MACHINED CAGES
Internal Differences

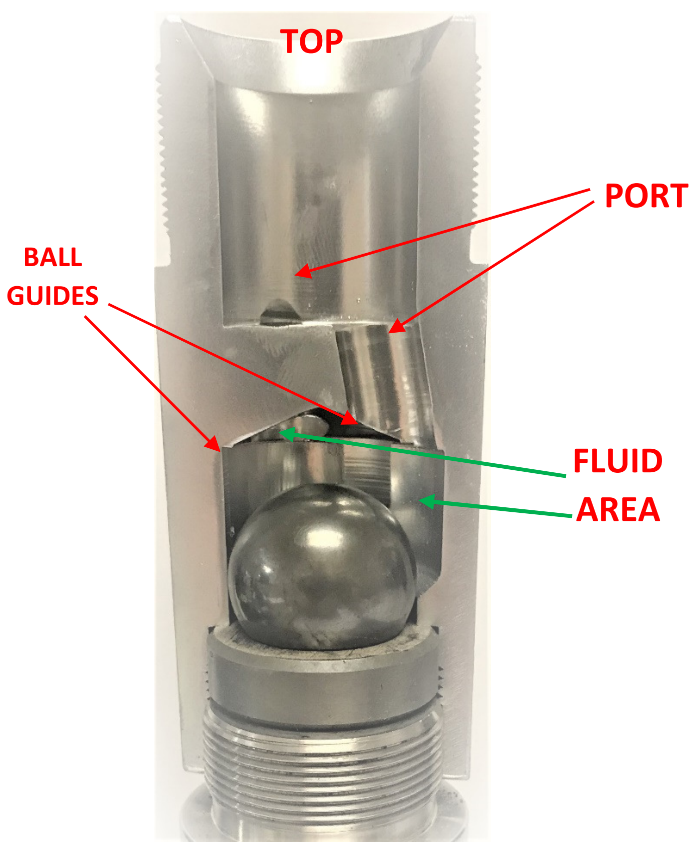
The cage is a hollow chamber that houses a ball and seat. During the work cycle pressure from below the cage forces the ball off the seat towards the top of the cage permitting the fluid to enter, flow around the ball, and out through the ports in the top of the cage. When the pressure above the cage becomes greater than the pressure below the cage, the ball will return and rest on the seat. Depending on pumping speeds and run time, the cage in conjunction with the ball and seat will possibly perform these work cycles millions of times.

The API specifies the dimensions of cages manufactured for rod pump applications regarding OD tolerances, thread type, and thread depth. Due to this specificity, it would be easy to believe that all machined cages are alike regardless of who manufactures them. However, API notes that "*Dimensions and configuration of ball chamber shall be such as to provide adequate ball clearance and fluid passage.*" With the latitude given regarding the internal configuration of the cage, manufacturers can develop an internal design they believe provides the best "Adequate ball clearance and fluid passage".

For the purpose of this paper we are only going evaluate the port configuration and ball guides of the following:

- 3-port cage
- 4-port cage
- Open flow cage

as well the performance of these designs during service. All three cages are commonly used and accepted in the industry. The picture below is an example of the basic internal design of a 2-1/4" API cage with an API ball and seat.



3-PORT MACHINED CAGE

The 3-Port cage has 3 holes in the top section of the cage to permit fluids to travel, as well as 3 ball guides that aid in guiding the ball back to the seat. Let us look at the two 3-port examples below.

Example A has a flat surface where the three ports are located, and material has been machined out between the ball guides to increase the amount of fluids that can go through the cage and around the ball.

Example B is the internal view of a 3-port cage with a concave area where the 3-ports are located instead of a flat surface.

EXAMPLE A

EXAMPLE B

4-PORT MACHINED CAGE

The 4-Port cage has 4 holes in top section of the cage to permit fluids to travel as well as 4 ball guides that aid in guiding the ball back to the seat. Similar to the 3-port example A (above), material has been machined out between the ball guides to increase fluid flow. In Example C the cage has a concave area where the 4 ports are located.

Example C

OPEN FLOW MACHINED CAGE

The Open Flow cage has the center removed in top section of the cage to permit fluids to travel as well as 3 or 4 ball guides that aid in guiding the ball back to the seat.

The material in **Example D** has also been machined out between the guides.

Example D

Differences in Area

Each of the three cages differ in area regarding the top ports of the cage.

- 3-PORT Each port of the 3-port cage has an approximate Individual Port area of 0.95 in^2 and a Cumulative Port area of 2.85 in^2.

- 4-PORT Each Individual port area has an approximate Individual Port area of 0.94 in^2 which is 11.8% smaller than the 3-port; however, the Cumulative Port area at 3.40 in^2 is 19% larger than the 3-port cage.

- OPEN FLOW The cumulative area of the open flow cage is approximately 4.05 in^2. This is 42% greater than the 3-port cage and 19% larger than a 4-port cage.

Cage Type	Individual Port (IP)	Cumulative Ports (CP)	Conclusions
3-Port	0.95 in^2	2.85 in^2	IP is 11.8% larger than 4-Port
4-Port	0.94 in^2	3.40 in^2	CP is 19% larger than 3-Port
Open Flow		4.05 in^2	CP is 42% larger than 3-Port and 19% larger than 4-Port

The port surface area of each cage varied greatly, and the area of each cage is segmented differently.

CAGE SELECTION & PERFORMANCE

Fluid conditions vary greatly depending on the geographical area and pay zone of producing wells. Due to these conditions, selecting a cage to accommodate the produced fluid is critical.

Open Flow Cage

Advantages: The Open Flow cage provides the greatest area for fluid to pass and since the area is not segmented, this valve is a great choice for moving larger solids and provides the least restriction for fluids.

Disadvantages: Since the center material of the cage is removed to increase fluid, the port area and ball can begin to wear quicker than other non-open flow cages. This is due in part to the ball impacting the cage at the three points in the top of the cage.

4-Port Cage

Advantages: The 4-port cage provides the second largest available surface area for fluids. This cage design can be beneficial when the fluids have an elevated gas content and minor solids. The cage utilizes four ball guides enabling the ball to track on and off seat easier. The ball and impact area at the top of the cage tend to wear better because the energy at impact is dispersed over a greater area.

Disadvantages: Since each port of the 4-port cage has the smallest area and four ball guides, the cage has a greater chance of plugging off or sticking the ball when fluids have large solids.

3-Port Cage

Advantages: The 3-port cage provides the smallest available area for fluids; however, each port has a greater area than the ports of the 4-port cage allowing for larger particulates without the risk of plugging off. Since the 3-Port cage has three ball guides, this is less likely to stick. This cage also wears well for the same reasons stated for the 4-port cage.

Disadvantages: Since the cage provides the least area for fluid flow, it may not be beneficial for wells where pump size and speeds are at max capacity and the unit is running 100%.

It is important to note that some manufacturers will machine a concave area in the top of the cage, whereas, others will leave the area flat. The concave area provides the best wear resistance since the energy generated at impact is dispersed over a greater area minimizing stress on the ball and cage. When the ball impacts the top of a cage with a flat surface, the energy is localized in a smaller area potentially damaging the ball.

FUTURE STUDIES

As a follow up to the cages discussed in this paper, the Artificial Lift team at B-P Pump & Supply will be conducting flow tests on multiple manufacturer's cages. The testing will also include specialty cages that offer a larger flow area, but for the purpose of this paper were not included. Our goal will be to determine which designs performed best regarding varying fluid conditions.

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