Development of a 3D Transient Thermo-Electric Cathode Panel Erosion Model of an Aluminum Reduction Cell

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Plan of the Presentation

- Introduction
- Model Description
- Base Case Model Solution
  - Maximum expected life: 2012 days
- Analysis of the First Retrofit Proposal
  - Maximum expected life: 2468 days
- Analysis of the Second Retrofit Proposal
  - Maximum expected life: 3509 days
- Conclusions

Introduction

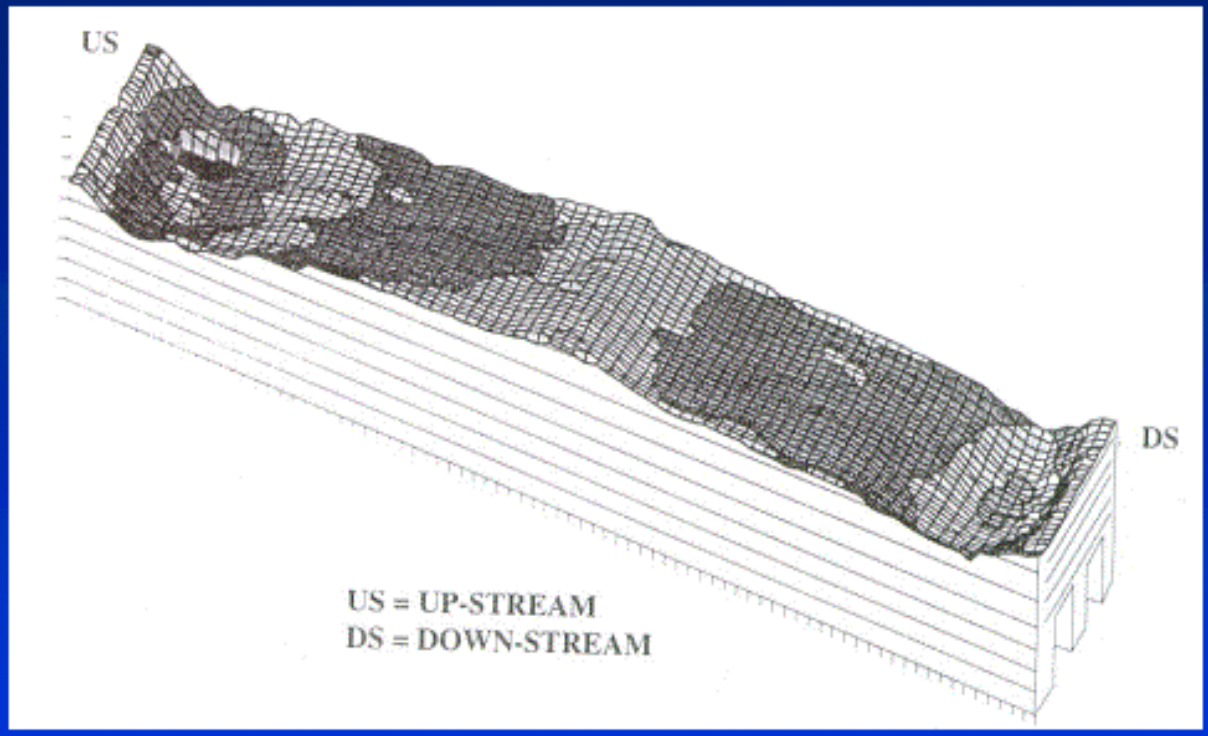
- For high amperage cells, graphitized carbon cathode blocks are now the preferred choice because, contrarily to the graphitic blocks, their use prevent the cathodic resistance to increase to catastrophic level with cell age

- Unfortunately, graphitized cathode blocks are characterized by an increased erosion rate that limits, in current cell designs, the cell life to a maximum of 2500 days

Model Description

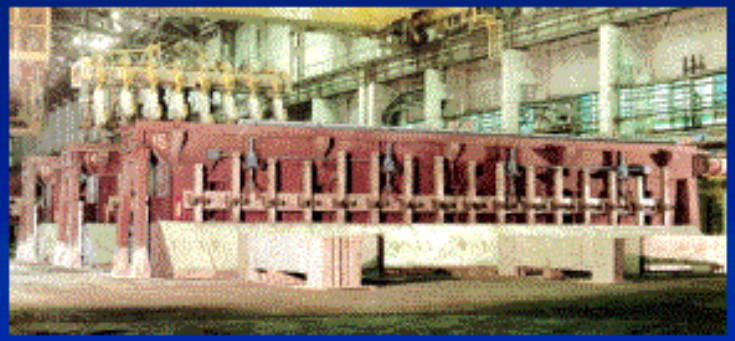
- Extensive measurement campaigns clearly show that the erosion rate is proportional to the cathode block surface current density

