RELIABILITY OF ENTERPRISE HARD DISK DRIVES

This paper discusses the various factors that impact upon the reliability of Hard Disk Drives (HDD). It introduces the specification parameters and operating constraints that influence the reliability. Examples of existing and new classes of HDD are described along with a discussion of how specific applications impact upon their design and specification.

Content

1. Reliability Specifications

1.1 Operating Duty

A major reliability-related criterion for the selection of storage components is the operating duty, which typically refers to how many hours in a day a drive has been designed to be active for. While business critical enterprise drives are designed for 24 hours per day, 7 days a week, 365 days a year (24/7/365 or 24/7) continuous operation, the operation duty of client drives may be limited, i.e. 8 or 16 hours per day for dedicated hard disk drives for desktop or laptop computers.

1.2 Warranty

The manufacturer warrants the reliability for a certain period, typically 5 years for enterprise components, 1~3 years for client products, as long as the operating duty limitation (in case of non-24/7 products) and other environmental conditions or constraints (see chapter 2.) are not violated.

1.3 Mean Time to Failure (MTTF)

As there is no perfect technical device, components may fail with a certain probability. Within the warranty period, a drive manufacturer estimates that a population of drives will not exceed a specified failure rate. Again, upon the condition that operating duty and other environmental constraints are adhered to.

Mean Time to Failure[1] (MTTF, measured in hours) is a statistical value to specify the time to a first failure in a population of technical devices. A typical MTTF of storage components of 1 million hours means that for a population of 1 million drives running in systems, one device failing per hour can be expected if operated within the reliability specifications. With 1000 drives, it would mean a failure may happen every 1000 hours.

1 million hours is equal to 114 years. But this does not mean that a single drive would operate for 114 years, because the MTTF specification is only valid for drives operating within the warranty period. In a very hypothetical scenario where a single drive was in operation, and was replaced upon the expiry of the warranty period (i.e. every 5 years), the first failure would statistically occur after 114 years and 22 replacements.

1.4 Annualized Failure Rate (AFR)

For drives operated 24/7, the expected statistical failure rate per year can be calculated from the MTTF by the following formula:

$$AFR = 1\text{-}e^{(-8760h/MTTF[h])} \quad (1 \text{ year} = 8760 \text{ hours})$$

The reduction by an exponential term is because the already failed drives have to be considered in the statistics. However, for small AFR%, this reduction by already failed drives is negligible and the formula can be approximated as:

$$AFR[\%] = \frac{8760\ [h]}{MTTF\ [h]} * 100$$

A MTTF of 1 million hours would mean an AFR of 0.876% or up to 9 drives in a population of 1000 drives in operation would be predicted to fail within a year. Datacenters would have to budget for this number of repairs or replacement drives. At a specified MTTF of 1 million hours, an actual failure rate of approximately 9 drives per 1000 would be expected within a year. Assuming, these drives were within the warranty period, and used in accordance with the operational duty and environmental constraints. Higher failure rates would mean that the manufacturer does not meet the committed reliability specification.
Instead of MTTF, the term MTBF (Mean Time BETWEEN Failures) is sometimes used. MTBF means the time from one failure to the next one, after the first failure had been repaired. As storage components are not typically repairable items, MTBF is not relevant; MTTF is therefore the correct term in this instance.

2. Reliability Constraints / Operating Conditions

When a manufacturer commits to a specified MTTF for a warranty period, it does so on the understanding the drive will be operating within certain environmental and workload conditions. The operating duty constraint has already been explained in section 1.1. Further operating specification limits are:

2.1 Operating Temperature

Drives are specified to operate within certain temperature ranges. The typical temperature specification range for a drive, designed to operate in a datacenter with cooling equipment, is from 5°C to 55°C. Consumer or client drives are typically rated for and operational temperature range of 0°C to 60°C, while drives designed for industrial applications tend to be rated for extended temperature ranges of -40°C to +85°C. The temperature specification typically refers to either the ambient temperature (Ta), the temperature of the air outside or around the device, or the case temperature (Tc), measured on the case of the device itself. Operation outside of the specified temperature range can cause higher component wear and decrease the MTTF, and exponentially increase the AFR.

2.2 Rated Workload

Hard disk drives have mechanical components which are stressed as the components move. This causes the workload (amount of data read or written) to have an influence on reliability. For this, HDD manufacturers have started to specify the maximum yearly

workload under which the MTTF and AFR values are valid. Typical rated workloads are up to 55 TB/year for client devices and up to 550 TB/year for enterprise/server drives. There is no difference between read and write workloads for HDD.

2.3 Load/Unload Cycle

When an HDD is switched to idle-mode, the HDD's actuator arm parks the read/write head on a mechanical ramp to avoid any damage to the rotating media. Due to mechanical stress, the number of these so called load/unload cycle is limited. Today's drives can accept several 100,000 load/unload cycles, which theoretically translates into up to 11 load/unload cycles per hour in 24/7 operation over the warrantied lifetime.

2.4 Start/Stop Cycle

For non-24/7 hard disk drives, a maximum number of start/stop cycles of the spindle motor is specified, and this is usually in the region of around 50,000 cycles.

