

Key [Blue \(Carol Wieseman\)](#)
 Black (Boucke/Ballmann)

Subject: Re: Beam Finite Element
Date: Friday, May 6, 2011 8:37 AM
From: Josef Ballmann <ballmann@lufmech.rwth-aachen.de>
To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>
Conversation: Beam Finite Element

Attached you will find the Timoshenko beam model of the wing which was established by my co-workers Carsten Braun, Lars Reimer and Alexander Boucke, who finalized in its attached version for his beam finite element model. It has been successfully applied to the HIRENASD wing model mounted in the European Transonic Windtunnel. Elastic properties of the suspension components comprising the wind tunnel balance are included.

Best regards,
Josef Ballmann

For better understanding Alexander Boucke has prepared the following explanation:

The basic model for our beam model of the elastic wing is based on the Timoshenko-Beam (read http://en.wikipedia.org/wiki/Timoshenko_beam_theory here for a good start). The beam formulation has been extended by torsion and longitudinal forces and modified to be valid for generalized cross sections (see a. Boucke's thesis <http://sylveste.rwth-aachen.de/dissertationen/2004/119/index.htm> written in German).

This generalization involves the representation of the beam through three separate axes: The axis of centre of mass (line C), the axis of centre of bending (line B) and the axis of centre of shear (line D). Slightly simplified the mass inertia works on line C, external bending forces on line B and torsion happens around line D. Throughout the wing, Lines B and C generally fall together, while the centre of shear is in a different location.

The attached file is an excerpt describing the complete beam model for the HIRENASD wing as used by A. Boucke's own FE-program. The coordinate system used is the same as used in the grids and geometry files on the website with x pointing downstream. Due to the history of the software some of the description seems somewhat complicated.

The properties are described in three parts:
Nodes, Material properties and Elements.

0) any text starting with '--' is seen as comment on the data

1) Nodes: The description starts with 'Node ==>' followed by the name of the node and the 3 coordinates. If the mentioned lines of mass centre C, bending centre B or shear centre D differ by a set margin from the reference line, then the coordinates of C, B or D are given in the lines following immediately after the node definition. If B and C fall together the letter BC are joined.

2) Material properties: The description starts with 'Elastic_Material ==>' followed by the name and then the basic values for the elastic law used for the beam model. Please beware, that the shear modulus 'G_Mod' may deviate from the actual value of the material, as it is set so that the products involving it are of the correct size - this is due to the evolution of the program. The shear coefficient 'kappa' is material and geometry dependant, so it should be with the properties of the beam. The value given is set for the flap bending movement of the wing,

3) Beam properties: The description starts with 'Cylindric_Module =>'. This naming should not be mistaken for a circular cross section. Data given are the names of the Nodes Node_1 and Node_2. These correspond to a definition given before. Same for a material to be applied to this beam. Further given are the cross sectional area, the second moments of area for the local beam main axes, an rotational angle 'Alpha' (more later) and the second moment of area for torsion 'J'.

The beam is formulated in local coordinates. The beam's x-axis runs from node_1 to node_2 of the beam. The local y-z plane is rotated by the angle 'Alpha' around the local x-Axis, with the local y-Axis enclosing Alpha to the global y-Axis.

The weight distribution also contains the wiring inside the wing.

Subject: Re: Beam Finite Element

Date: Tuesday, May 17, 2011 3:29 PM

From: Wieseman, Carol d. <carol.d.wieseman@nasa.gov>

To: Josef Ballmann <ballmann@lufmech.rwth-aachen.de>

Cc: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

I guess this means you don't have a Nastran finite element model. Any plans to make one. I can't use the model directly as is and would need to create one if the AePW is going to use the Beam model as the standard. At this point I don't know that the time is worth it to create it with the file that you gave me.

Thanks for the thesis. Too bad I don't know German but we might dissect the equations..

Did you ever do frequency sweeps wind-off? Could you send me that data if you did? Also if you didn't then how did you confirm the modal frequencies of the model.

Subject: Re: Beam model HIRENASD

Date: Wednesday, May 18, 2011 5:05 PM

From: Wieseman, Carol d. <carol.d.wieseman@nasa.gov>

To: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

Conversation: Beam model HIRENASD

I got the FEM - Sure wish it was in Nastran format.
I have created a Nastran FEM with the data which is attached.

