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THE PROCESSING OF TUNGSTEN CARBIDE POWDER WITH THE Q (CIRCULATION) ATTRITOR

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THE PROCESSING OF TUNGSTEN CARBIDE POWDER WITH THE Q (CIRCULATION) ATTRITOR

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THE ATTRITOR WAS DEVELOPED over 40 years ago by the inventor, Dr. Andrew Szegvari. The first Attritors -- batch Attritors, were sold in the 1940's. The Attritor went through many developments as it was modified to suit various industries. Some of the major developments were the continuous Attritor, the tungsten carbide Attritor, the circulation Attritor, dry grinding Attritor, and lately the non-metallic Attritor systems.

In addition to tungsten carbide, the machine is used in such diverse industries as chocolate and confectionary, agricultural flowables, paints and coatings, ceramics, paper coatings, ferrites, and chemicals.

The batch Attritor was adapted to the tungsten carbide industry by tapering the grinding tank, putting tungsten carbide sleeves on the arms, specially designing the bottom arm, and obviously using greater horsepower on the motors.

The Attritor has been referred to generically as a "stirred ball mill." The basic Attritor has a jacketed stationary tank that sits on trunnions in a steel frame. The frame supports the motor and gear reducer which are connected to a shaft through a coupling. The shaft is located in the center of the tank and has several arms that agitate or stir the media.

What makes the Attritor more efficient than ball mills or vibratory mills is its efficient way of causing irregular movement of the grinding media, and not group movement.

As can be seen from Figure 1, there would be no impact from the grinding media if both media and slurry (solids in the medium) were moving together.

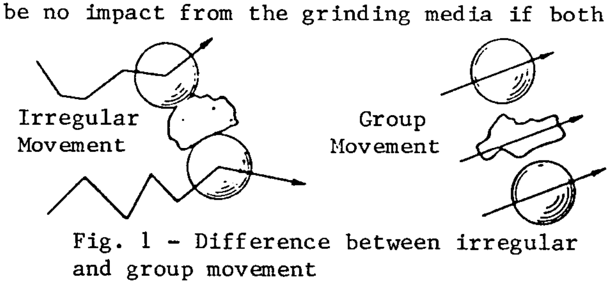


Fig. 1 - Difference between irregular and group movement

This irregular movement is caused by the movement of the arms through the grinding media. See Figure 2. This generates three types of forces:

1. Impact action on the media which later collides with other media
2. Rotational force on the media
3. Tumbling force as media falls into the void left by the arm

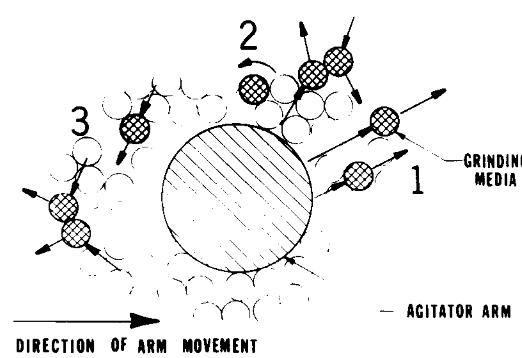


Fig. 2 - Action of media

For efficient fine grinding, both impact action and shearing force must be present. See Figure 3. In the Attritor, impact action is present by the constant impinging of the grinding media due to its irregular movement.

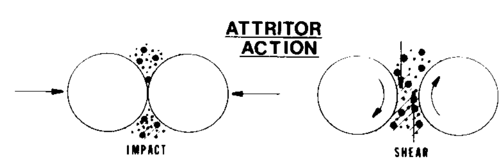


Fig. 3 - Impact and shear action from the grinding media

Shearing action is present in the Attritor in that the balls (media) in their random movement are spinning in different rotation and, therefore, exerting shearing forces on the adjacent slurry. As a result, both liquid shearing force and impact force are present. Such combined shearing and impact results in size reduction as well as good dispersion.

The action of the grinding media, as shown in Figure 2, increases as the arm extends from the shaft -- but falls off sharply at the end of the arm. See Figure 4. As a result, the media is rolling along the edge of the vessel, not striking or tumbling against it.

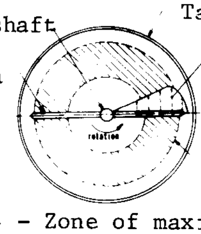


Fig. 4 - Zone of maximum action

As the walls of the grinding vessel of the Attritor act as a container and not as a grinding surface, they not only last longer and cause less contamination, but because they are thinner, there is much better heat transfer so there is better temperature control.

