AGN 183 - Rotor Inertia

MOMENTS OF INERTIA

The moment of inertia, otherwise known as the angular mass or rotational inertia, of a rigid body is a tensor that determines the torque needed for a desired angular acceleration about a rotational axis.

Rotor Moments of Inertia values (WR^2 in kgm^2) for AvK and STAMFORD alternators are published in the alternator's Technical Data Sheet and on the Rotor Torsional Drawing that is available for each alternator.

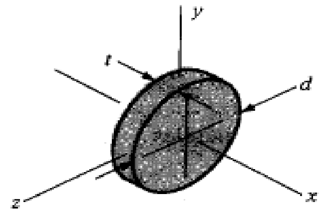
ROTOR INERTIA CALCULATION

For each rotating component, and this breaks right down to include everything from core packs, copper wire, insulations, wedges, bearings, fan, etc., etc., the geometry needs to be divided into equivalent volumes. These volumes are typically disks, cylinders or rectangular prisms. These volumes can then be used to calculate the total Rotor Inertia.

Once the equivalent volumes are known, standard equations can be used to calculate the inertia about their own centres of gravities.

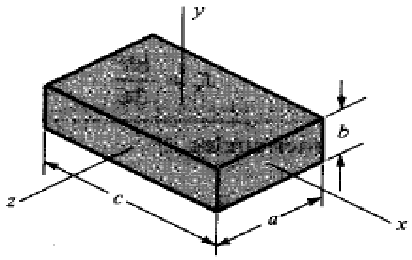
The figures on the following page show how to calculate Inertias for typical volumes:

Round disks



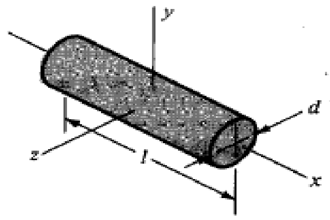
$$m = \frac{\pi d^2 t \rho}{4g} \qquad I_x = \frac{md^2}{8} \qquad I_y = I_z = \frac{md^2}{16}$$

Rectangular prisms



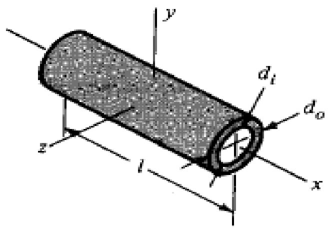
$$m = \frac{abc\rho}{g} \qquad I_x = \frac{m}{12}(a^2 + b^2) \qquad I_y = \frac{m}{12}(a^2 + c^2) \qquad I_z = \frac{m}{12}(b^2 + c^2)$$

Cylinders



$$m = \frac{\pi d^2 \ell \rho}{4g} \qquad I_x = \frac{md^2}{8} \qquad I_y = I_z = \frac{m}{48}(3d^2 + 4\ell^2)$$

Hollow cylinders



$$m = \frac{\pi \ell \rho}{4g} \qquad I_x = \frac{m}{8}(d_o^2 + d_i^2) \qquad I_y = I_z = \frac{m}{48}(3d_o^2 + 3d_i^2 + 4\ell^2)$$

These inertias are then corrected due to their positions relative to the main rotor centreline. This is done using the parallel axis theorem.

The parallel axis theorem is represented by the following equation:

- $I + (MR^2)$

Where: I = Calculated INERTIA values (taken from above)
M = MASS of simplified shape of rotating component
R = RADIUS from Rotor shaft centre line to centre point of simplified shape of rotating component.

The final total Rotor Inertia is simply a summation of all of the individual Inertias.

INERTIA CONSTANT

To gain an understanding of power system stability, various parameters must be considered. Typically these are:

- Synchronous machine characteristics.
- Generating Set equipment package in terms of the engine combined with alternator overall performance characteristics.
- Excitation and engine governing characteristics.
- Power system design along with the supported electrical loads.
- Transmission system.
- Circuit breaker and protection strategy.
- Neutral grounding scheme.

The power system engineer will need to identify such factors as Critical Clearance Time (cct), and may well be applying protection settings based on Equal Area Criterion (EAC) and furthermore establishing the Transient Stability Limit.

The most commonly requested system stability related value for an alternator is the value of the inertia constant '**H**'.

H is a measure of the alternator rotor's stored kinetic energy, based on the operational running speed and alternator output kVA rating - remember the alternator could well be running at unity power factor, so kVA is used rather than kW.

H is provided as a numeric value in seconds.

With alternators being cost effectively designed to ensure the optimum use of materials along with practical physical dimensions (stator bore and core length) all being very similar in proportion terms across a complete product range, it is perhaps no surprise that for a typical Class H temperature rise rated industrial Low Voltage alternator, that **H** is typically **0.3 s**.

Furthermore, for a complete – modern high BMEP engine powered – industrial Generating Set, that H for this power generation package is typically 0.5 s to 0.6 s.

Alternator manufacturers will quote the value of H based on a customer request. This may take into account that the alternator is being operated at a rating purposely selected – for a Generating Set based on a special application or duty.

H can be calculated:

$$\mathbf{H} = (\mathbf{WR^2} \times \mathbf{C}) / \mathbf{kVA}$$

Where:

H is in seconds

WR² for the rotor in kgm² the value taken from the alternator's published Technical Data Sheet

C is a constant that takes into account; running speed, and a factor to deal with the kgm² units of WR²

For 1500rpm the value of C = 12.33
For 1800rpm the value of C = 17.75

kVA is the alternator's operational kVA.

Note; **C** has base value of 49.3 based on a 2-pole alternator running at 3000rpm. For a 4-pole alternator, the following factor must be used: $(N_{new} / N_{base})^2$.

In this instance, this is $(1500/3000)^2 = 0.25$.

So, for a 4-pole alternator at 1500rpm, **C** becomes; 49.3 x 0.25 = 12.33
For a 4-pole alternator at 1800rpm, **C** becomes 49.3 x $(1800/3000)^2 = 17.75$

Example

A PI734B Winding 312 alternator, operating at 400V 50Hz at the published rating of 1400kVA. The following extracts are taken from the published Technical Data Sheet:

PI734B
Winding 312 / 0.8 Pow

RATINGS

Class - Temp Rise		Cont. F - 105/40°C				Cont. H - 125/40°C			
50Hz	Star (V)	380	400	415	440	380	400	415	44
	kVA	1265	1305	1305	1280	1360	1400	1400	13

	1 BEARING
WEIGHT COMP. GENERATOR	2760 kg
WEIGHT WOUND STATOR	1306 kg
WEIGHT WOUND ROTOR	1139 kg
WR² INERTIA	32.7498 kgm²

For the PI734B Winding 312:

H = (32.7498 x 12.33) / 1400 = 0.29 s