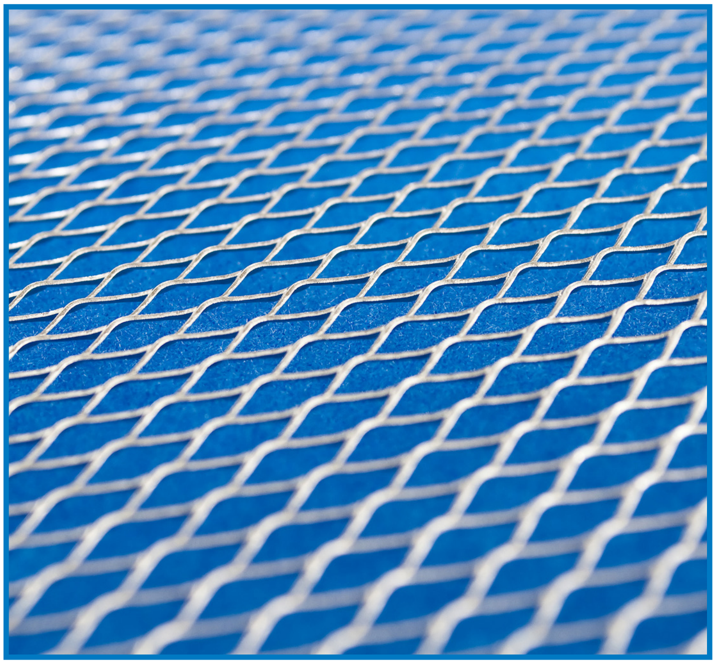


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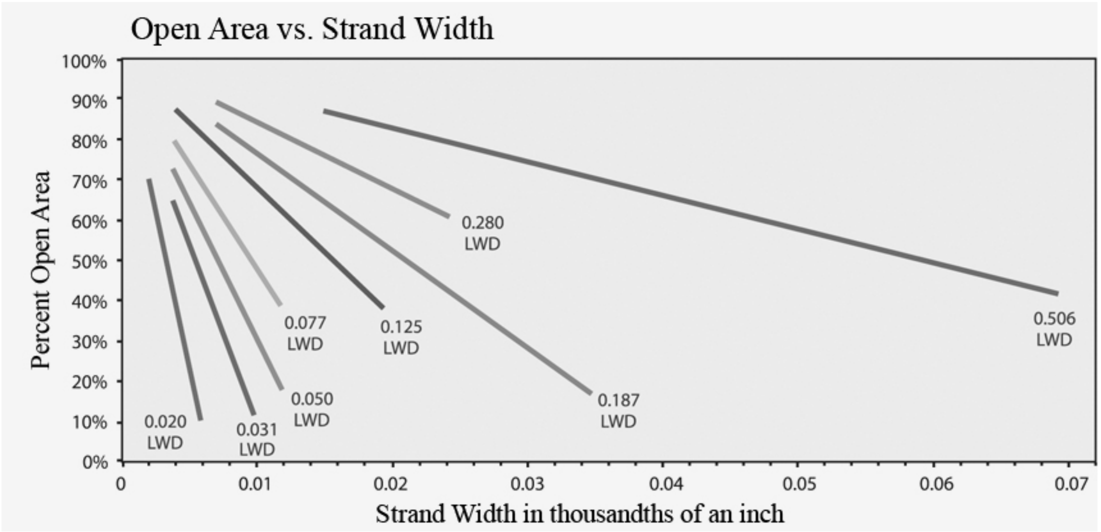
Figure. 5



Overall or final thickness is another critical factor when space/area is limited. After the expand process, the overall material thickness is greater than the original material thickness. Each configuration has a practical range of overall thickness. As a rule, the maximum thickness is 1.6 times the strand width.

The minimum thickness is the original/base material thickness. Secondary operations can level or reduce the material to a specified thickness. Flattening is a process of reducing the material back to the original base thickness and creates a smooth surface. (See Figure 6)

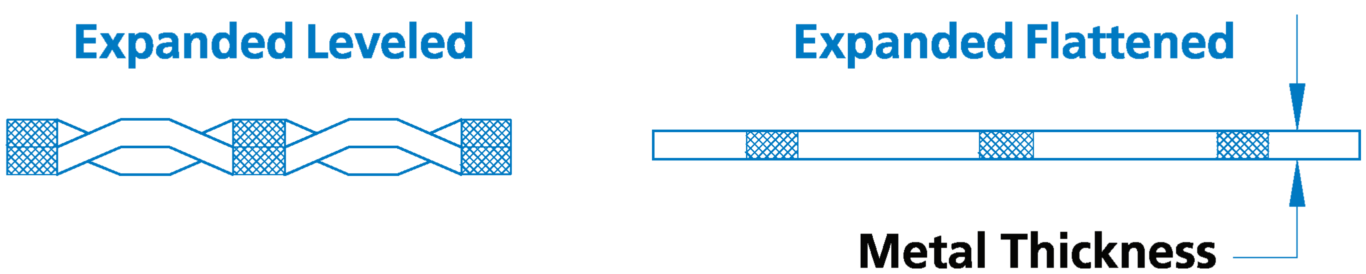


Figure. 6

Annealing or heating treating MicroGrid® enhances the shape and flatness of the material. With the expand process, stresses are introduced to the raw material and can affect shape and formability. By batch annealing or strand annealing, the material becomes very pliable or soft and will lay flat for ease of further manufacturing processes. Annealing is application specific and is not required for every product.

