FUJI IGBT Module 6MBI800XV-075V-01

Calculation of power cycling lifetime when there are multiple different temperature rise peaks

The power cycling lifetime of the IGBT module depends on the temperature swing (and maximum temperature) during power cycle. Therefore, when there is only one temperature swing of the IGBT module in one particular operation cycle of the inverters/converters, the number of times calculated from the power cycling lifetime curve is the life cycle of the IGBT module.

However, when there are multiple temperature rise peaks in one operation cycle of the inverter, the life cycle becomes shorter because the module is influenced by the multiple temperature rises. The calculation method of power cycling lifetime when there are multiple different temperature rise peaks like the driving pattern of an automobile is shown below.

The following explains how to calculate the power cycling lifetime by taking as an example a pattern in which the junction temperature of the IGBT fluctuates as shown in Fig. 1 within one cycle of the operation pattern.

①Count the number of occurrences of each junction temperature fluctuation (ΔT_{vj}) within one cycle of the operation pattern.

②From the number of occurrences of each junction temperature fluctuation (ΔT_{vj}) and the ΔT_{vj} power cycling lifetime curve of the IGBT module, calculate the power cycling lifetime using the cumulative fatigue damage rule.

①Counting the number of occurrences of each junction temperature fluctuation (ΔT_{vj})

★There are several methods for counting ΔT_{vj}, such as the range pair method and the rainflow method.

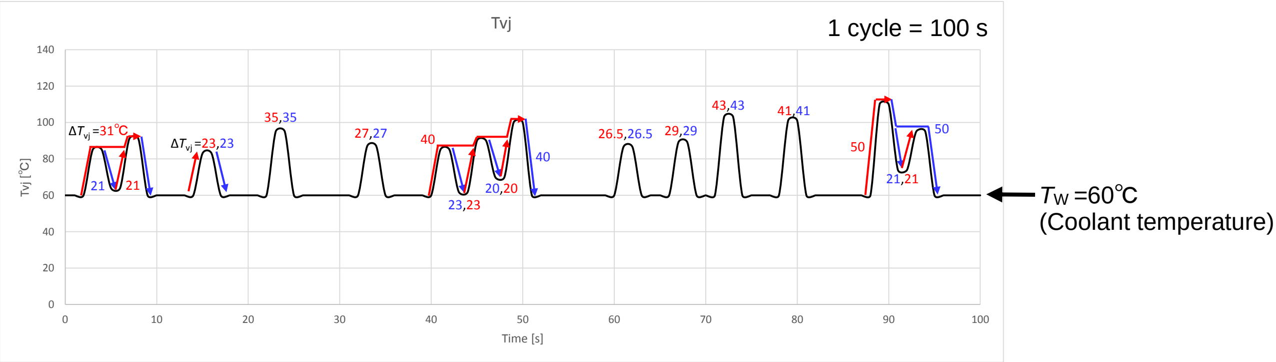

Fig. 1 Junction temperature fluctuation within one cycle of operation pattern

Table 1 Number of occurrences of each junction temperature fluctuation

i	ΔT_{vj}	Number of occurrences n_i’
1	20～22℃(21±1℃)	3
2	22～24℃(23±1℃)	2
3	26～28℃(27±1℃)	2
4	28～30℃(29±1℃)	1
5	30～32℃(31±1℃)	1
6	34～36℃(33±1℃)	1
7	40～42℃(41±1℃)	2
8	42～44℃(43±1℃)	1
9	50～52℃(51±1℃)	1

②Calculation of power cycling lifetime using cumulative fatigue damage rule

If junction temperature fluctuation of ΔT_{vj1}, ΔT_{vj2}, ΔT_{vj2}･･･occurs, the number of cycles until the IGBT breaks is read from ΔT_{vj} power cycling lifetime curve and these are taken as N_1, N_2, N_3･･･.

Next, if the number of occurrences of junction temperature fluctuation such as ΔT_{vj1}, ΔT_{vj2}, ΔT_{vj3}･･･is n_1, n_2, n_3･･･, the cumulative fatigue damage ratio is expressed by the following equation..

$$D = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \cdots\cdots + \frac{n_i}{N_i}$$

When D becomes 1, fatigue failure occurs. However, in actuality, calculate the number of cycles that D becomes 0.7 or less in anticipation of the margin (Recommend example).

If the number of lifetime cycles is 280,000 cycles, n is the number of occurrences shown below and the cumulative fatigue damage ratio D is 0.69 (<= 0.7). Since 1 cycle of the pattern in Figure 1 is 100 s, the lifetime will be "100 s × 280,000 Cycles / 3,600 s = 7,778 hours".

