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Study of Busbar Displacement of Aluminum Reduction Cells

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Abstract

With the increase of the cell capacity, the busbar length, the current load in each busbar and the magnetic field intensity around the cell are all increasing consequently, so are the electromagnetic forces on each busbar and the thermoelectric stress inside them. As a result, big displacements occur on busbars and even worse, the insulation bricks are crushed by busbar movement. Displacements of busbars lead to deformation of flexes, which may be detrimental to cell life. The displacement of the longest and highest-current branch is taken as study object, its displacement and stress status are studied systematically.

1. Introduction

In the past, the main safety concern of reduction cell busbar has usually been focused on prevention of current overload[1,2]. However, with the success and application of large PB cells, their surrounding magnetic intensity and busbar current are getting bigger and bigger. Combined with bigger busbar length, magnetic forces born by busbars and resulting displacement have become a problem needing much attention. One typical busbar displacement is shown in Fig.1.

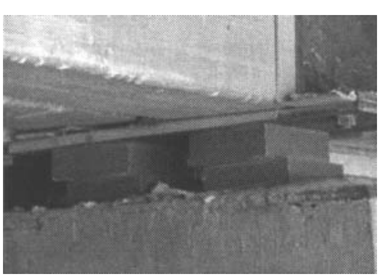

Fig.1. Displacement of insulation bricks under round-end busbars

It can be seen in Fig.1 that there is obvious movement of insulation bricks toward the cell center. This phenomenon is common on some large PB cells, both at tapping end and duct end, and some bricks are even crushed. Another feature is that, in most cases, the movement is also along the current direction while moving inwardly. But the current-oriented displacement is usually smaller than that of the inward direction. As to the causes, it should be the result of the magnetic forces on round-end busbars. But the amount of displacement is also dependent on busbar thermal expansion since busbars will expand after energized especially in cell longitudinal direction. If the displacement is too big, it will certainly affect the busbar safety and even the cell itself. By analyzing the thermoelectric effect of the busbars, displacement of busbars and its influence on the cells are studied.

2. Methodology

There are quite a number of branches in one cell's ring-bus. The longest and the highest-current loaded is usually the one running around cell ends. Its displacement by magnetic forces and thermal effect is also the biggest, so a study on it is representative. Here, one such branch is selected to study its displacement.

2.1 Model buildup

The model was built with actual busbar sizes. In the model, -X is with potline current direction, +Z is vertical up and X, Y, Z are following right-hand law.

2.2 Boundary conditions

Three kinds of conditions are considered:

(1) Round-end busbar is not constrained, free moving, but constrained at both ends on US&DS sides.

(2) Initial displacement (from magnetic forces) is imposed on round-end busbar. Others are the same as (1).

(3) Round-end busbar is constrained at two points, i.e., two fixed supporting brackets are added, but the busbar end at US side is free. Others are the same as (1).

Other boundary conditions include equal potential and initial temperatures at both ends of the branch, surface thermal emission conditions, etc.

3. Results and analysis

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3.1 Results of thermal expansion displacement

The temperature distribution, displacement and stress of the busbar with only thermoelectric effect are shown in Fig.2 to Fig.5 respectively.

It can be seen from Fig.2 that the highest temperature point occurs at the joint of flex and steel bar and flex temperature is far higher than any other position. Meanwhile, the joint of flex and cast-bus has a much higher temperature than other positions on the cast-bus. The round-end section has the lowest temperature due to its lower surrounding air temperature and better ventilation.

In addition, the biggest displacement of the busbar occurs at the corner position of the US side (see Fig.4), being only about 0.005m. Generally, such thermoelectric displacement is negligible in normal operations. Busbar stress is shown in Fig.5.

