BRAZING IN SPACE

The next frontier...

4/27/2005

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OUTLINE

• WHY DO WE NEED TO JOIN COMPONENTS IN SPACE
• WHY BRAZING?
• HISTORY OF BRAZING IN SPACE
• ELECTRON BEAM VACUUM BRAZING
• CURRENT EFFORT AT GSFC
• FUTURE WORK
BRAZING IN SPACE

WHY DO WE NEED TO JOIN COMPONENTS IN SPACE

BOEING VISION OF ON-ORBIT CONSTRUCTION SITE FOR SPS

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BRAZING IN SPACE

WHY DO WE NEED TO JOIN COMPONENTS IN SPACE

- In-space assembly can enable the deployment of large systems that cannot be accommodated in current or near-term launch vehicle payload provisions, whether limited by total mass, volume, density, or mission criticality.

- Risk mitigation and failure-intervention provisions, both for mission objectives and for humans space flight support, can be more readily accommodated on an assembly mission than on a build-and-deploy mission.
BRAZING IN SPACE

WHY DO WE NEED TO JOIN COMPONENTS IN SPACE

"As for the future, your task is not to see it, but to enable it"
Antoine de-Saint Exupery

A DRAWING OF HUMANS AND ADVANCED ROBOTIC ASSISTANTS BUILDING A SPACE TELESCOPE,

NASA, The Vision for Space Exploration, Feb. 2004
WHY BRAZING?

STRUCTURAL JOINING PROCESSES:

- MECHANICAL JOINING
- WELDING
- ADHESIVE BONDING
- BRAZING
• WHY BRAZING?

• NO SINGLE METHOD CAN SATISFY ALL JOINING NEEDS IN SPACE

• SELECTION OF JOINING METHOD DEPENDS ON:
  
  - APPLICATION
  - TYPE OF STRUCTURE
  - MATERIALS
WHY BRAZING?

OUR FOCUS IS ON CONSTRUCTION OF LARGE TRUSS STRUCTURES IN SPACE:

• TEDEIOUS AND SLOW PROCESS;

• CONSISTS OF A LARGE QUANTITY OF REPETATIVE STEPS;

• REQUIRES PERMANENT JOINTS
• WHY BRAZING?

SPACE IS A NATURAL ENVIRONMENT FOR VACUUM BRAZING:

• no extra cost is required to create vacuum!
• does not depend on gravity - relies on capillary action
• molten metal is drawn into the joint interface
• joins any shape and any wall thickness
• generates no debris or fumes
• WHY BRAZING?

.... AND THE WINNER IS ... ELECTRON BEAM VACUUM BRAZING!

• ELECTRON BEAM IS A VERY FLEXIBLE, HIGHLY CONTROLLED METHOD OF DELIVERING PRECISE AMOUNT OF ENERGY TO A SPECIFIC LOCATION – BEAM CAN BE DEFLECTED, CHANGE SPOT SIZE, ACCELERATION VOLTAGE, PULSING, ROTATION – ALL BEAM MANIPULATIONS CAN BE DONE ELECTRONICALLY, I.E. NO MECHANICAL MOVEMENT IS REQUIRED!

• ELECTRON BEAM GUN IS A MATURE TECHNOLOGY, IDEALLY SUITED FOR SPACE ENVIRONMENT!

• IT HAS BEEN SUCCESSFULLY USED IN SPACE FOR WELDING, BRAZING, CUTTING AND METAL VAPOR DEPOSITION BY THE RUSSIAN COSMONAUTS.

• TRADE-OFF ANALYSIS SHOWS THAT EB BRAZING IS A BETTER CHOICE THAN LASER, RESISTANCE, INDUCTION OR EXOTHERMIC PROCESS
<table>
<thead>
<tr>
<th>PLATFORM</th>
<th>MATERIALS BRAZED</th>
<th>BRAZE ALLOY</th>
<th>HEAT SOURCE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skylab Station, USA, 1973</td>
<td>Pure nickel/tubes and sleeves, 304L stainless steel tubes and sleeves.</td>
<td>AWS BAg8a (71.8%Ag, 28% Cu and 0.2% Li)</td>
<td>Exothermic reaction</td>
<td>Excellent filler metal flow. Nice fillet formation. 0-g helps capillary action.</td>
</tr>
<tr>
<td>TEXUS II sounding rocket, Germany, 1978</td>
<td>Pure nickel cylinders</td>
<td>58%Ag, 39%Cu, 3% Li</td>
<td>Isothermal furnace</td>
<td>Extremely wide gaps of up to 2 mm could be filled under microgravity owing to capillary forces.</td>
</tr>
<tr>
<td>STS-9, Launch # 9, Columbia, USA, 1983</td>
<td>Nickel cylinders</td>
<td>AWS BAg8a</td>
<td>Isothermal Heating Facility</td>
<td>Microstructure was found to be independent on the gravitational level.</td>
</tr>
<tr>
<td>Solyut 7 Space station, USSR, 1984 - 1986</td>
<td>Thin wall nickel chromium alloy tubing plated with Ni to promote wetting.</td>
<td>Low melting alloy Sn-2Ni-4Ge developed at Paton Welding Institute.</td>
<td>Hand held Universal Electron Beam Gun</td>
<td>Good wetting and formation of fillets. After melting, pre-placed filler metal did not flow outside the joint gap. Much wider gaps can be filled under 0-g.</td>
</tr>
<tr>
<td>TR-IA sounding rocket, flight # 5, Japan, 1996</td>
<td>Stainless steel sleeves</td>
<td>Ag-Cu-Li alloy</td>
<td>Multipurpose furnace</td>
<td>Samples were subjected to isothermal and temperature gradient conditions. All joints showed complete penetration under microgravity. Future plans include additional metallurgical studies to develop basic data for structural construction in space.</td>
</tr>
</tbody>
</table>
ELECTRON BEAM VACUUM BRAZING EXPERIMENT WAS PERFORMED QUITE SUCCESSFULLY BY THE RUSSIAN COSMONAUTS IN OPEN SPACE ON SALYUT-7 IN 1986.
BRAZING EXPERIENCE IN SPACE – CONSTRUCTION OF "MIR-2"
• ONGOING EFFORT AT GODDARD

IN-SPACE ROBOTIC INTEGRATION SYSTEM (IRIS)

(initiated in 2005)

• BRAZING PROCESS
• BRAZEABLE TRUSS STRUCTURE
• AUTOMATION
EFFORT AT GODDARD – brazing process

ROTATING ELECTRON BEAM IS APPLIED TO THE INTERNAL SURFACE OF THE BRAZE JOINT

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EXAMPLE OF BRAZEABLE TRIANGULAR TRUSS

TOP VIEW

45° ROTATION
BRAZING IN SPACE

- EFFORT AT GODDARD – brazeable truss structure
• EFFORT AT GODDARD – brazeable truss structure

EXAMPLE OF 2-WAY "OPEN" FITTING
BRAZING IN SPACE

- EFFORT AT GODDARD – robotics

MAJOR CHALLENGE – ROBOTIC PRECISION POSITIONING

FITTING  TUBULAR STRUT

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• EFFORT AT GODDARD – brazeable assembly

2-WAY NODE ASSEMBLY SHOWING THE BRAZE JOINTS READY FOR BRAZING

PRE-PLACED FILLER METAL