Adaptor Core Technology:

The Inception and Adapting of Calculus Based Truths within Geometric Entities

900 Global would like to introduce a leap forward in a technological advanced core design. First featured within "Inception" and "Truth", the "Adaptor" core design stems from complex calculus based methodology that enables the use of the exact same volumetric core shape to yield both an asymmetric and symmetric bowling ball. The following journal will explore the defining characteristics of convergent and divergent surface integrals across the X, Y, and Z Radius of Gyration axis for this particular core design. Understanding the theory for this particular design will allow a bowler to become more familiar with the diversity of this particular shape and hence understand the many diverse options that can be sustained within this design to influence ball motion.

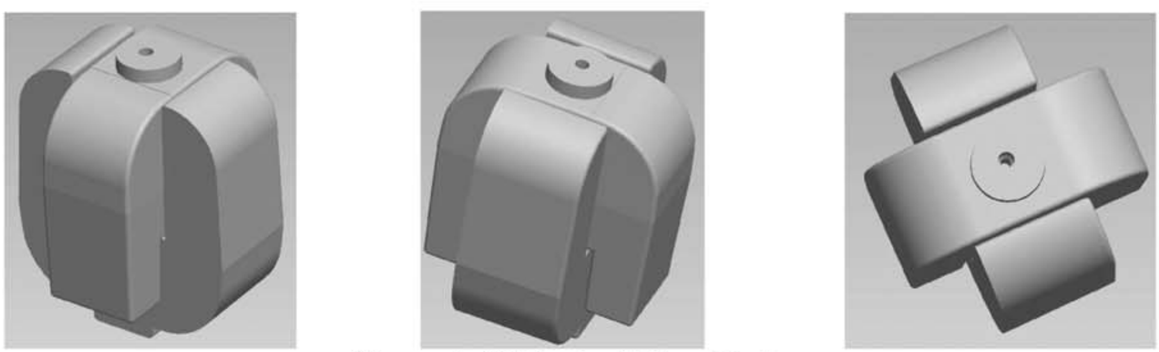

Figure 1: "Adapter" Core Design

As with any core design within a bowling ball, the primary purpose is to yield a particular Radius of Gyration (RG) and Differential radius of gyration on the primary axis. There are three primary axis (X,Y,Z) on a bowling ball where the RG is routinely evaluated.

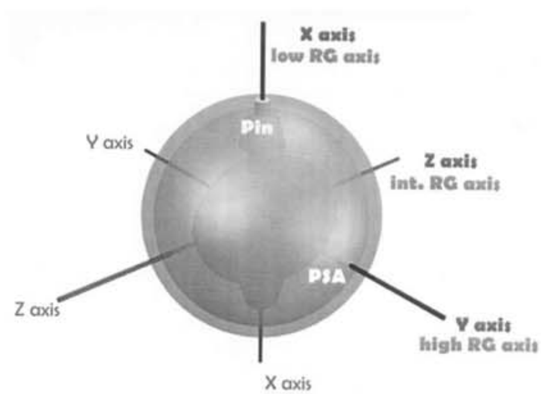

Figure 2: Primary Axis of Bowling Ball (X,Y,Z)

The characteristics of the core's size, shape, and density play a vital role in determining how the core will influence the rotation of the bowling ball by altering the calculated RG and Differential RG. It is known from previously documented research that technically speaking, the radius of gyration is defined as the square root of the moment of inertia (I) divided by mass (M) of the object.