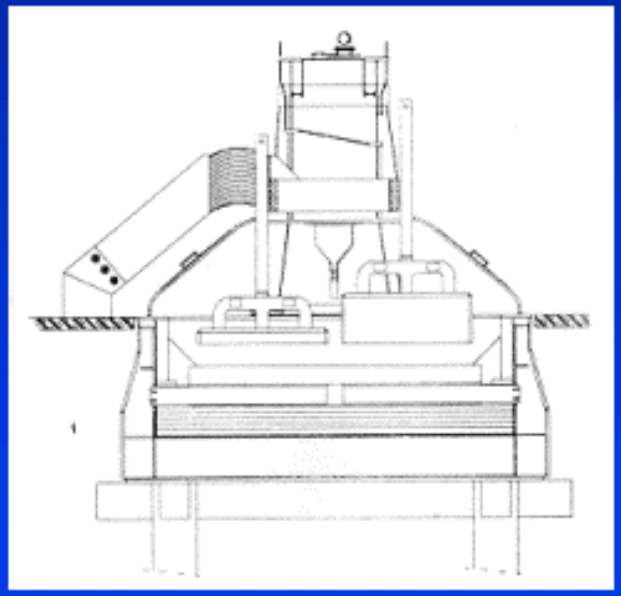
Model Description: Erosion Law

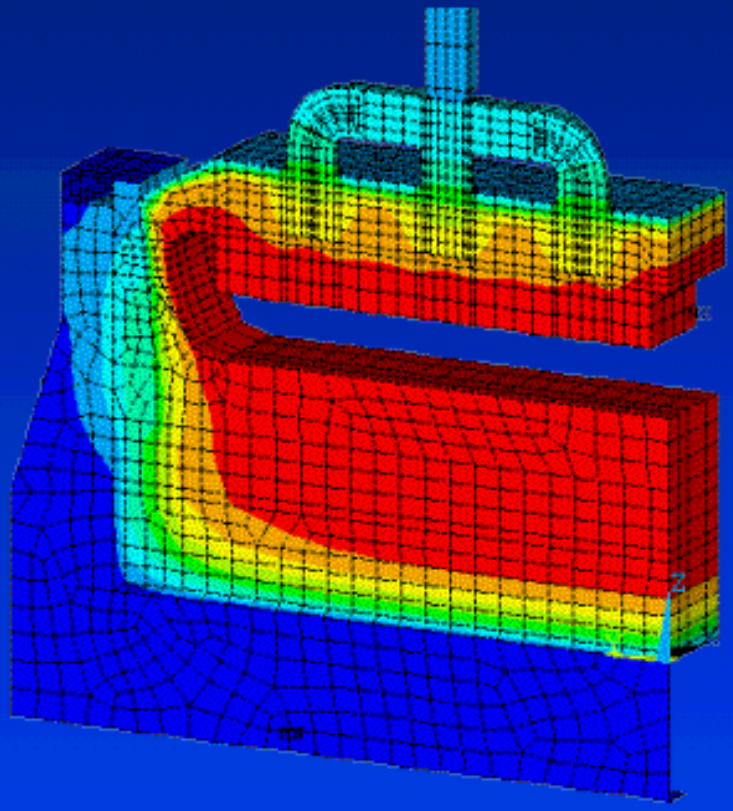


- $ER_{(cm/year)} = A_{(cm/year)} + B_{(cm/(year\ A/cm2))} * CD_{(A/cm2)}$
- Constants A and B should be adjusted in order to minimize the difference between the model predictions and measured erosion profile

Base Case Model Solution







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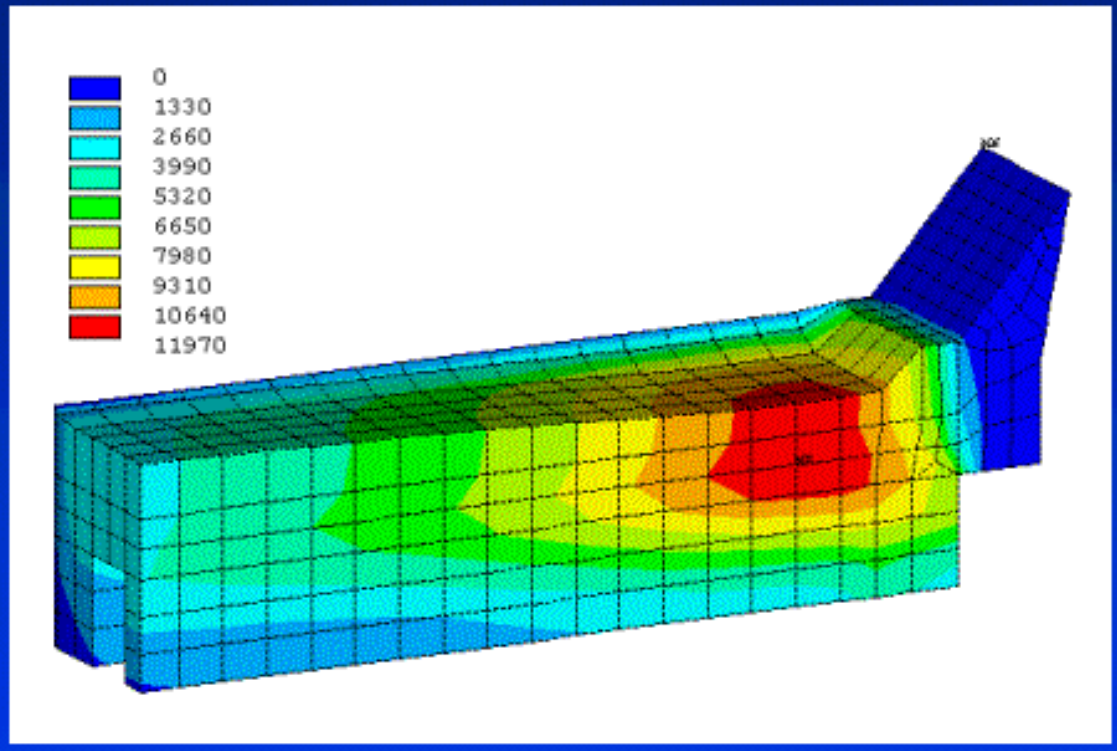
Base Case Model Solution



- Erosion profile of the base case model after 2 years

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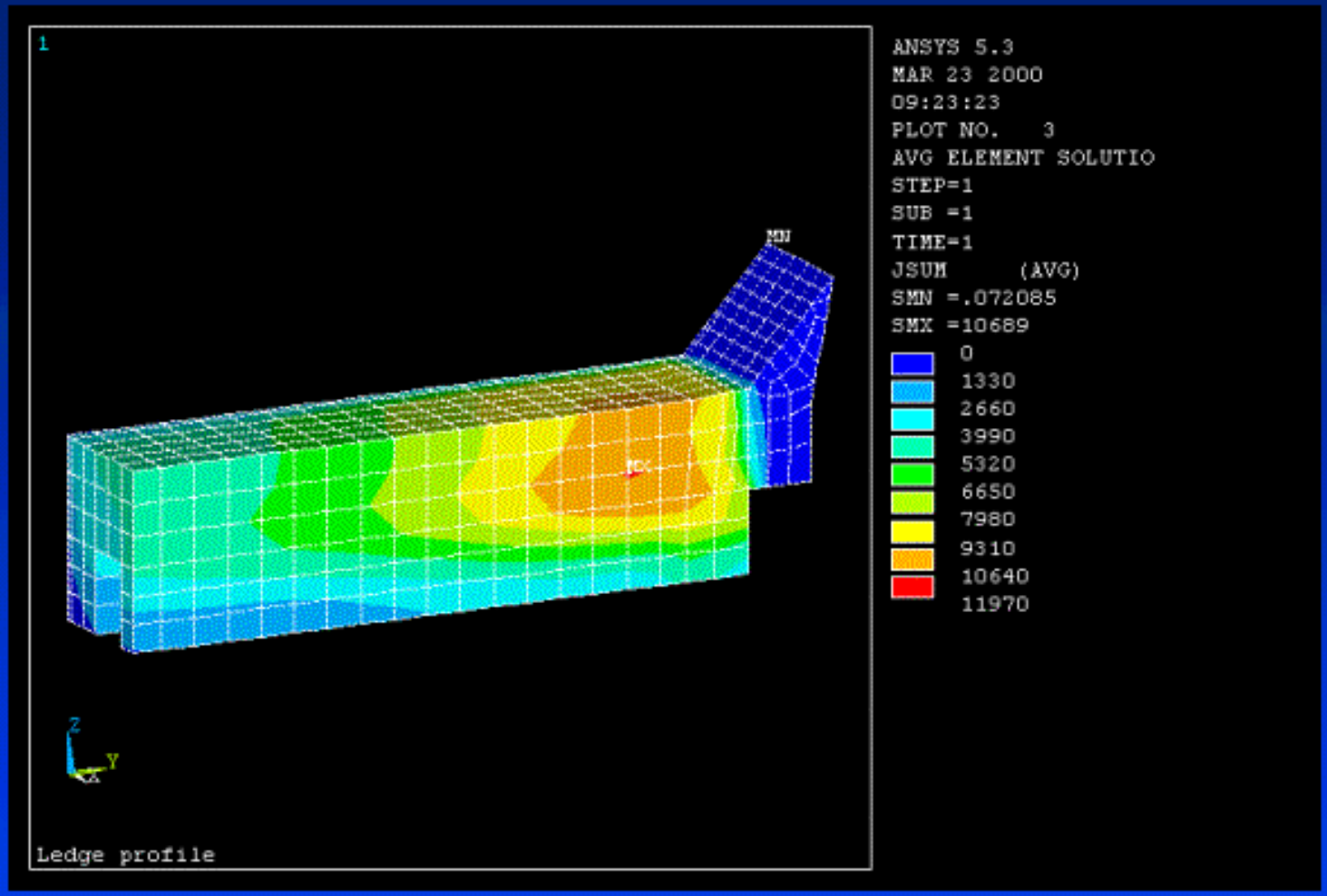
Base Case Model Solution