The calculation of the mass doesn't match what you have in the file if I do density*area*length of each segment of the beam.

I cantilevered the balance for this study.

I'm not sure if the CBEAM cards have the right beam orientation but I'm quite sure it is correct.

I don't use the Alpha - I'm not sure what this is I also don't use the kappa.

I kept your coordinate system although I was going to change it so that it is x in the flow direction, y out the span.

These are the frequencies I obtained from the Beam FEM.

Mode Frequency (Hz)

1 26.9601
2 89.582
3 141.766
4 200.595
5 277.284
6 328.291
7 346.341
8 468.925
9 527.293
10 583.208

As far as trying to get mode shapes on the "wing" for use in Deflection interpolation. I haven't even started that and am not quite sure how to go about it.

On 5/4/11 6:05 AM, "Alexander Boucke" <Alexander.Boucke@itam-gmbh.de> wrote:

> Hello Carol.
>
> currently I am preparing the beam model for the HIRENASD wing. It will contain
> the complete wing, not only the balance and clamping area missing from the 3D
> model. I hope to have a human-readable form of this dataset ready in the
> afternoon.
>
> Regards,
>
> Alexander Boucke

Subject: Re: Beam model HIRENASD
Date: Thursday, May 19, 2011 10:37 AM
From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>
To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>
Conversation: Beam model HIRENASD

On Wednesday 18 May 2011 23:05:22 you wrote:
> I have created a Nastran FEM with the data which is attached.

Hi Carol,

I'll have a look into these once I got the report finished I'm writing now.

Just two remarks:

- The Alpha defines the rotation angle of the beam's main axes around the longitudinal axis. The result for these small angles is a slightly different I_{YY} and I_{ZZ} and an $I_{YZ} \neq 0$.
- Kappa will have some influence on the modes, this might be set with the beam data rather than the material data. It depends on beam shape and is generally a symmetric tensor. So if my program would have been more accomplished, it should have featured K_{YY} and K_{ZZ} (to be rotated by the same angle Alpha as the tensor of second momentum of area I).

Subject: Re: Beam model HIRENASD
Date: Thursday, May 26, 2011 11:02 AM
From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>
Conversation: Beam model HIRENASD

On Monday 23 May 2011 19:35:57 you wrote:

> I need clarification on definitions.

>

> Beam axis?

> Longitudinal Axis?

>

> From grid # to grid # - which axis is this? I'm sure pictures would probably help.

>

> I'm thinking and used to Nastran terminology.

>

> Hope you have a chance to look at the FEM soon. I know that there is pressure on me to understand the results from the SPT's.