The configuration of the arms on the shaft, including the special bottom arm, causes the slurry to move upward along the outside of the tank and down at the center of the tank along the shaft.

In production machines, this is enhanced in that the slurry is pumped from the bottom of the machine (for tungsten carbide machines an air diaphragm pump is used) and deposited at the top. See Figures 5 and 6. This same pump is also used for discharging the slurry.

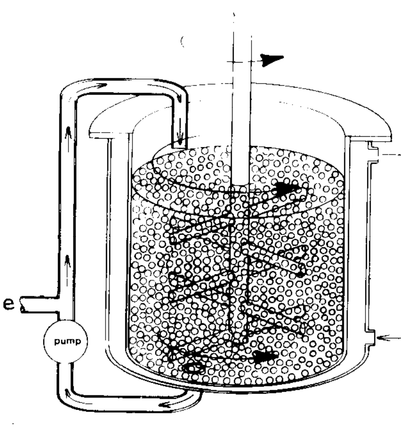


Fig. 5 - Batch Attritor

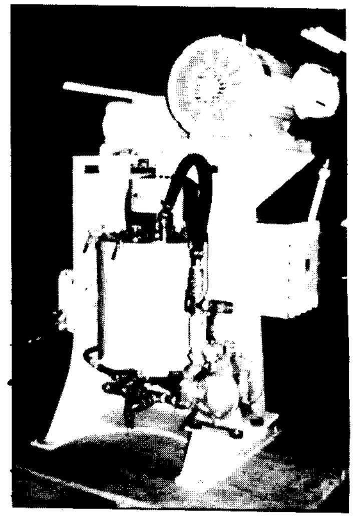


Fig. 6 - 30-SC tungsten carbide Attritor

The Q-Attritor (circulation) was developed in the 1970's and is now successfully used in the chocolate, paint and coatings, agricultural flowables, ferrite, paper coatings, and chemical industries.

The reason for these tests and this paper was to see if, with modifications, the advantages of the Q-Attritor could be applied to tungsten carbide processing.

The Q-Attritor system is composed of a grinding chamber, pump, and holding tank. See Figures 7 and 8. Typically, the holding tank is sized so that it is ten times that of the gross capacity of the Q-Attritor tank. The pump is sized such that the contents of the holding tank are pumped through the grinding chamber at least once every 7-1/2 minutes, or eight times per hour.

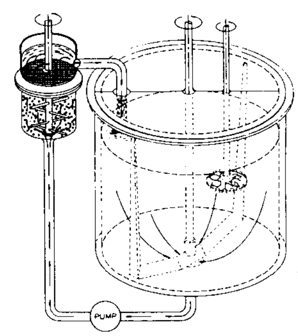


Fig. 7 - Q-Attritor system

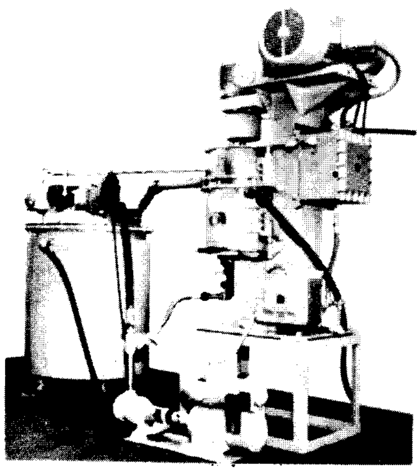


Fig. 8 - Q-25 Attritor system

The Q-Attritor, similar to the batch Attritor, has a central shaft with arms, in a jacketed tank filled with grinding media. However, the grinding media is retained by grids at both the top and bottom of the tank, and the slurry is pumped at a high rate from the bottom, up through the top, and back to the holding tank. This system results in a faster grind and a narrower particle size distribution. The reason for this is "preferential grinding." See Figure 9.

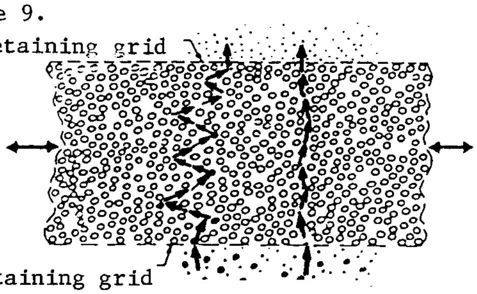


Fig. 9 - Passage of small and large particles through a layer of agitated media

The fast pumping stream through the agitated media bed makes the Q-Attritor grinding chamber act as a dynamic sieve or filter, allowing the fines to pass and move quickly through, while the coarser particles flow in a more tortuous path through the media bed because of their larger size.