- Erosion profile animation of the base case model for the first 2 years

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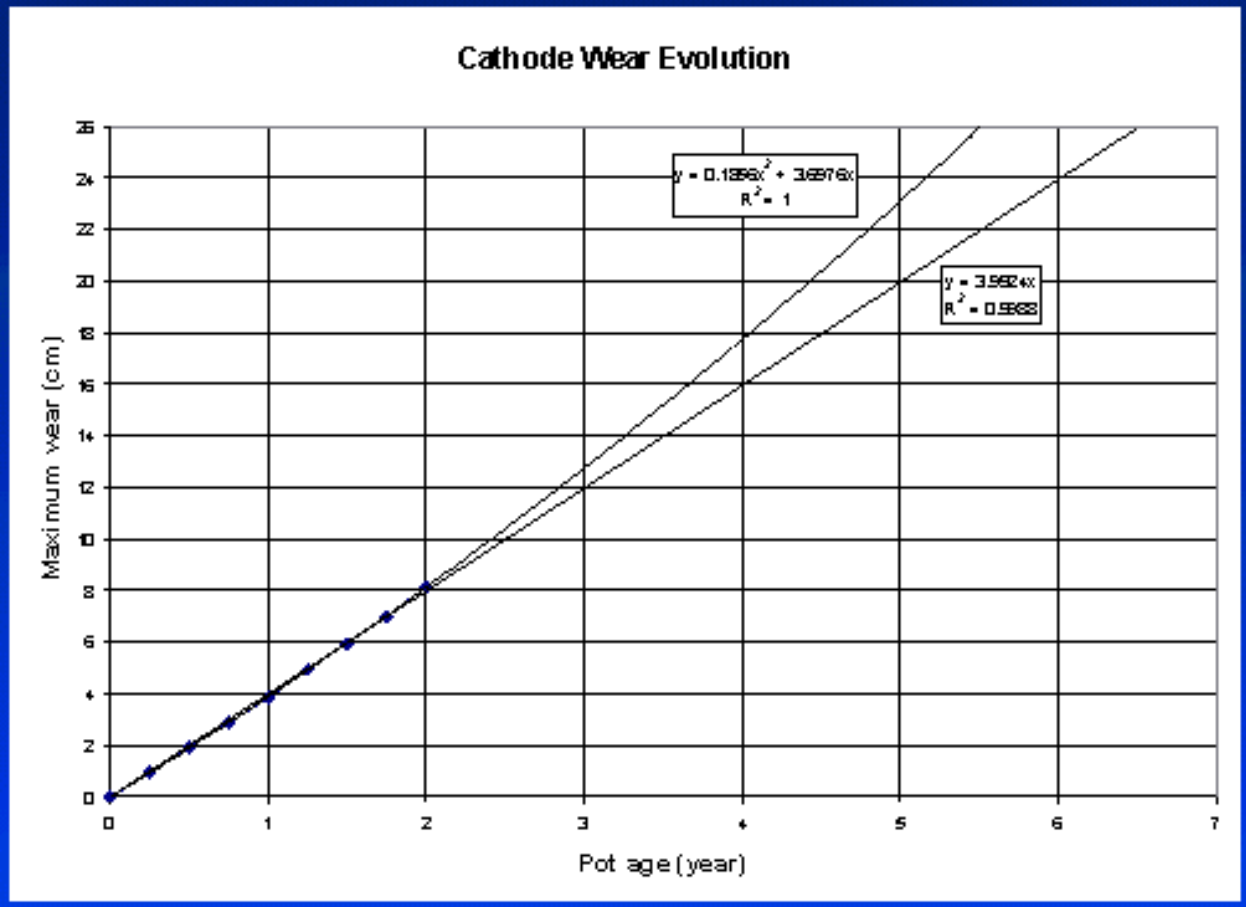
Base Case Model Solution



