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Low Cost Design for Reducing Leakage in Microwave Applicator for Industrial Applications

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Abstract - Microwave applicator is used in industry for drying/ heating purpose. It should leak microwave energy of minimum level because of following three major reasons are safety purpose, reduction of power loss , not interfere in communication system. For fulfillment of the above these three major reasons various types of choke design techniques are there. We have design a low cost and appropriate solution for chocking of microwave.

1. INTRODUCTION

Microwave oven, invented by the Raytheon Company in 1945, is one of the first spin-off products from aerospace technology. The Raytheon-Amana trademark Radar range® accurately identifies the origins of the device and hints at the application of sophisticated technology to the home. Before 1967, most microwave ovens were built for restaurants and institutional feeding. In the fall of 1967, Amana Refrigeration put the first domestic low-cost countertop model on the market. Since that time, other manufacturers have entered the marketplace to bring this high-speed cooking and convenience appliance closer to everyday use. [1, 3-5]

2. EXIST TYPES OF DOOR-CHOKE DESIGN

It is most important that the microwave oven contain the microwave power. Yet a means for inserting the food for heating via a door is necessary. Besides the fundamental frequency, the magnetron may have harmonic output power which also must be contained within the oven. Spurious frequency radiation just outside the assigned band and harmonic energy can cause interference with communication services.

So different types of door seal design are used, given below. [1, 3-9]

1. Contact door seal.
2. Wire-gasket door seal.
3. Flat external door choke seal.
4. Dielectric filled inserted choke door seal.

The fundamental problem in designing a microwave oven that will stay within guaranteed safe limits for the life of the product is the proper design of the door seal. Various approaches to door-seal design have been discussed, with

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Particular emphasis placed upon the inserted Dielectric-filled choke-seal, augmented with lossy gaskets for absolute suppression. This design is strongly favored since it is capable of being produced with very low leakage (much less than 1.0 mW/cm^2) on a large-volume production basis. [1, 6-8]

As already discussed above in chemical industry microwave applicator is used for heating chemical continuous. So, one can design the microwave applicator which is used to heat the chemical continuous. One of the method is discussed here for the above purpose which use the glass tube of diameter (d) and length (l) placed inside the oven from which the liquid material will pass continuously.

3. MODIFICATION FOR DESIGNING IN CHOKE

In this type of design the chemical will pass continuously flow from the tube. This chemical is heated by the microwave energy. And heated chemical will store in one chamber and using the pumping system chemical flows in tube continuously.

Now major problem in this type of design is same discussed above is leakage from the applicator. But difference is only that oven used in home appliances having leakage is at door whereas applicator discussed above having a leakage at the both corner end of the tube (fig. 1) from which the chemical in passed.

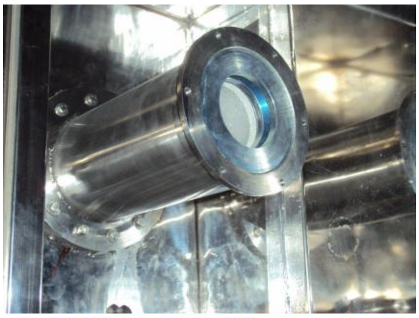

Fig.1 End view of the tube of choke cylinder

For microwave applicator operation at 1KW power one need to reduce the leakage up to 10 mW per centimeter square at 50mm from the surface of applicator according to international safety standards. As the microwave is electromagnetic waves, it follows the inverse square law in reduction in power, Microwave power (P) is inversely proportional to the square of the distance (r) from the surface.