3. Reliability Specifications for different HDD Classes

3.1 Reliability Specification for traditional HDD Classes

The following table shows an overview of reliability specifications and operating constraints:

Device Class	Enterprise Performance	Enterprise Capacity	Desktop
Form Factor	2.5-inch	3.5-inch	3.5-inch
Capacity[2] (2015)	300GB~1.2TB	1~6TB	500GB~4TB
Spindle Speed	15,000 rpm/10,000 rpm	7,200 rpm	7,200 rpm
Interface	SAS	SAS/SATA	SATA
Operating Temperature	5 - 55°C	5 - 55°C	0 - 60°C
Operating Duty	**24/7**	**24/7**	**8h/day**
Rated Workload	**no practical limitation**	**550TB/year**	**55TB/year**
Load/Unload Cycle	600,000	600,000	300,000
Start/Stop Cycle	N/A	N/A	50,000
Mean Time To Failure	2 million h	1.2~1.4 million h	600,000 h
Warranty	**5 year**	**5 year**	**2 year**

Hard disk drives for enterprise server and storage usage (Enterprise Performance and Enterprise Capacity Drives) have MTTF of up to 2 million hours, at 5 years warranty, 24/7 operation. Operational temperature range is limited, as the temperature in datacenters is carefully controlled. These drives are rated for a workload of 550TB/year, which translates into a continuous data transfer rate of 17.5 Mbyte/s[3]. In contrast, desktop HDDs are designed for lower workloads and are not rated or qualified for 24/7 continuous operation.

3.2 Video and Surveillance HDD

HDDs for video surveillance applications require 24/7 operation. However, the workload is significantly lower than for enterprise/server applications. They are therefore positioned in between enterprise and desktop drives in terms of lifetime- and reliability.

The most crucial feature for this type of drive is 24/7 operation, and some firmware features that support video/streaming specific requirements. Error correction time is limited, so rather than spending time correcting read errors which may interrupt the frame stream, surveillance HDDs drop a frame of data, which is acceptable for such picture streaming applications. Surveillance HDDs typically have a wider operating temperature range, as surveillance storage systems are often located in building automation rooms or studios that are not cooled as precisely as data server rooms.

Device Class	Enterprise Capacity	Video / Surveillance	Desktop
Form Factor	3.5-inch	3.5-inch	3.5-inch
Capacity[2] (2015)	up to 6TB	up to 5TB	up to 4TB
Spindle Speed	7,200 rpm	5xxx rpm	7,200 rpm
Interface	SAS/SATA	SATA	SATA
Operating Temperature	5 - 55°C	0 - 70°C	0 - 60°C
Operating Duty	24/7	**24/7**	8 h/day
Rated Workload	550TB/year	N/A	55TB/year
Load/Unload Cycle	600,000	600,000	300,000
Start/Stop Cycle	N/A	N/A	50,000
Mean Time To Failure	1.2~1.4 million h	1 million h	600,000 h
Warranty	5 year	3 year	2 year

3.3 Capacity HDD for Cloud Data

In the emerging cloud computing segment, many applications need large capacity storage, but workload is significantly lower than for server applications where Enterprise Performance and Enterprise Capacity drives are used.

Device Class	Enterprise Capacity	Enterprise Cloud	Desktop
Form Factor	3.5-inch	3.5-inch	3.5-inch
Capacity[2] (2015)	up to 6TB	up to 6TB	up to 4TB
Spindle Speed	7,200 rpm	7,200 rpm	7,200 rpm
Interface	SAS/SATA	SATA	SATA
Operating Temperature	5 - 55°C	5 -55°C	0 -60°C
Operating Duty	24/7	**24/7**	8 h/day
Rated Workload	550TB/year	**180TB/year**	55TB/year
Load/Unload Cycle	600,000	600,000	300,000
Start/Stop Cycle	N/A	N/A	50,000
Mean Time To Failure	1.2 - 1.4 million h	800,000 h	600,000 h
Warranty	5 year	3 year	2 year

Manufacturers have introduced cloud-class drives, which are rated for the lower workload (approx. 180TB/year), expected for the majority cloud storage applications. In addition, typically, MTTF is limited to 800,000 hours and warranty is 3 years. In contrast to other non-high reliability drives like desktop HDDs, cloud HDDs are qualified for continuous 24/7 operation. And unlike surveillance HDDs, cloud HDDs firmware is tailored for data storage applications, so that for Enterprise Performance or Enterprise Capacity HDDs more time is allowed for read error correction. Also, data reliability is more important than consistent response time.

Cloud HDDs are also suitable for private and enterprise local storage applications, such as NAS (Network attached storage) boxes. In the past, desktop HDDs have been used in such NAS boxes, with users accepting the higher failure rates because the data was protected by the redundancy provided by a RAID array architecture. However, with desktop HDDs not being recommended for 24/7 operation, reliability has always been a concern. Now, with the availability of the cloud-class HDDs, a lower cost, 24/7 device is available for this application.

4. Conclusion

With enterprises facing increasing challenges meeting the ever-growing volumes of data, it is crucial that the right drives are specified for any given application. The discussion in this white paper has been designed to explain the terminology and answer a number of frequently asked questions that pertain to storage endurance and reliability, so that users can specify the storage solutions most appropriate for their needs.

Note:
[1] The MTTF (Mean Time to Failure) is not a guarantee or estimate of product life; it is a statistical value related to mean failure rates for a large number of products which may not accurately reflect actual operation. Actual operating life of the product may not resemble the MTTF.
[2] Definition of capacity: Toshiba defines a megabyte (MB) as 1,000,000 bytes, a gigabyte (GB) as 1,000,000,000 bytes and a terabyte (TB) as 1,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1GB = 230 = 1,073,741,824 bytes and therefore shows less storage capacity. Available storage capacity (including examples of various media files) will vary based on file size, formatting, settings, software and operating system, such as Microsoft Operating System and/or pre-installed software applications, or media content. Actual formatted capacity may vary.
[3] Read and write speed may vary depending on the host device, read and write conditions, and file size.

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