- Evolution of the maximum erosion of the base case model

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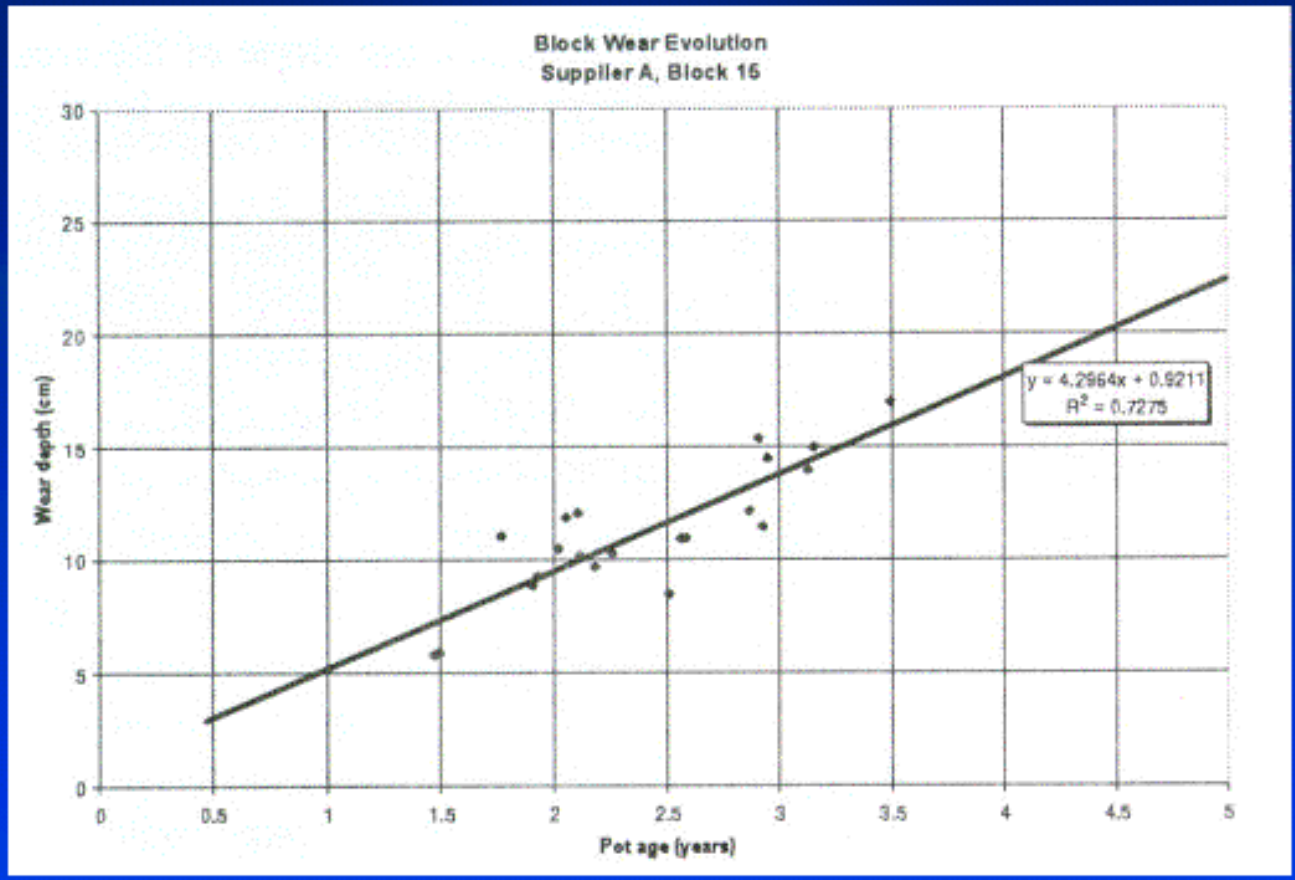
Base Case Model Solution

- Faster erosion in location of initial higher current density will promote further concentration of that current density as the cathode resistance is getting smaller where carbon thickness is getting thinner
- So maximum cathode erosion evolution is not linear
- Linear extrapolation predicts a maximum cell life expectancy of 2379 days
- A more accurate quadratic extrapolation predicts a maximum cell life expectancy of 2012 days

Base Case Model Solution



- Model prediction in good agreement with measured data

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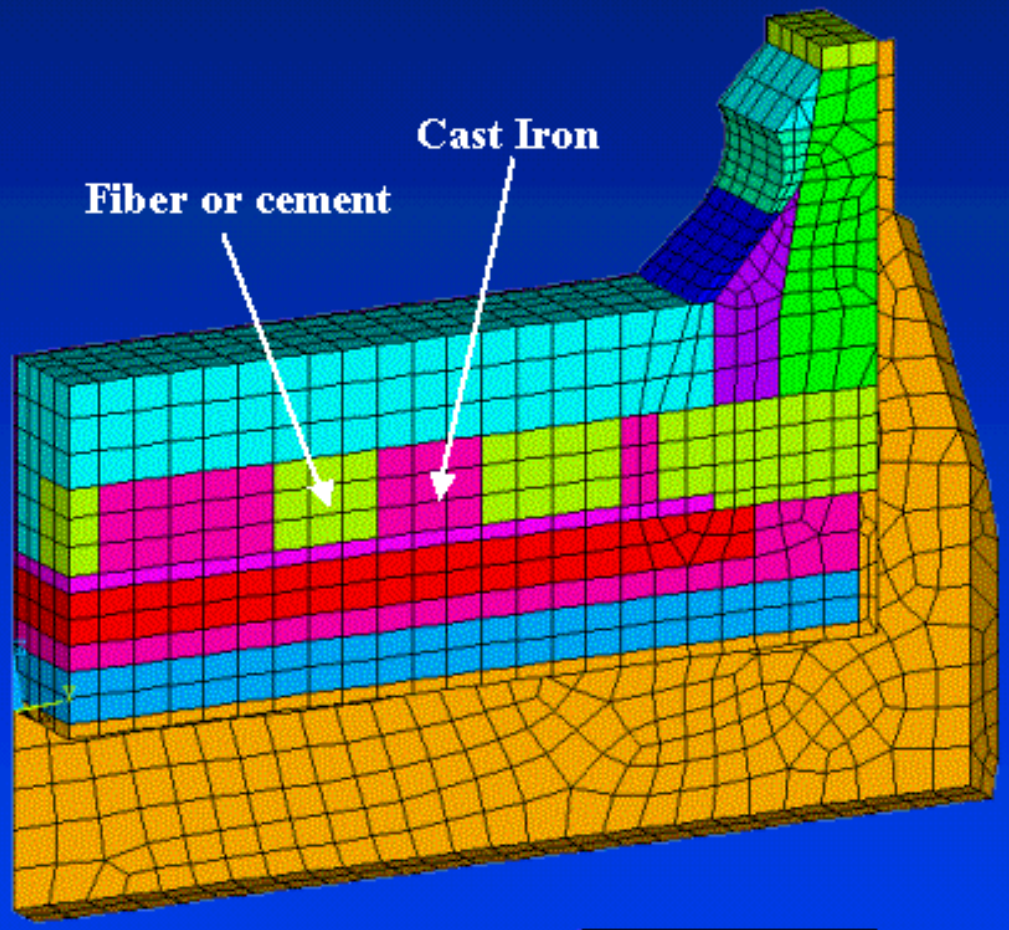
Analysis of First Retrofit Proposal

- Partial cast iron rodding in order to promote a uniform current density at the surface of the cathode block
- Increase of 20% of the collector bar width from 10 to 12 cm