4. MEASUREMENT OF LEAKAGE

Meeting emissions regulations is more critical for continuous processes, because they require product inlet and outlet ports that can readily cause leakage of RF/microwave radiation. In addition, many microwave/RF processes may require openings for various reasons. An example is infrared thermometers and imaging equipment that must have line-of-sight view of the material. Such open ports in practice cause the same concerns as those for product inlet and outlet ports. In this section we will discuss various methods to eliminate or reduce emissions from open ports to an acceptable minimum. Figure 3 shows a general view of a cylindrical attenuation tunnel. Design considerations for an open port depend entirely on the minimum required size of the opening for the function it is supposed to serve. All openings must include a metallic tunnel, which is also called a vestibule, or attenuation. choke or attenuation tunnel. An opening without a vestibule is bound to radiate energy, unless it is extremely small compared to the operating wavelength. [2]

Open ports attached to a microwave or RF heating chamber can generally be categorized into two types from a size standpoint. An electrically small or below-cutoff opening is one where the waves do not propagate, but the wave amplitude diminishes quickly with distance (also called the evanescent mode).

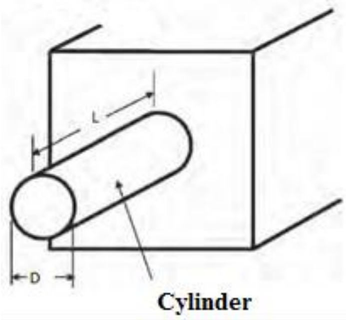

Fig. 2 Attenuation Cylindrical duct (choke) for prevention.

In above-cutoff openings the attenuation of a vestibule with metallic walls is minimal, and energy leaks out regardless of the vestibule's length, unless certain techniques are used. Therefore the first consideration is to find out if the required opening is below or above cutoff for the operating frequency, which will be discussed in the next section.

4.1 Cutoff Frequency For Cylindrical Waveguide

In the case of a cylindrical vestibule, the mode with the longest cutoff wavelength is TE_{11}. The cutoff wavelength for this mode is given as $\lambda c = 1.7\,D$, where D is the inner diameter of the vestibule. Therefore the cutoff frequency (in MHz) for a cylindrical vestibule becomes:

$$f_c = 1.76\,/D$$

Where D is the inner diameter of the vestibule (in meters).Below-cutoff attenuation ducts (chokes)

For below-cutoff vestibules of any geometry, the attenuation constant is given as equation no. 1:

$$\alpha = \frac{2\pi}{\lambda}\sqrt{\left[\frac{\lambda}{\lambda c}\right]^2 - 1} \qquad (1)$$

For a cylindrical vestibule, α =1.7*D. After simplification, Eq.1 becomes:

$$\alpha = 0.18\sqrt{\frac{31,000}{D^2} - f^2} \qquad (2)$$

Using only reactive or reflective material one can design the door-choke. But the best practice is to use reflective chokes adjacent to the oven to reduce the power density, and then to alternate between absorptive and reflective techniques until the desired attenuation is achieved.

Practical setup for measuring the attenuation is as shown.

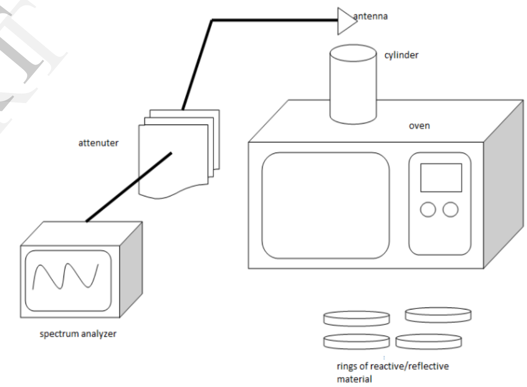

Fig.3**:** Practical setup for choke design

Components used for practical setup are: industrial oven, spectrum analyzer, attenuator, different types of materials for testing, regulated DC power supply, water (as a load).

5. STEPS ARE MENTIONED FOR MEASUREMENT

1. Put the cylinder of appropriate height and diameter on the industrial oven and the put the water inside the oven as load.
2. Connect an antenna with an attenuator. Make sure that the receiving end of an antenna is on the center of the cylinder.
3. Second end of the attenuator is connected with the spectrum analyzer.
4. Set the operating frequency 2.45 GHz and span of 100 MHz in the spectrum analyzer.
5. Now put the material in cylinder and take the reading in the spectrum analyzer.