$$I \stackrel{\text{def}}{=} \int_V r^2(m)\, dm = \iiint_V r^2(v)\, \rho(v)\, dv = \iiint_V r^2(x,y,z)\, \rho(x,y,z)\, dx\, dy\, dz$$

$$\Downarrow$$

$$R_g = \sqrt{\frac{I}{M}}$$

Figure 3: Radius of Gyration Mathematical Model

Therefore, the radius of gyration is the distance that, if the entire mass of the object were together at only that specific radius, would yield the same moment of inertia. The moment of inertia for an object is the ratio of applied torque and the resultant angular acceleration of the object. Translating the physics definition, the moment of inertia measures how easy an object will rotate when a force is applied. Thus, in simple terms, the radius of gyration determines how easy it is for the bowling ball of particular weight to rotate about a given axis and is a measurement of where the weight is located inside the ball, relative to the center. To help explain this term further, imagine a figure skater twirling on the ice. If the skater spins on the ice with arms extended out, the rate of rotation is slower than if the arms are pulled inward towards the body. The same physics principle applies for a designed core inside of the bowling ball. For a given core shape, the more dense (heavier) the inner core becomes, the more the bowling ball will simulate rotation like a figure skater with arms tucked close the body. In other words, the core will have a low RG and will help the ball rev up in a quick manner. The less dense (lighter) the inner core is, the more the ball will behave as a spinning figure skater with arms extended out and it will take longer for the ball to rev up as it travels down the lane, thus, having a higher RG. Every ball has a high RG axis and a low RG axis. For an example in terms of the figure skater, the high RG axis would be when the skater has arms out and the low RG axis is when the skater has arms in. It is the difference between the maximum and the minimum RG that is defined as the differential radius of gyration. In summary, RG helps define "when" the ball will rev-up and Differential RG helps define how much of fresh ball surface will contact the lane with each ball revolution as the ball travels down the lane. Increased Differential RG equals increased fresh surface of ball contacting the lane and hence will product more friction which equals increased potential hook.

In bowling the published RG of a bowling ball is the lowest RG of the ball. As briefly eluded to in the preceding, a ball has not only has a low RG location (X Axis) but also has a high RG (Y Axis) and an Intermediate RG location (Z Axis). However, anywhere in-between those locations on the ball other RG values will exist in-between the high, intermediate, and low. 900 Global design engineers use a software extension to the 3D-CAD Pro-Engineer/Creo program called “BMX modeling” to map the different RG values across every location on the bowling ball. This map contains a representation of what is called “RG Contours” of the ball. An example can be seen below in Figure 4.