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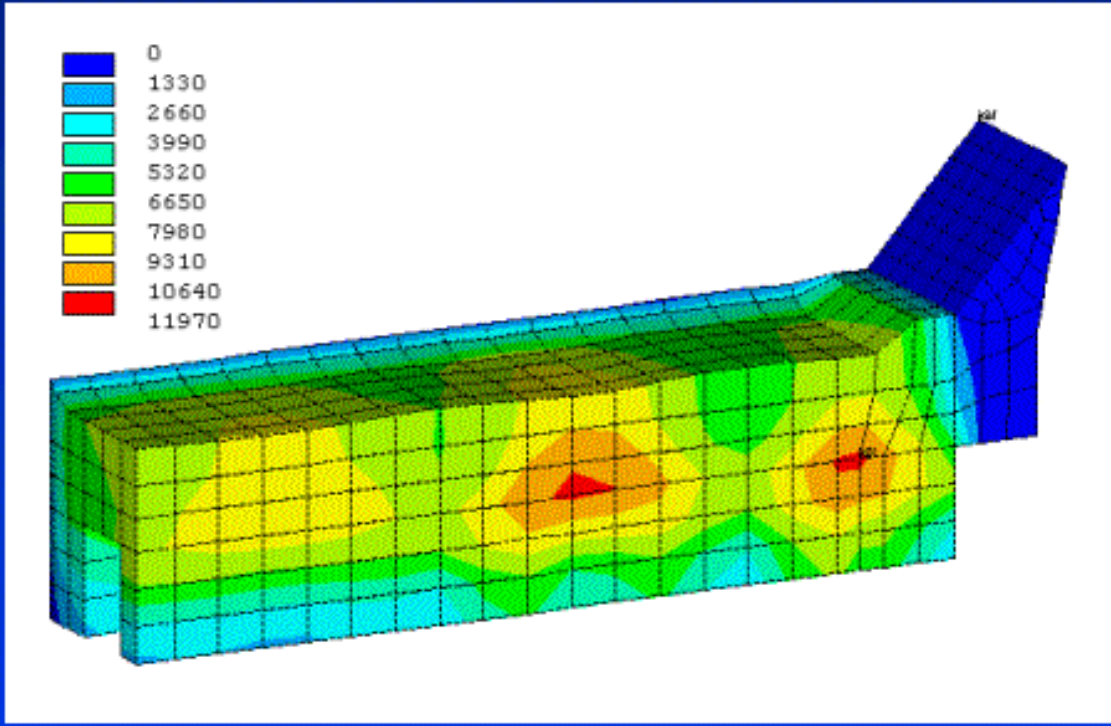
Analysis of First Retrofit Proposal



- Erosion profile of the first retrofit proposal after 2 years

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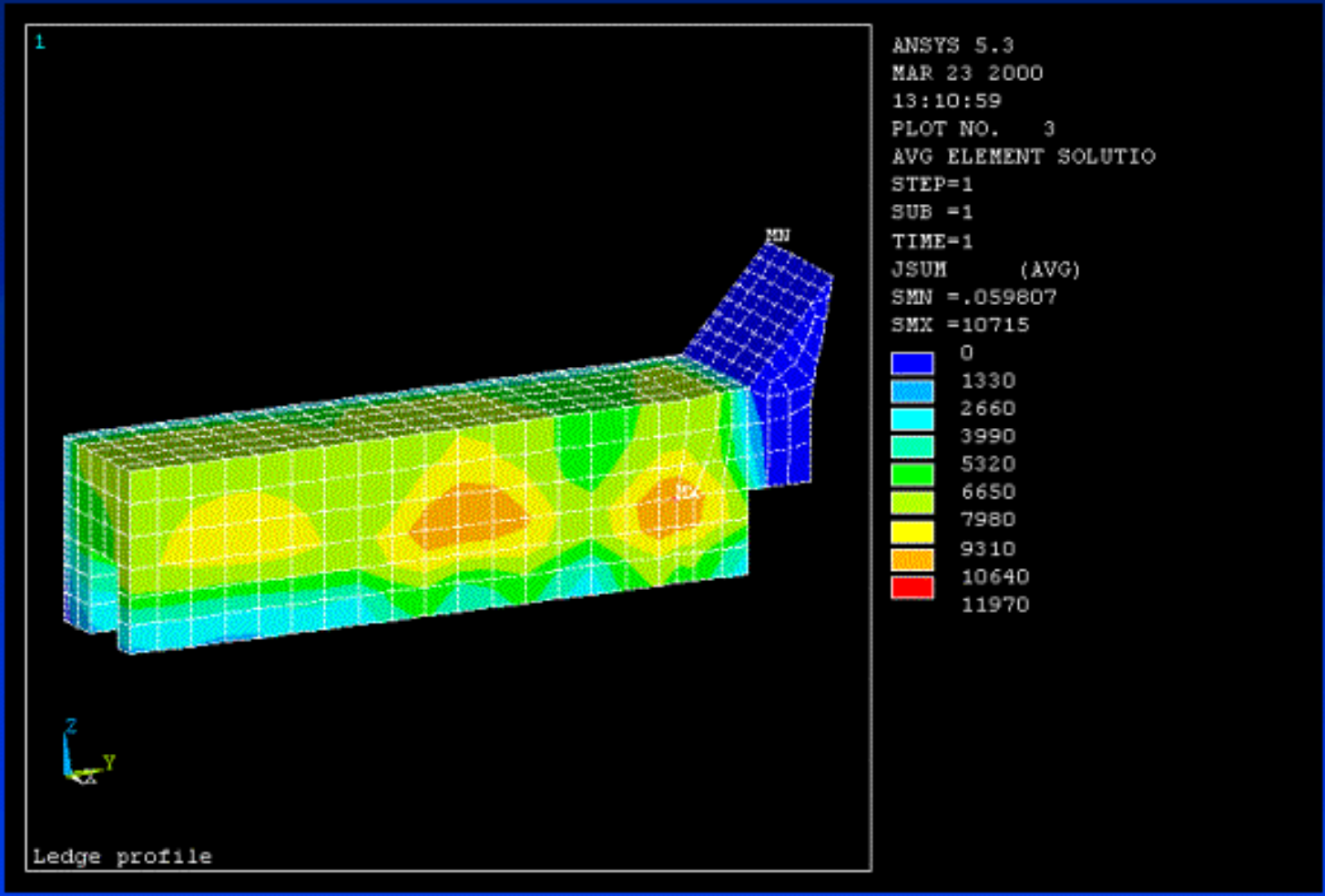
Analysis of First Retrofit Proposal