6. After taking the reading, switch off the oven. Put another material and repeat the same procedure.

Fig. 4 Photo image of practical setup

6. OBSERVATION

TABLE I: Attenuations Results Observed At Different Materials At 300 Watts

Sr. No.	**Reading of choke material**	**Results 1**	**Results 2**
1	8(A)+15(B)+11(B)+10(A)+15(B)+7.5(A)+13(B)+7.5(A)	-35.41	-35.94
2	8(A)+15(B)+11(B)+10(A)+15(B)+7.5(A)+13(B)+7.5(A)+10(B)	-44.97	-45.12
	Only Mild Steel	**Results 1**	**Results 2**
1	8(A)+15(B)+11(B)+10(A)	-28.62	-30.22
2	8(A)+15(B)+11(B)+10(A)+7.5(A)	-26.45	-26.34
3	8(A)+15(B)+11(B)+10(A)+7.5(A)+7.5(A)	-41.86	-34.15
Sr. No.	**Carbon loaded ring**	**Results 1**	**Results 2**
1	8(A)+15(B)+11(B)+1^{st} ring	-23.08	-22.88
2	8(A)+15(B)+11(B)+1st+2^{nd} ring	-30.22	-32.19
3	8(A)+15(B)+11+1st+2nd+3^{rd} ring	-37.58	-44.55
4	8(A)+15(B)+11(B)+1st+2nd+3rd+4^{th} ring	-35.88	-36.83
5	8(A)+15(B)+11(B)+1st+2nd+3rd+4th+5^{th} ring	-34.36	-35.62
6	8(A)+15(B)+11(B)+1st+2nd+3rd+15(B)	-32.52	-32.05
Sr. No.	**Only Carbon Ring**	**Results 1**	**Results 2**
1	1^{st} ring	-2.93	-2.57
2	1st+2nd+3rd+4th+5^{th} ring	-29.13	-30.86
3	1st+2nd+3rd+4th+5^{th} ring +15(B)	-31.62	-32.3
4	1st+2nd+3rd+4th+5th+15+10(A)	-31.8	-29
5	1st+2nd+3rd+4th+5th+15(B)+13(B)	-39.69	-38.52
Sr. No.	**One Carbon loaded ring+ other material**	**Results 1**	**Results 2**
1	1st+15(B)	-18.19	-17.2
2	1st+15(B)+10(A)	-21.66	-21.8
3	1st+15(B)+10(A)+10	-28.63	-28.8
4	1st+15(B)+10(A)+10+12+7.5(A)+7.5(A)	-38.69	-36.6
5	1st+15(B)+10(A)+10(B)+12(B)+7.5(A)+7.5(A)+2^{nd}	-42.16	-44.58

Using different combination the result is as shown in the table above table the power is 300Watts and the load as some absorbing material.

Where

A- Reflective Material.

B- Reactive Material.

No. shows the height of the material in mm.

Now, load as a water and power is 1 KW then result for different combination of material is shown in the table.

TABLE II: Attenuations Results observed at Water at 1Kilo Watts

Sr. No.	**Different material combination**	**Results 1**
1	3(A)+2(B)+3(A)+2(B)+2(A)+4(B)	-45.2
2	5(A)+3(B)+4(A)+3(B)	-46.3
3	3(A)+3(B)+3(A)+2(B)+2(B)+2(A)+2(B)	-48.61

Where

A-Reflective Material

B-Reactive Material

No. shows the total piece of rings.

As per the above table we reach to the attenuation of -48.61dBm. And it is maximum compare to conventional heating. At this point the leakage is minimum and the efficiency of applicator is enhanced.

CONCLUSION

Microwave heating has been established in a number of industrial sectors. Undoubtedly the food industry with its diverge operations such as tempering, blanching, sterilizing, cooking, puffing and vaccum drying offers the biggest opportunity for microwave processing, but the formidable challenge of other competitive techniques must be seriously addressed. Recent developments in the ceramics industries point to major applications which may come on stream involving large microwave power the near future. Our goal of maximum attenuation i.e -48.61 dB is achieved and so, further application of this type of continuous liquid heating is also increased.

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