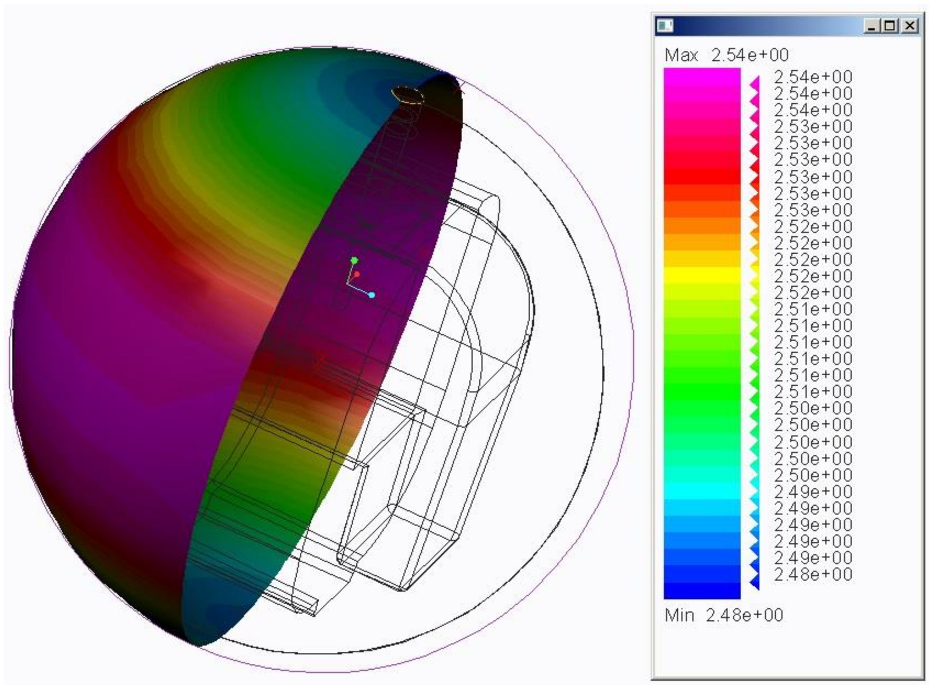

Figure 4: BMX Modeling Circular RG Contours Adaptor Symmetrical

Each different colored band represents a different RG value. As also proven in previous research, RG contours have a role in affecting ball motion through the core design. Drilling techniques yield different ball motions because they place the starting PAP on different Rg contour bands from one drill pattern to the next. The 2007 Axis Migration Study conducted by USBC concluded that a bowling ball created a flare path (Axis Migration) that stays on the same RG contour band. Using “BMX Modeling” software, 900 Global can predict the axis migration and flare path of a bowling ball based on the RG contour that the PAP starts on.

A key design feature of the Adapter core is seen within an extensive analysis of the extrapolated 2D cross sectional RG contour shape created around the x-axis portrayed on the y/z 2D plane. As manipulation of densities within the Adapter core pieces occurred, the measured distance from the low RG x-axis of the contour bands themselves changed geometric shape. Each contour is either in a circular or elliptical 2D shape around the x-axis. As the two core pieces converge towards the same density the RG contours become circular (Adapter/C) in nature and as the densities diverge (Adapter/D) from one another the RG contours become elliptical in 2D shape.

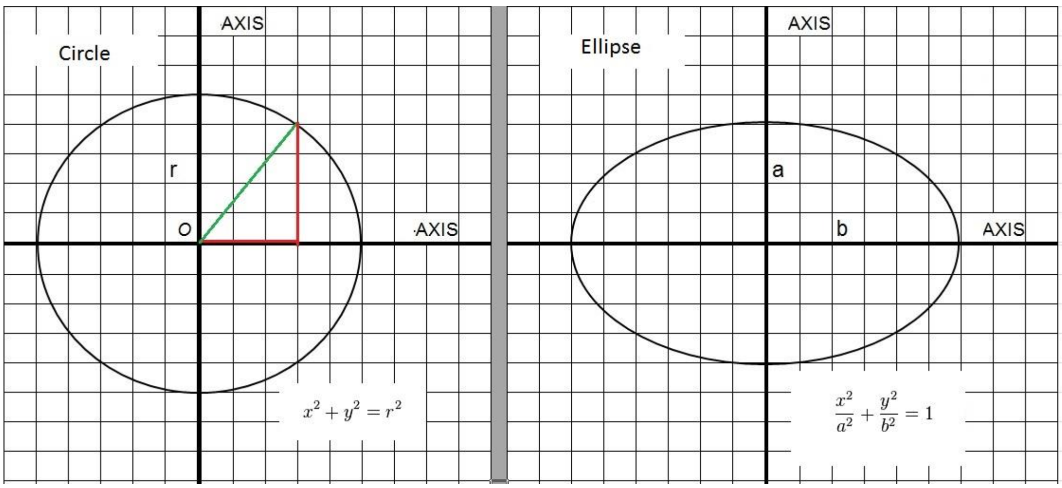

Figure 5: Graphical Representation of 2D Circle and Ellipse

Using calculus and geometric based methodology for the analysis of circular vs. elliptical surface shapes the area within the RG contours was examined. The mathematical formula that represents a circle is as follows:

$$x^2 + y^2 = r^2.$$

The area of a circle can be determine through an integral calculus based analysis:

$$\begin{aligned} A &= \int_{-r}^{r} \left(\sqrt{r^2 - x^2} - \left(-\sqrt{r^2 - x^2}\right)\right) \mathrm{d}x \\ &= \int_{-r}^{r} 2\sqrt{r^2 - x^2}\, \mathrm{d}x \\ &= \int_{-r}^{r} 2r\sqrt{1 - \frac{x^2}{r^2}}\, \mathrm{d}x \end{aligned}$$

Let $x = r\sin\theta$ (note that we can do this because $-r \le x \le r$)

Thus $\theta = \arcsin\left(\frac{x}{r}\right)$ and $\mathrm{d}x = r\cos\theta\,\mathrm{d}\theta$.