With the circulation process, the material makes many passes through the grinding chamber until the desired particle size is obtained.

One advantage of the circulation system is that large quantities of material can be handled with a smaller investment in grinding media and equipment.

Secondly, the slurry can be continuously monitored, additional ingredients can be added to the premix tank at any time during the grinding, and the processing can be terminated precisely.

Thirdly, there is better temperature control in the Q-Attritor which is achievable for two reasons:

1. The holding tank is jacketed for cooling or heating and acts as a heat sink
2. The slurry passes through the grinding chamber very quickly (20 - 30 seconds per pass), therefore having less time to be heated up

A fourth advantage, especially for tungsten carbide grinding, would be if there were a power outtage. Whereas the tungsten carbide batch Attritors are equipped with 450% high starting torque motors, once the tungsten carbide has settled in the tank it is impossible to restart the machine without dumping the charge.

In a Q-Attritor system, very little slurry stays in the grinding chamber, therefore, it would be much easier to restart the machine.

For the comparison, a 1-S Attritor and a Q-1 Attritor, both manufactured by Union Process Inc. of Akron, Ohio were used. See Figures 10 and 11. The 1-S was equipped with a torque sensor and rpm meter (the readout shows torque inch/lb., horsepower and rpm), a 3-hp Vari-Drive motor, and a 2-1/2 gallon grinding tank.

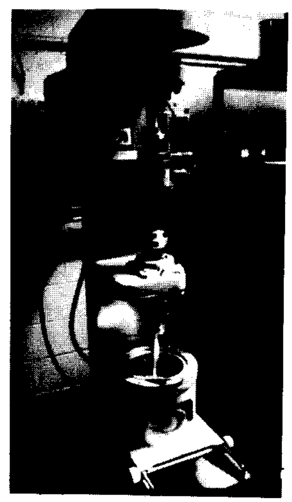


Fig. 10 - 1-S Attritor used in test

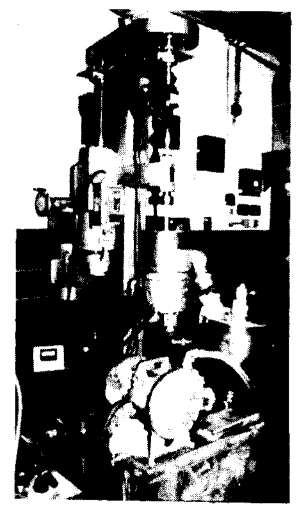


Fig. 11 - Q-1 Attritor used in test

The Q-1 Attritor was also equipped with the same torque sensor and rpm meter, a 5-hp Vari-Drive motor and a 2-1/2 gallon grinding tank, a 5-gallon holding tank with high-speed and low-speed anchor stirrer, and a 1" Sandpiper air diaphragm pump. For test criteria, see Table 1.

Table 1 - Test Criteria

Model	RPM	Torque (in./lb.)	HP	Media[1] Wt. (lbs.)	WC (lbs.)	CO (lbs.)	Acetone (gal.)
1-S	250	455.5	1.8	120	10.75	0.688	0.48
Q-1	250	459.5	1.8	120	67.00	4.280	3.0

(1) 3/16 inch tungsten carbide media

NOTE: For a given hour of processing, the Q-1 was processing 6.23 times more material than the 1-S.

Each machine was charged with 120 lbs. of 3/16 inch tungsten carbide balls as manufactured by MacDonald Carbide Company, Baldwin Park, California. The tungsten carbide and cobalt raw materials were also provided by MacDonald Carbide Company.

The charging procedure used in the 1-S was to first add the solvent, then the cobalt, and finally the tungsten carbide.

The same procedure was used for the Q-1, except when the cobalt and the tungsten carbide were added, the pump was on and the Attritor was running. This procedure was used to prevent settling in the lines and holding tank before startup. Samples were taken at 2, 4, and 6 hours in the 1-S; and at 9, 15, 20, 25, 30, and 35 hours in the Q-1.