- Erosion profile animation of the first retrofit proposal for the first 2 years

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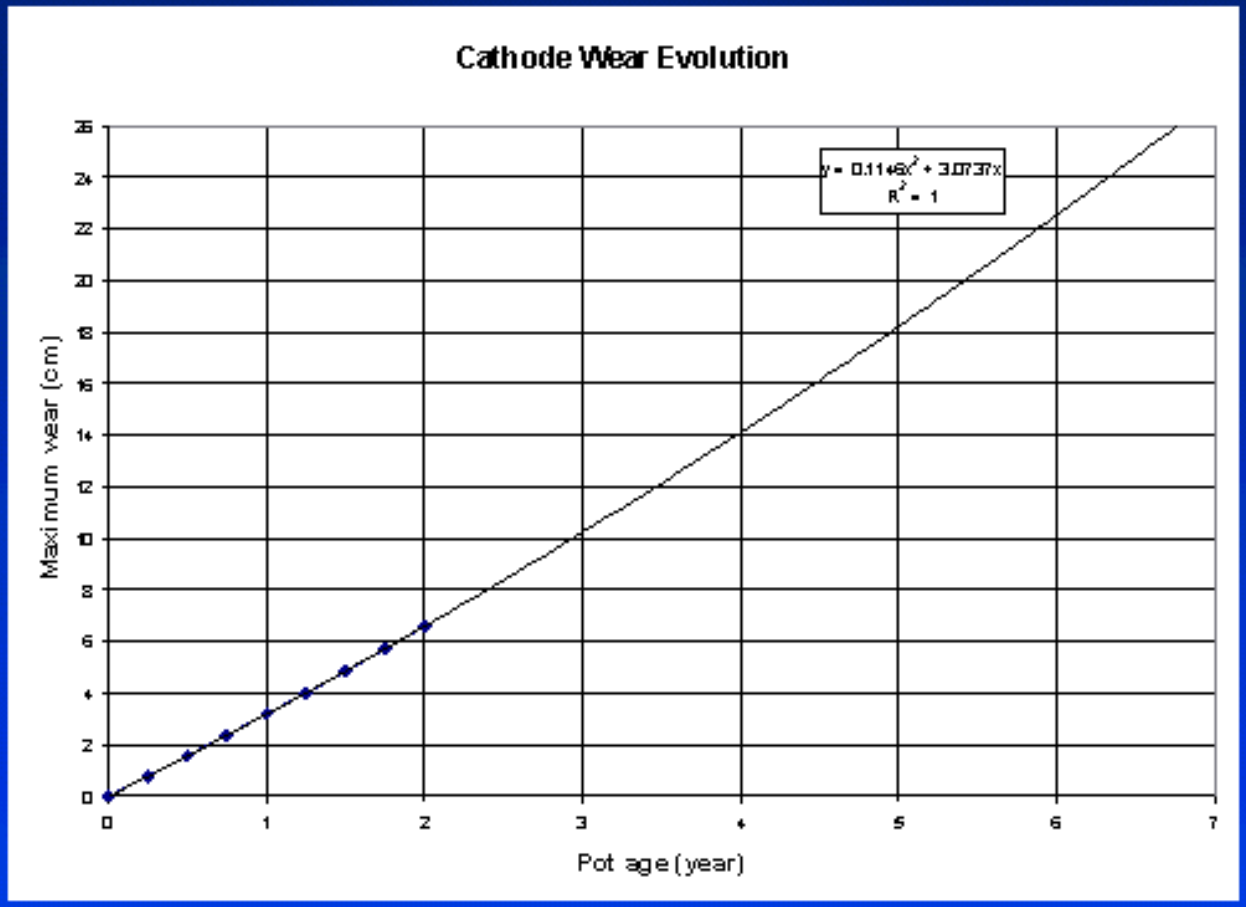
Analysis of First Retrofit Proposal



- Evolution of the maximum erosion of the first retrofit proposal

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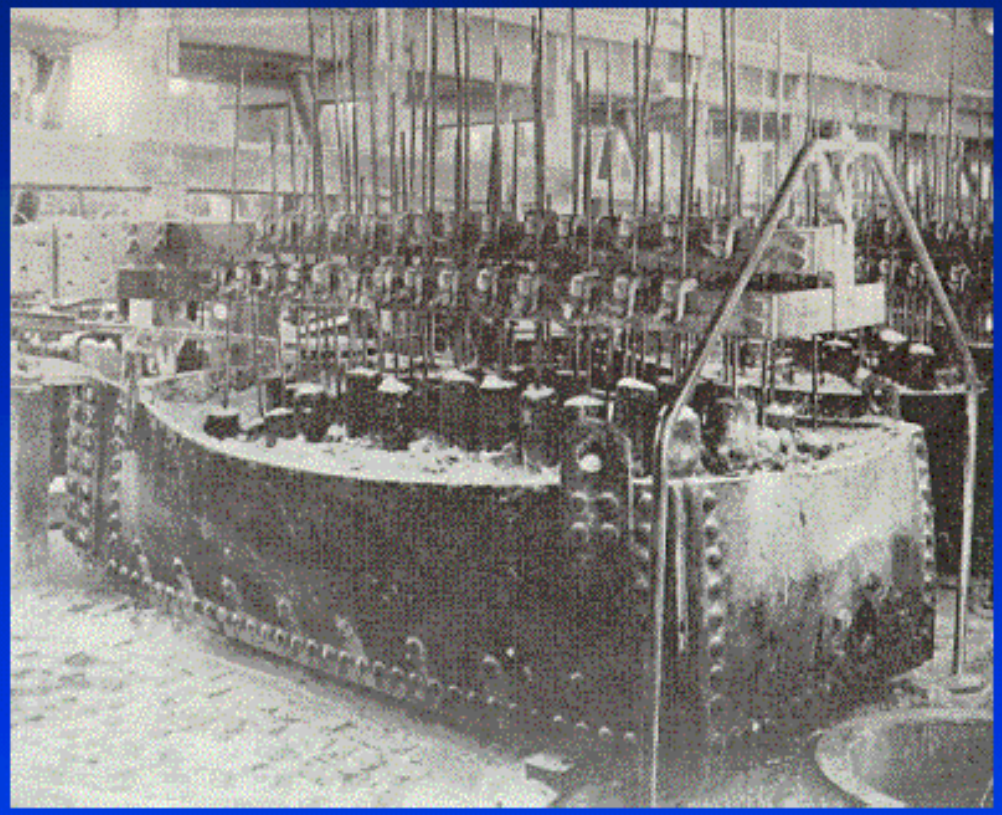
Analysis of First Retrofit Proposal

- Almost uniform current density at the surface of the cathode block
- Corresponding almost uniform cathode surface erosion
- Quadratic extrapolation predicts a maximum cell life expectancy of 2468 days
- The price to pay is an increase of 23% of the cathode drop from 273 to 335 mV

Analysis of Second Retrofit Proposal

- For almost a century the aluminum industry was designing pot shells too weak to maintain their integrity while exposed to the huge internal pressure resulting from the high sodium expansion coefficient of anthracite carbon blocks
- In the 70's, pot shells were finally designed strong enough to withstand that huge pressure
- Nowadays, the same strong pot shells are being used with the graphitized carbon blocks that do not have a big swelling coefficient!