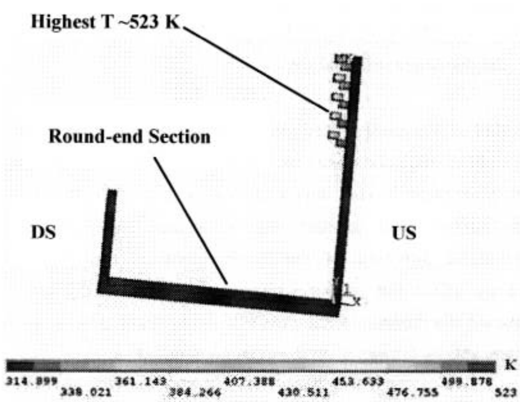

Fig.2. Temperature of the whole branch

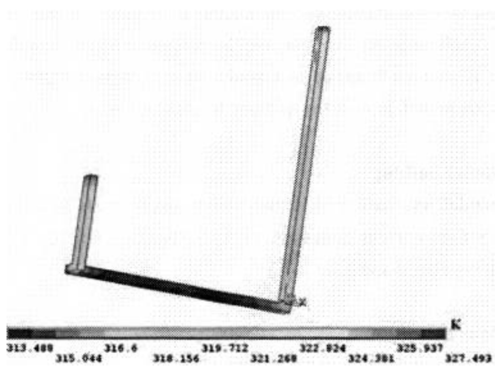

Fig.3. Temperature of cast-busbar

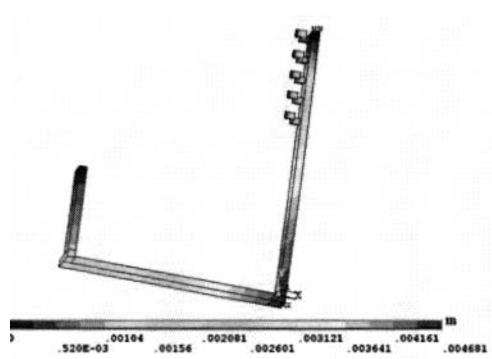

Fig.4. Busbar displacement with only thermoelectric effect

It can be seen that the stress mainly occurs at both ends of the busbars and at the ends of the flex because these points are constrained.

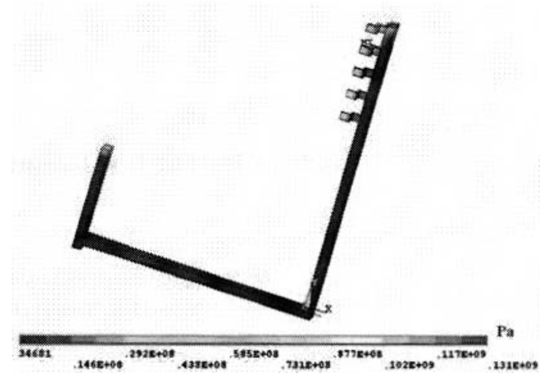

Fig.5. Busbar stress with only thermal effect

3.2 Actual displacement of the busbar

To calculate the actual displacement, a displacement of 0.01m from electromagnetic forces (Assume the average displacement by electromagnetic forces is 0.01m.) is imposed initially on the round-end busbar and the constraint on the end of US side busbar is lifted. Other boundary conditions are unchanged. Simulation results are shown in Fig.6 to Fig.8.

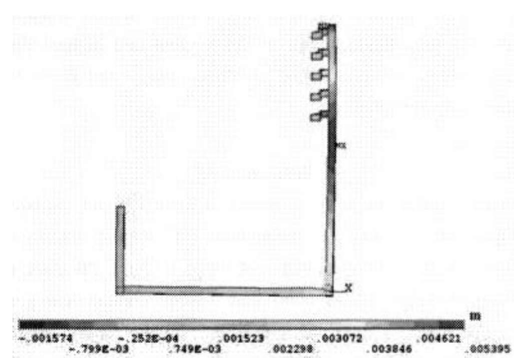

Fig.6. X-displacement of the busbar

It can be seen from Fig.6 that the X-displacement is very small, only about 0.005m, i.e., the cast-bus bulges outside for about 0.005m, with the biggest bulge occurring at position next to the ou

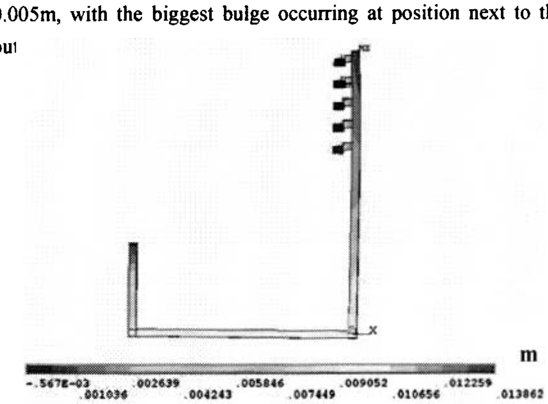

Fig.7. Y-displacement of the busbar

From Fig.7, it can be seen that busbar displacement occurs mainly in the Y direction and the busbar end at US side moves inward for about 0.014m, pulling the flexes inwards for 0.011m to 0.014m respectively. Because of their horizontal deformation, the deflective characteristics of the flexes can not be fully used. Hence, the displacement will exert forces on steel bars, which may be detrimental to cell life.

Besides, it can also be seen from Fig.8 that there is no obvious concentrated stress on US side busbar because it's not constrained and the stress can be easily released. Different from US side busbar, there is obvious stress buildup in DS side busbar because its end is constrained.

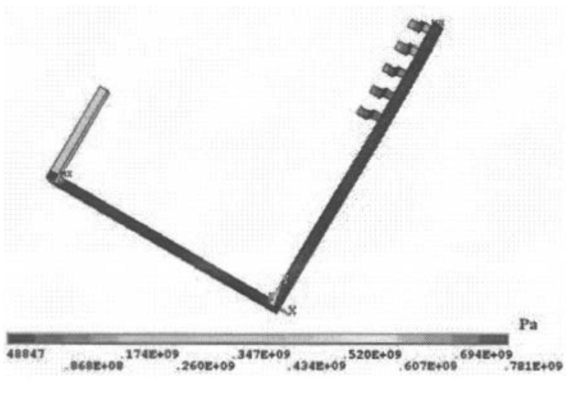

Fig.8. Busbar stress

3.3 Results with two fixed brackets on round-end busbar

The busbar displacement and stress distribution with two fixed brackets (It should be a U-type clamp welded or bolted to the concrete supporter to limit busbar's Y-direction displacement, not the X-direction.) on round-end busbar are shown in Fig.9 to Fig.11.