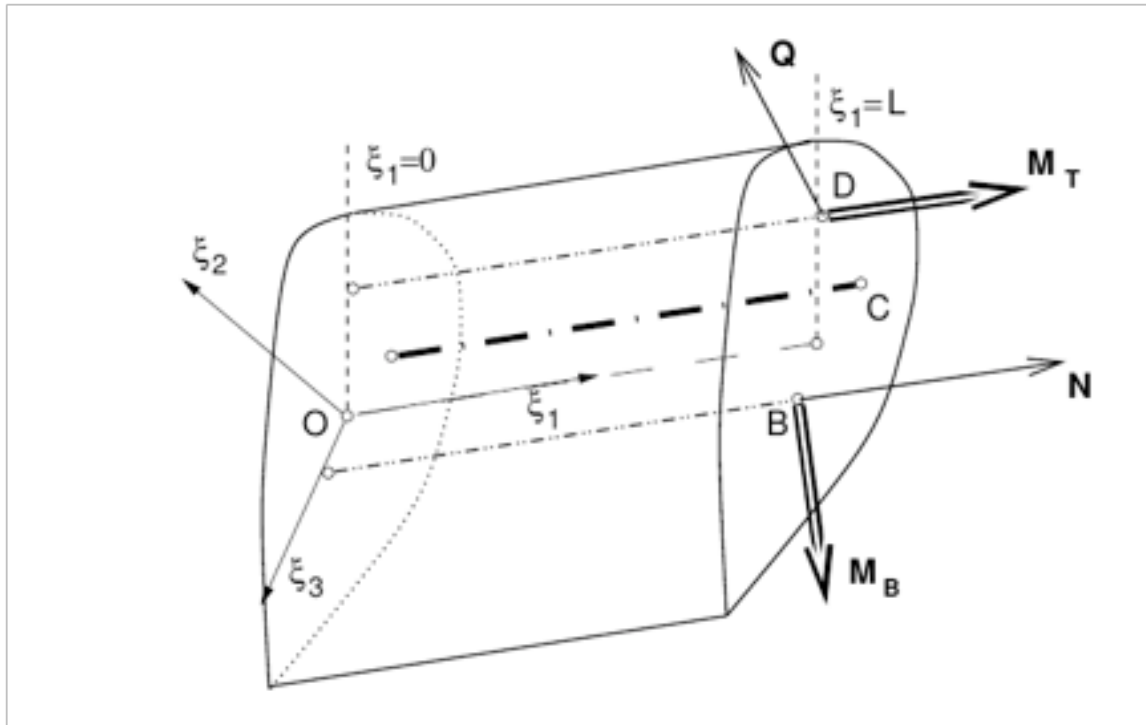
Hello Carol,

there is a drawing on page 32 of my dissertation. I have included a screen shot in this e-mail. There you see the reference axis (longitudinal axis x_{i1}) of the beam, as given by the coordinates of the points in my input-file. In case the beam has an irregular shape, the neutral line for bending ('B'), the neutral line for torsion ('D') and the line of the centre of gravity ('C') will differ from each other. In case they differ significantly from the given reference axis, I have included the coordinates of the points B, C or D in the given input file. I'm sure you'll be able to find a general beam model in Nastran, that will allow such a definition.

The angle Alpha describes a rotation of the tensor of second momentum of area around the axis x_{i1} , so that the give I_{yy} and I_{zz} will be transformed into a set I'_{yy} , I'_{zz} and I'_{yz} .

Kappa is usually given as a tensor, so you'll likely find k_{11} , k_{12} and k_{22} or k_{yy} and so forth in a general beam definition file. For a non-symmetric beam cross section, these are generally different values, not a single constant as given by me (there is a flaw in my program, due to the way it evolved). The value I have given in the file is one matching the flap-bending mode.

I have looked into your question about the masses and have not yet found a conclusive answer. The comments with the element masses have been generated by a program that created the basic structure of my input file. It is likely that a colleague and I have introduced a change later on and I did not reflect this into the comments. Basically you can use the numbers I gave above the elements as a guide, the beam elements as defined gave a good representation of the complete wing model.



Subject: Re: Beam model HIRENASD
Date: Thursday, May 26, 2011 3:50 PM
From: Wieseman, Carol d. <carol.d.wieseman@nasa.gov>
To: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>
Conversation: Beam model HIRENASD

So X1 is the same as psi_1 on your figure.
 And XI_1 is the same axis as XI_1'?

Nastran allows for an offset of the Shear center at the ends of the beam sections.

I've attached the information from the Nastran manuals. And need to figure out how I incorporate what you have said with what Nastran requires and expects. I still don't know what Kappa is and how to use It in the equations.

Does it in some way correspond to K1,K2?

Date: Thursday, May 26, 2011 7:13 PM
From: Wieseman, Carol d. <carol.d.wieseman@nasa.gov>
To: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>
Conversation: Beam Model

Below – red dots are the grid locations from the BEAM Model you sent to me.

The other symbols are from the SPT data file time histories.

I was expecting them to be right on top of each other. Why aren't they? (x[m],z[m]) The data also doesn't change with angle of attack.

Subject: Re: Beam model HIRENASD
Date: Friday, May 27, 2011 8:44 AM
From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>
To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>
Conversation: Beam model HIRENASD

On Thursday 26 May 2011 21:50:33 you wrote:

> So X1 is the same as psi_1 on your figure.
> And XI_1 is the same axis as XI_1'?
>
> Nastran allows for an offset of the Shear center at the ends of the beam sections.
>
> I've attached the information from the Nastran manuals. And need to figure out how I incorporate what you have said with what Nastran requires and expects. I still don't know what Kappa is and how to use It in the
> equations.
>
> Does it in some way correspond to K1,K2?

Hello Carol,

I've looked at this for you.