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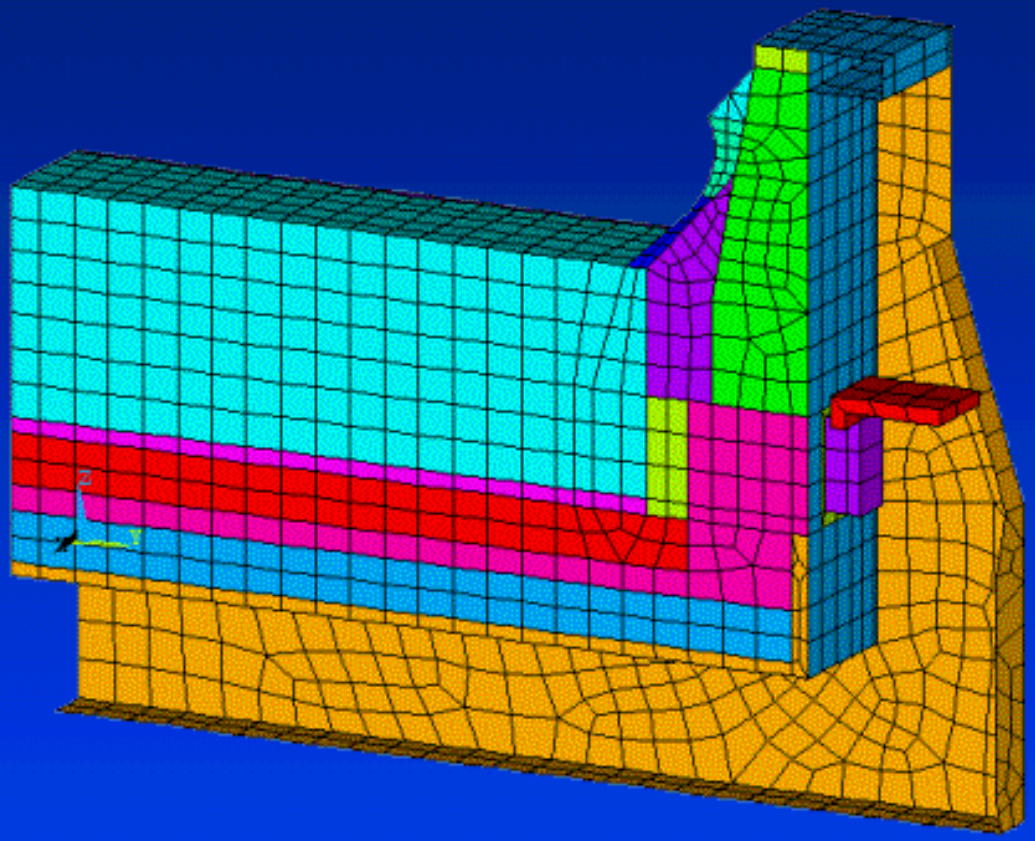
Analysis of Second Retrofit Proposal

- Same changes as first proposal
  +
- Increase the collector bar height by 20% from 20 to 24 cm
- Increase of 10 cm of the block height
- Decrease by 10 cm the height of the horizontal cradles web under the pot shell floor



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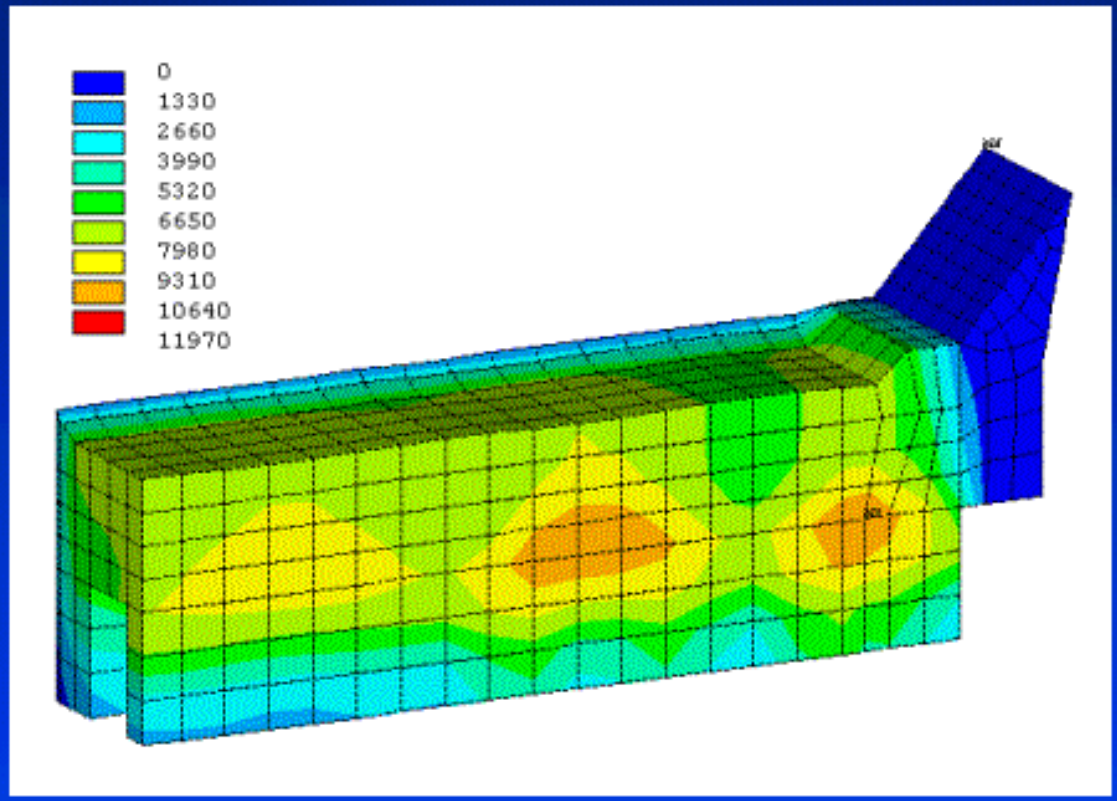
Analysis of Second Retrofit Proposal