$$\begin{aligned} A &= \int_{\arcsin(\frac{-r}{r})}^{\arcsin(\frac{r}{r})} 2r^2\sqrt{1 - \frac{(r\sin\theta)^2}{r^2}} \cos\theta\,\mathrm{d}\theta \\ &= \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} 2r^2\sqrt{1 - \sin^2\theta}\cos\theta\,\mathrm{d}\theta \\ &= \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} 2r^2\sqrt{\cos^2\theta}\cos\theta\,\mathrm{d}\theta \\ &= r^2\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} 2\cos^2\theta\,\mathrm{d}\theta \\ &= r^2\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} (1 + \cos(2\theta))\ \mathrm{d}\theta \\ &= r^2\left[\theta + \frac{1}{2}\sin(2\theta)\right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \\ &= r^2\left[\frac{\pi}{2} + \frac{1}{2}\sin\left(2\cdot\frac{-\pi}{2}\right) - \frac{-\pi}{2} - \frac{1}{2}\sin\left(2\cdot\frac{\pi}{2}\right)\right] \\ &= r^2\left[2\cdot\frac{\pi}{2} + 2\cdot\frac{1}{2}\cdot 0\right] \\ &= \pi r^2 \end{aligned}$$

The mathematical formula for an ellipse is:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1.$$

The area of an ellipse can also be determined through an integral calculus based analysis. Rearranging the equation above solving for y and then integrating over the length of the ellipse:

$$y = \pm\sqrt{\frac{a^2b^2 - b^2x^2}{a^2}}$$

$$\begin{aligned} A_{\text{ellipse}} &= \int_{-a}^{a} 2b\sqrt{1 - x^2/a^2}\, dx \\ &= \frac{b}{a}\int_{-a}^{a} 2\sqrt{a^2 - x^2}\, dx. \end{aligned}$$

The integral portion of the equation is solved above in the circle proof and is equal to πa^2. Simplifying the remaining calculation, the area of an ellipse becomes:

$$A_{\text{ellipse}} = \frac{b}{a}A_{\text{circle}} = \pi ab.$$

Using the derived formulas for the area of a circle, an ellipse, and the rates of change in density between the Adaptor core pieces a mathematical relationship was formed to establish where the area's convergent and divergent boundaries within the RG spectrum occur. By definition, a bowling ball is symmetric if both the y and z axis RG values converge to the same value and hence create a circular 2D cross sectional RG contour about the x-axis. A ball is asymmetric if the y and z axis RG values diverge from one another and create an elliptical 2D cross sectional RG contour band about the x-axis. By adjusting the densities of the Adaptor core pieces the area of the resulting contours bands were calculated (circular or elliptical). The unique design of the Adaptor core allowed for varying points of convergent and divergent area measurements thus yielding the remarkable defining characteristic of this design. The Adaptor core design contains multiple values across the RG spectrum where the same low RG, same Total Differential RG, and then has an option to have an intermediate differential or not. In other words, the design can yield a symmetric or asymmetric bowling ball with the same low RG and Total Differential RG. The first examples of this design are in the following 900 Global releases:

Ball Name	**Core Name**	**Low RG**	**Total Diff RG**	**Intermediate Diff RG**
Inception	Adaptor/D	2.485''	0.055''	0.024''
Truth	Adaptor/C	2.485''	0.055''	0.000''

Figure 6: Mass Properties of 15# Inception and Truth Bowling Balls

A vast amount of bowling ball core designs are sometimes fabricated by the ability to manufacture a specific shape and cost driven factors. However, over the years 900 Global has been able to use factual scientific principles, sound mathematical derivations, and the unchanged laws of physics coupled with the ease of manufacturing to bring to market the most unique and technologically advanced designs within the industry. These designs are rooted with the mentality of giving bowlers the opportunity to have an extensive amount of tools at their disposal in order to navigate the ever changing and demanding lane conditions and bowler styles. 900 Global is proud to introduce the latest in advanced core design technology, the Adapter/D and Adaptor/C first featured in "Inception" and "Truth". Performance for Your Game!

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