Other considerations that should be reviewed if necessary to a project would be camber, diamond direction in relation to product design, finished edges, and coil width/piece size tolerances. Ultimately, the more information that can be provided at the start of an application, will lead to a better foundation in designing an **expanded product**.

6. PolyGrid Processing

Expanded PolyGrid™/plastic is fairly new to the "Expanded Industry". In processing these various films a controlled environment is required. A Class 10,000 clean room provides such an environment with a maximum particulate rating of ≥ 0.5 µm. PolyGrid requires specifically designed equipment that enables a majority of the plastic films to be easily produced in thicknesses of .001" - .010". Dexmet has developed a proprietary expanded process used for most fluoroplastics, polyesters and high temperature films. Stabilizing these materials holds the configuration within tolerance and maximizes flow characteristics that are important to many filter and industrial applications.

Evaluating the Pore Size

In Figure 4, we relate pore size to the Short Way of the Opening, as this is the limiting dimension that prevents a particle from penetrating the aperture. Stating a tolerance on the pore size is somewhat of a challenge for some PolyGrid materials as compared to the MicroGrid products. The variability in the fluoropolymer films and their reaction to the expand process has created the need for stabilization. Other films such as Polypropylene and Polyethylene are not affected by stabilization (no change in dimension).

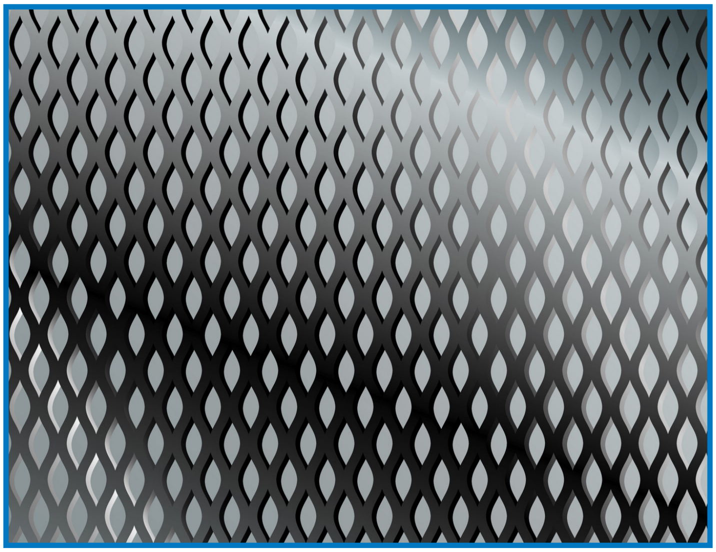
Expanded material is primarily used as a filter support/backing for filter media under 25 microns. Many questions are posed to the fine mesh industry as to what the micron rating is of a particular material or if there is test data available to determine such. In order to understand the filter industries' "micron rating" system as it pertains to expanded plastic, we needed to address the following questions: "If the Short Way of the Opening (SWO) is increased by a constant value, how is the pore size affected and can a micron rating be assigned by a standard industry test method? It was then proposed to gather test data based on resin type, thickness and varied SWO dimensions using a fixed tool, in this case Pattern 031.

Two separate tests were performed using Polytetrafluoroethylene (PTFE) and Polypropylene (PP) raw materials.

Dexmet Pattern 031 (LWD) was selected for the Capillary Flow and Glass Bead tests. (See Figure 7)

Dexmet 031 Pattern		
	PTFE	***Polypropylene***
Dexmet LWD (Pattern):	0.031"	0.031"
Original Material Thickness	0.002"	0.002"
Strand Thickness	0.004"	0.004"
	0.006"	0.006"
	0.008"	0.008"
	PTFE	***Polypropylene***
Dexmet LWD (Pattern):	0.031"	0.031"
Original Material Thickness	0.005"	0.005"
Strand Thickness	0.004"	0.004"
	-	0.006"
	0.008"	0.008"

Figure. 7



Test Analysis of Dexmet PolyGrid Polypropylene (PP) and Polytetrafluoroethylene (PTFE)

In a review of Figure 8, the samples are listed first by resin type, then by SWO Micron rating (largest to smallest pore).

The PTFE samples exhibit the following results (See Figure 8):

Optical Measurement verses Glass Bead Test Result

In averaging both sets of data, the result is a 12.5% variation between the two results.

This gives a mean of 7.8 microns.

Optical Measurement verses Capillary Flow (CFP) Result

In averaging both sets of data, the result is a 12.7% variation between the two results.