- Erosion profile of the second retrofit proposal after 2 years

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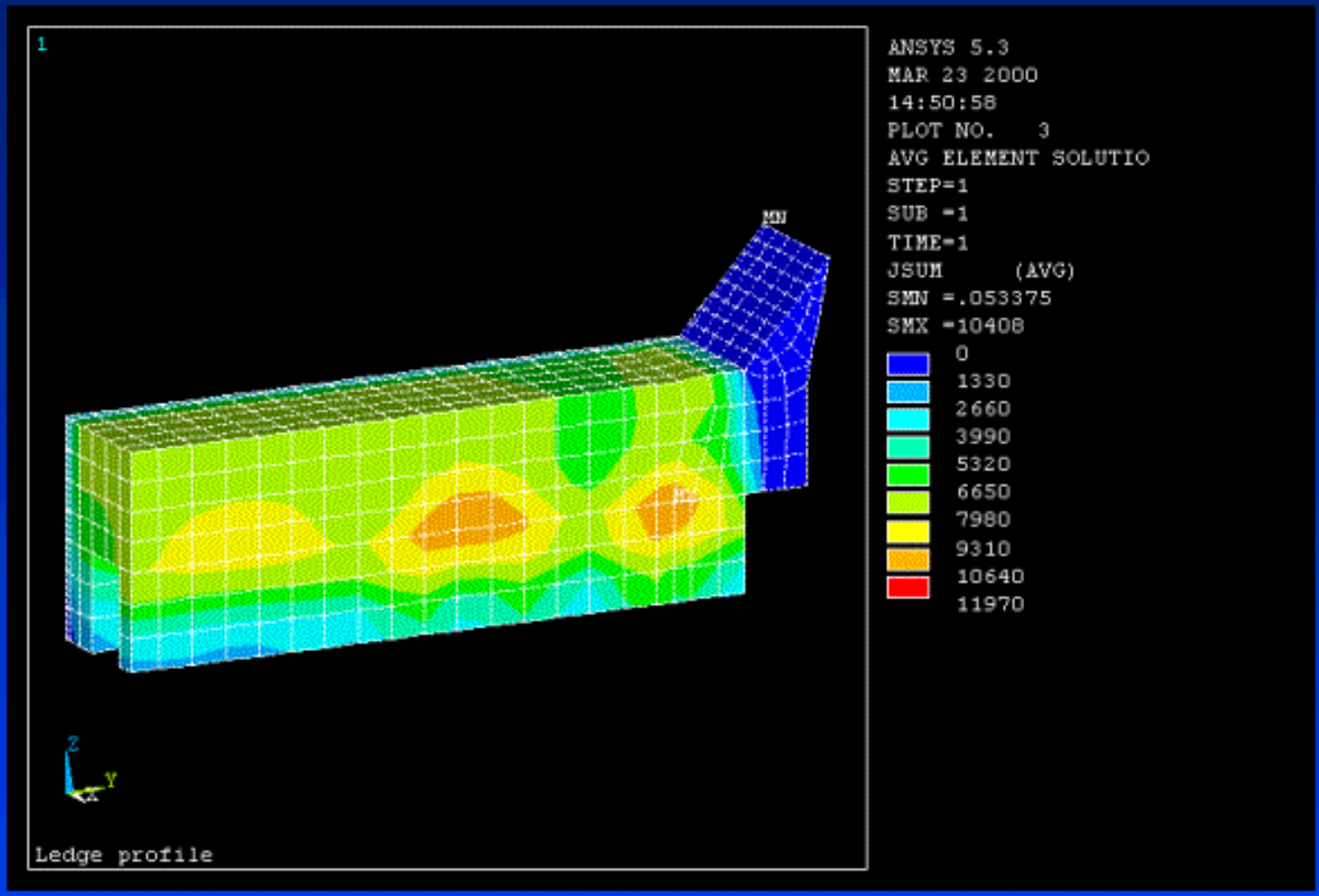
Analysis of Second Retrofit Proposal



- Erosion profile animation of the second retrofit proposal for the first 2 years

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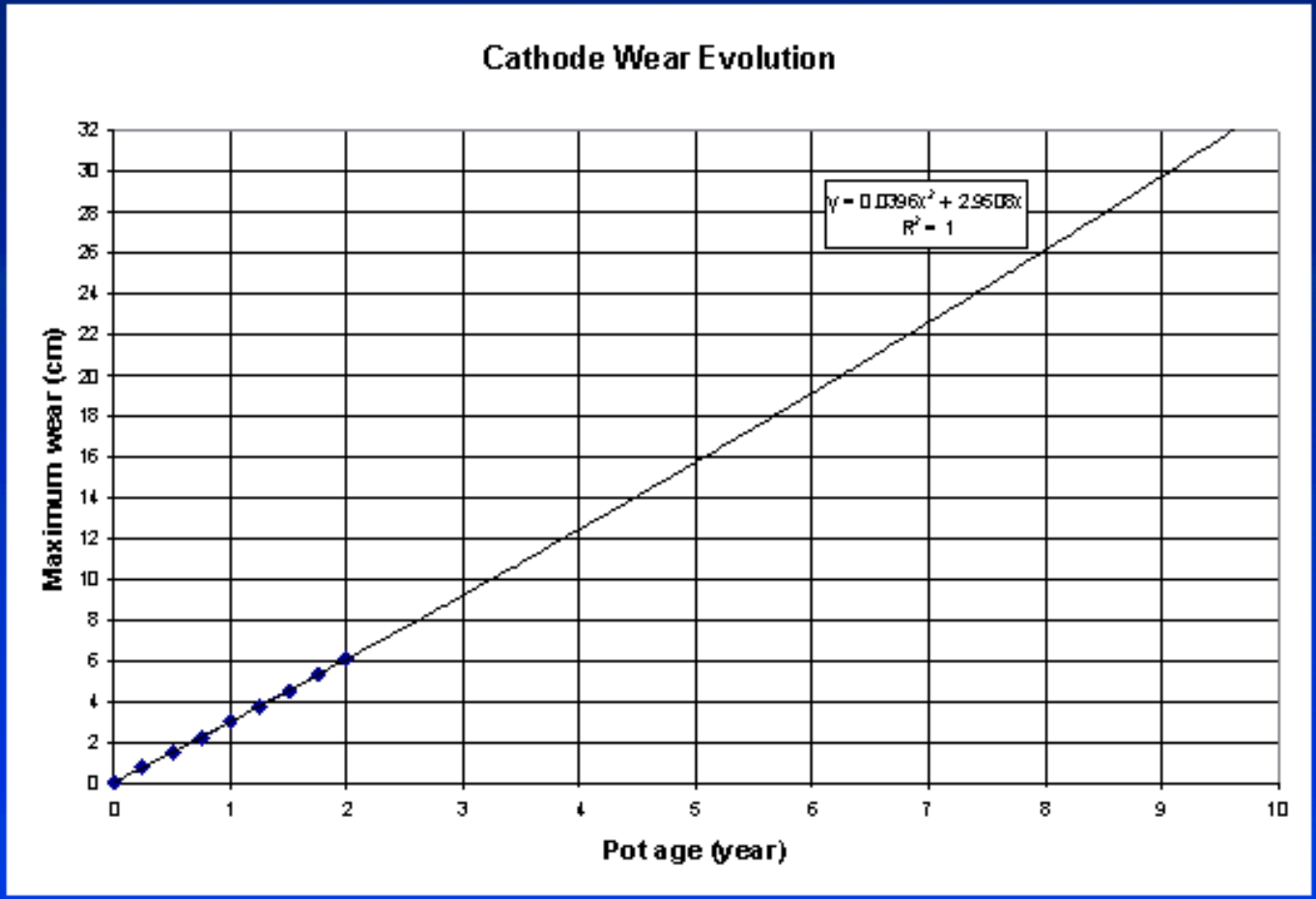
Analysis of Second Retrofit Proposal



- Evolution of the maximum erosion of the second retrofit proposal

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Analysis of Second Retrofit Proposal

- Almost uniform current density at the surface of the cathode block
- Corresponding almost uniform cathode surface erosion
- Quadratic extrapolation predicts a maximum cell life expectancy of 3509 days
- The price to pay is an increase of 7% of the cathode drop from 273 to 293 mV

Conclusions

- A new 3D transient thermo-electric cathode panel erosion model has been successfully developed and tested.
- This new tool can be used to predict theoretical cell life of any retrofit design proposal aiming at decreasing maximum erosion rate and improving cell life.
- An innovative yet simple retrofit design proposal was demonstrated to be an effective way to almost double the theoretical maximum cell life.