Table 2 Lifetime calculation

i	ΔT_{vj}	N_i	Number of occurrences of each temperature variation within one cycle n_i’	n_i (n_i’×280,000)	Cumulative fatigue damage ratio D ($\Sigma n_i/N_i$)
1	21±1℃	3.35E+09	3	840,000	2.51E-04
2	23±1℃	1.37E+09	2	560,000	4.10E-04
3	27±1℃	2.84E+08	2	560,000	1.97E-03
4	29±1℃	1.41E+08	1	280,000	1.98E-03
5	31±1℃	7.37E+07	1	280,000	3.80E-03
6	33±1℃	2.27E+07	1	280,000	1.23E-02
7	41±1℃	4.92E+06	2	560,000	1.14E-01
8	43±1℃	3.11E+06	1	280,000	9.01E-02
9	51±1℃	6.02E+05	1	280,000	4.65E-01
					D=0.69

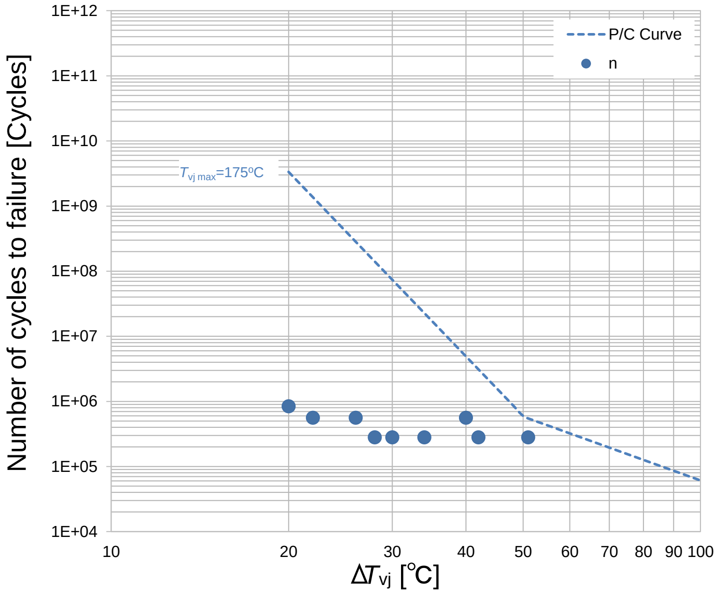

Fig. 2 ΔT_{vj} Power cycling lifetime curve and frequency of occurrence

③Junction temperature fluctuation caused by ambient temperature change ($\Delta T_{vj\ (long\ time)}$)

The above shows the calculation method considering only the self heat generation ($\Delta T_{vj\ (short\ time)}$) of the IGBT chip by inverter operation.

However, in fact, when it is greatly influenced by the outside air temperature like the automotive inverters, it is necessary to calculate the life in consideration of ΔT_{vj} caused by outside air temperature variation as shown in the following formula.

$$n[\Delta T_{vj}] = n[\Delta T_{vj\ (short\ time)}] + n[\Delta T_{vj\ (long\ time)}]$$

$\Delta T_{vj\ (long\ time)} = T_{vj\ (max)} - T_a$ (outside air temperature(Ambient temperature))

Example1 : $\Delta T_{vj\ (long\ time)}$ = 80℃－10℃ = 70℃

Example2 : $\Delta T_{vj\ (long\ time)}$ = 80℃－(－20℃) = 100℃

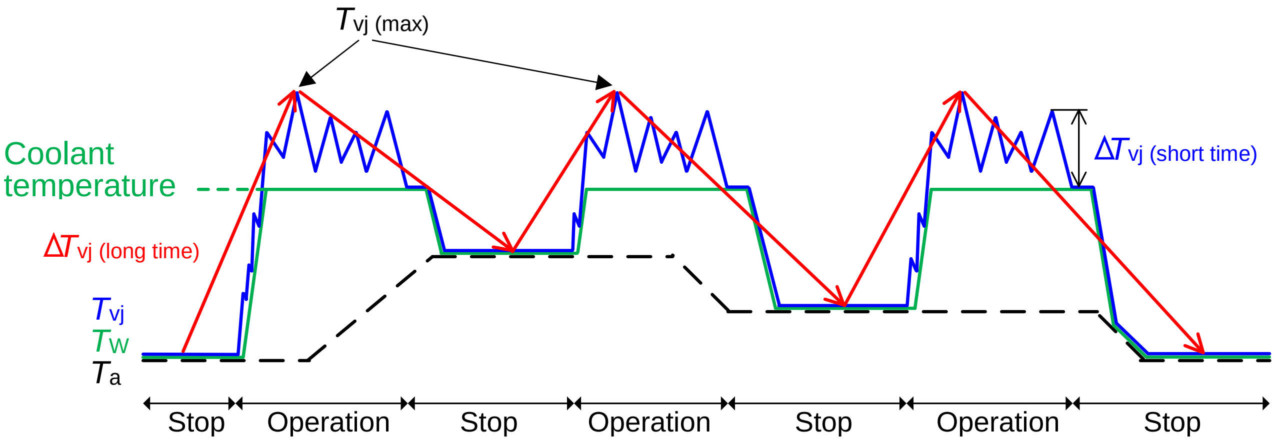

Fig. 3 Junction temperature fluctuation caused by ambient temperature change

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