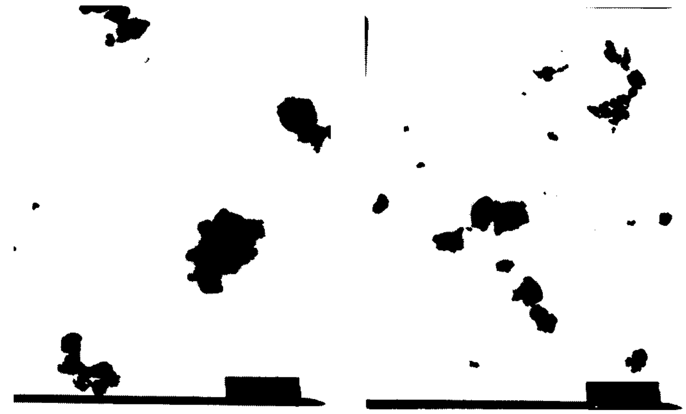
The 1-S was run at 250 rpm for a tip speed of 491.0 fpm.

The Q-1 was run at 250 rpm for a tip speed of 490.8 fpm.

The machines were run such that each used nearly the same torque in inch/pounds and, as they were run at the same rpm, they each consumed the same amount of horsepower.

Since the batch size of the Q-machine was larger (actually, it was 6.23 times the batch size of the 1-S -- 71.28 lbs. vs 11.44 lbs.), to achieve an equivalent 4-hour and 6-hour residence time, 25 hours and 37-1/2 hours of Q-system processing would be necessary.

Refer to Figures 12 and 13 below.



1 micron

Fig. 12 - Tungsten carbide

1-S 2 hours Q-1 9 hours

1 micron

Fig. 13 - Tungsten carbide

1-S 4 hours Q-1 21 hours

Looking through an electron microscope, we did the particle size comparison of the 1-S 2-hour sample with the Q-1 9-hour sample, and a 1-S 4-hour sample with a Q-1 21-hour sample. NOTE: The 4-hour 1-S sample is about equal to the 9-hour Q-1 sample.

In other words, on a volume basis, the particle size was reduced by the Q-machine in 9 hours instead of the expected 25 hours. Therefore, in this particular case, the particle size was reduced in the Q-system in approximately one-third the time that was required in the 1-S.

Designated hourly samples were sent to MacDonald Carbide Company for them to make into test parts and evaluate. The samples were made by first pressing at 18 tons psi, presintering under hydrogen, and sintering in a vacuum furnace. Then, all the samples were ground and polished for observation.

Rockwell-A hardness and density measurements were taken according to ASTM specifications. The samples were examined at 200X magnification for microporosity and etched and examined at 1500X magnification for microstructure. See Table 2.

Table 2 - Tungsten Carbide Milling Tests

Sample No.	Sample Hrs.	Porosity	Hardness	Density	Remarks
1-S	4	A1 B1 CO	92.5	14.96	No cobalt pools
1-S	6	A1 B1 CO	92.5	15.01	" " "
Q-1	9	A3 B1 CO	92.8	14.85	Hvy " "
Q-1	15-1	A2 B2 CO	92.7	14.98	Cobalt pools
Q-1	15-2	A2 B1 CO	92.8	14.98	" "
Q-1	20-1	A2 B1 CO	92.8	14.97	" "
Q-1	20-2	A2 B1 CO	92.9	14.97	" "
Q-1	25-1	A1 B1 CO	92.6	14.98	" "
Q-1	25-2	A1 B1 CO	92.8	14.98	" "
Q-1	30-1	A1 B1 CO	92.9	14.99	" "
Q-1	30-2	A1 B1 CO	92.8	14.98	" "
Q-1	35-1	A1 B1 CO	92.9	14.99	" "
Q-1	35-2	A1 B1 CO	92.8	15.00	" "

All these test data also indicate that the Q-system is doing an efficient job of reducing the particle size, but is not quite so efficient at mixing and smearing the cobalt with tungsten carbide.

One reason for this is that due to the different densities of the two materials, they were not being mixed well in the holding tank, and the cobalt was on the top portion of the slurry and staying behind.

So, we may conclude that if one wishes only to reduce the particle size and obtain a narrower distribution, the Q-machine will work well. But, if one wishes to mix cobalt with tungsten carbide, then the batch setup is better.

But there is still one possibility -- to combine the two systems by connecting a Q-Attritor to a batch Attritor, using the batch Attritor with its superior mixing ability as the holding tank, and achieve fast, high quality tungsten carbide powder processing.

The slurry capacity of a 30-S Attritor is equal to approximately what a Q-2 could use for a holding tank, and the capacity of a 100-SC would equal that of a Q-6. This means that without much additional capital cost and floor area or by utilizing an existing setup, the processing time might be significantly reduced.

Time did not permit the above to be tested, but these experiments will be conducted and reported on in the future.

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