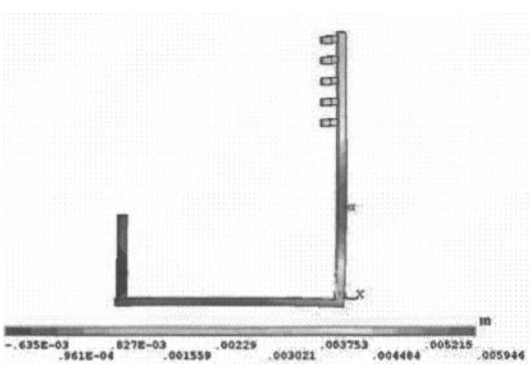

Fig.9. X-displacement with two fixed brackets on round-end busbar

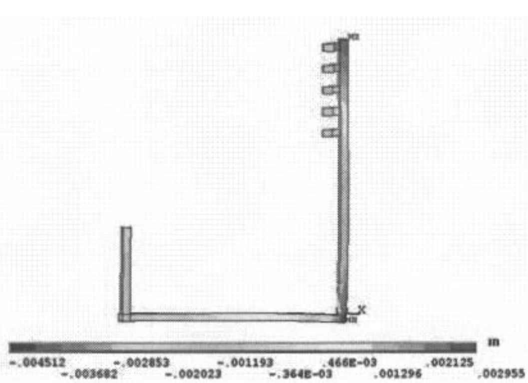

Fig.10. Y-displacement with two fixed brackets on round-end busbar

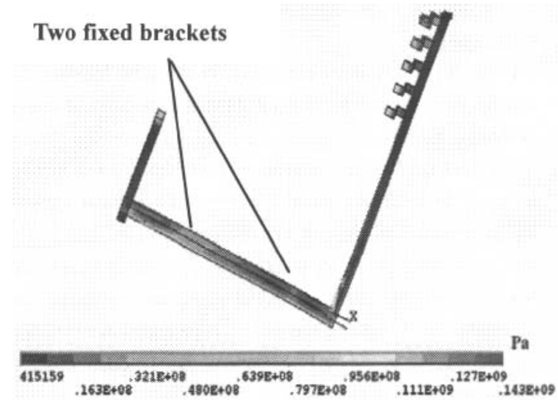

Fig.11. Busbar stress with two fixed brackets on round-end busbar

It can be seen from Fig.9 and Fig.10 that the Y-displacement in busbar extends towards two directions, which is helpful to reduce the effect on flexes. Meanwhile, the biggest X-displacement on US side busbar occurs at position which moves even more outside compared with Fig.6. However, the biggest difference arising from two fixed brackets on round-end busbar is the stress distribution. As shown in Fig.11, the concentrated stress at the two supporting points is about 3.0×10^7Pa which is less than the yielding strength of aluminum at room temperature (~10^8 Pa). So, the busbar is safe. However, the stress exerted on the brackets should be considered while designing the supporters.

4. Suggestions and measures

The direct consequence of busbar displacement is the horizontal deformation of flexes and internal stress in the cast-busbar, which will threat ring-bus safety and electrical insulation. Therefore, busbar displacement should be reduced to the lowest. However, highly controlled displacement will cause big internal stress concentration in the busbars. So, my suggestion is to compromise displacement and stress releasing. Based on the results above, my suggestions are as follows:

4.1 Setting fixed brackets on round-end busbar, permitting some movement of round-busbar but not freely. This will limit the movement of US busbar inwardly. However, the disadvantage of this structure is higher requirements for the installation of round-end brackets and the manufacture of busbars. Meanwhile, round-end concrete supporters must be able to bear high shear forces (see Fig.11).

4.2 Setting fixed bracket (a device tightly clamping the busbar) at the end of US side busbar to prevent busbar movement inwardly. The disadvantage of this structure is this bracket must be strong enough to bear the double forces of magnetic and thermoelectric forces (see Fig.5). Meanwhile, the biggest displacement will occur at the corner of US side busbar (see Fig.4).

4.3 Connecting round-end busbar and US&DS busbars with flexes and setting fixed bracket at the end of US busbar. The disadvantage of this structure is increased manufacture cost.

5. Conclusions

By studying the behavior of the longest and the highest-current loaded busbar under magnetic and thermoelectric effects, it is concluded:

5.1 The highest-temperature occurs at the joint between the flex and the steel bar and the biggest thermal expansion of cast-busbar is about 0.005m.

5.2 If there are no fixed brackets on round-end busbar, it will move inwardly by magnetic force. Together with thermal expansion, a big horizontal displacement will occur on US side busbar. This will pull and deform the flexes and even be detrimental to cell life.

5.3 To reduce the effect of busbar movement on flexes, cast-bus, especially the round-end busbar, must be constrained. Meanwhile, connecting the round-end busbar and the US&DS busbars with flexes may be helpful.

References

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