This gives a mean of 7.6 microns.

Glass Bead verses Capillary Flow (CFP)

In averaging both sets of data, the result is a 13.1% variation between the two tests.

This gives a mean of 7.8 microns.

The Polypropylene samples exhibit the following results (See Figure 8):

Optical Measurement verses Glass Bead Test Result

In averaging both sets of data, the result is a 15.2% variation between the two results.

This gives a mean of 19 microns.

Optical Measurement verses Capillary Flow (CFP) Result

In averaging both sets of data, the result is a 22.6% variation between the two results.

This gives a mean of 34 microns.

Glass Bead verses Capillary Flow (CFP)

In averaging both sets of data, the result is a 28.4% variation between the two tests.

This gives a mean of 34 microns.

It should be noted that the Polypropylene samples exhibit web/flashing within the pore dimensions which lead to variation in the final test results. The PTFE samples exhibit no web/flash within the pore dimensions. (Mitutoyo Tool Makers Microscope)

CAPILLARY FLOW POROMETRY (CFP) AND GLASS BEAD RESULTS

CFP-1200 AEXC****

Sample (Date)	Material Type*	Dexmet SWO Optical Measurement (µm) **	Glass Bead 98% Cut Point ***	B.Pt. (µm)	B.Pt/τ (µm)	σ	
5PTFE4-031 (5/22/10)	PTFE	163	154	268 257 246	162 155 149	16 8 3	[4]Comments [5]Comments [5]Comments
2PTFE6-031 (5/22/10)	PTFE	140	131	222 204	135 124	6 4	[5]Comments [5]Comments
2PTFE4-031 (5/22/10)	PTFE	135	151	245 217	148 132	13 8	[5]Comments [5]Comments
2PTFE8-031 (5/22/10)	PTFE	76	73	150 146	91 88	6 5	[5]Comments [5]Comments
5PTFE8-031 (5/22/10)	PTFE	62	64	95 95	58 58	3 2	[5]Comments
2PP6-031 (5/22/10)	PP	119	134	233 218	141 132	5 3	[4]Comments [5]Comments
2PP8-031 (5/22/10)	PP	109	140	197 130	119 79	2 2	[4]Comments [5]Comments
5PP6-031 (5/22/10)	PP	109	130	237 219	143 138	15 10	[4]Comments [5]Comments
2PP4-031 (5/22/10)	PP	105	110	214 217	130 132	25 8	[4]Comments [5]Comments
5PP4-031 (5/22/10)	PP	79	107	198 195	120 118	12 4	[4]Comments [5]Comments
5PP8-031 (5/22/10)	PP	56	71	133 123	81 75	7 1	[4]Comments [5]Comments

Special References and Notes for Figure 8

Material Type*	PTFE = Polytetrafluoroethylene PP = Polypropylene
Glass Bead Test***	Gilson Sonic Sifter; 90 mm diameter test piece used in Glass Bead Test
SWO / Optical Measurement**	Dexmet Tool Makers Mitutoyo Microscope (Code #176-808A), SWO measured using test pieces after Glass Bead Test was performed
Capillary Flow (CFP)****	PMI Unit 1200 AEXC, 25 mm diameter test piece used in Bubble Point Test Bubble Point (B.Pt.) = the largest pore size (B.Pt/τ) = tortuosity factor set at 1.65 since material is reasonably tortuous
Comments	4 = Results on 1200AEXC unit with Typar® support underneath sample (new cut samples) 5 = Results on 1200AEXC unit with Typar® support on both sides of sample (new cut samples)

8. Conclusion

In our evaluation of the PTFE test results, Optical, Glass Bead and CFP, all methods are acceptable for measuring the micron rating of expanded PolyGrid mesh regardless of original material thickness. The average variation of all three methods is 12-13% and 7.8 microns.

Instability of Polypropylene expanded mesh complicates micron rating measurement techniques. The Optical measurement average 15% (19 microns) is smaller than the Glass Bead Test. Understanding the Glass Bead test offers less variation, we are able to more accurately predict a realistic micron rating at +15% of the actual optical reading.

The resin film used to produce expanded polypropylene is an extruded product. The properties of this material at expansion produce web/flash that affects the two tests performed in this report. Further testing on this resin is required to determine if other factors are involved.

References

1. Standards For Expanded Metal, "Applications Terminology, Manufacturing Process, Manufacturing Tolerances, Special Meshes", Expanded Metal Manufacturers Association, Chicago, IL (1978).
2. T. Richardson, and E. Lokensgard, "Industrial Plastics, Theory and Application", 340, (1997)

Dexmet CORPORATION

The Influence of the Expansion Process on Pore Size

For more than 60 years Dexmet Corporation has been providing its customers with expanded foils and polymers of exceptional quality. Our experience, just-in-time manufacturing capability, and superior customer service is why our customers keep coming back.

Dexmet corporation is committed to providing our customers with quality products, manufactured to fully meet their requirements, delivered on time. Our goal is to deliver quality customer satisfaction through manufacturing of superior products.

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