K1/K2 is the same that I have referred to as kappa. If you choose the given value for both numbers, the flap bending modes should be OK. This value is essential for the Timoshenko beam. If set to 0.0 the result will be a

Bernoulli beam (in my formulation and according to the manual excerpt also on NASTRAN's PBEAM).

If you compare my drawing with the one from NASTRAN, the following are synonymous:

NASTRAN \Leftrightarrow Boucke

"Neutral Axis" \Leftrightarrow "Line B"

"Shear Center" \Leftrightarrow "Line D"

"Nonstructural Mass Center of Gravity" \Leftrightarrow "Line C" <-- I'm not 100% sure if this means the same, but I'm sure it can be made the same. If B and C differ, this means that there is some non-structural mass there. They hardly differ in our wing model and where they differ it can safely be ignored, so that C and B are made the same (with the coordinates of B). So you'll get around defining the non-structural mass.

Subject: Beam Model
Date: Thursday, June 2, 2011 2:11 PM
From: Wieseman, Carol d. <carol.d.wieseman@nasa.gov>
To: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

FEMs

It looks like the origin of the coordinate system for the beam model is not the same as the Finite Element model because the beam extends off from the grids of the structural finite element model.

Please confirm... I'm trying to get to the point of interpolating beam mode shapes to the wing planform using RBE's or RBARS or PLOTELS.

The coordinate system was changed so X is in the flow direction and Y is out the wing.

I didn't do anything with the origin.

Subject: Re: Beam model HIRENASD
Date: Monday, June 6, 2011 1:01 PM
From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>
To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>

On Thursday 02 June 2011 16:52:06 you wrote:

> Thanks for the email. I don't know the values of the NSM (non structural mass) to include. All I have is the density - that I know of unless there is some clue in that the mass listed in the comment cards are not equal to what I calculated.

Dear Carol,

the centre of gravity only deviates from the neutral axis in a few places and only a little bit, I think this can be neglected. I added the mass of the cables to the centre of gravity of the wing profile, probably making a small error there, but the exact distribution of this additional mass is mostly important in span-wise direction. As I just returned into the office today, I can not yet report why my comment cards have different masses than the actual values are.

> I'll put the Kappa value into K1, K2 in and see what impact that has.

That's what I meant and this is also how it is handled by me. I think I've written this before, but due to the development of my program not being complete when entering this data set I had to do some changes to the values:

The individual values might not make sense (Kappa should be less than 1), but all the products are correct ($E \cdot I$, $k \cdot G$ etc...).

> What are the modal frequencies of this model and with what boundary conditions. I should have an exact match within the accuracy of the calculations. This will help to identify any errors in my FEM.

The model is fixed in "Balance Node 1" with all 6 DOFs. The first 9 eigenfrequencies are:

1 2.53387954681863E+01 < 1st flap bending
2 7.86364229872245E+01 < 2nd flap bending
3 1.15935545706247E+02 < 1st pivot bending
4 1.58407621637152E+02 < 3rd flap bending
5 2.43513090631692E+02 < 4th flap bending
6 2.67283214274505E+02 < Torsion dominated
7 2.69912364149533E+02 < 2nd pivot bending
8 3.42097844428355E+02
9 4.24524111720869E+02
(pivoting = for-aft movement??)

I can send you files with the according wing surfaces on a medium grid without fuselage substitute.

> Alpha is rotated clockwise or counter clockwise ? I'm not sure if I have
> X1,X2 and X3 calculated properly for the Alpha value. The model I had sent
> to you I'm pretty sure didn't account for the Alpha rotation.

Looking from 1st to 2nd node of a beam it is clockwise (mathematical positive order).

Subject: Re: Beam Model

Date: Monday, June 6, 2011 1:09 PM

From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>

Conversation: Beam Model

On Friday 27 May 2011 01:13:09 you wrote:

> Below – red dots are the grid locations from the BEAM Model you sent to me.

>

> The other symbols are from the SPT data file time histories.

>

> I was expecting them to be right on top of each other. Why aren't they?

> (x[m],z[m]) The data also doesn't change with angle of attack.

Carol,

agreed, it is a bit surprising. Two possible reasons spring to mind:

1) We have had two beam models for two programs - the earlier software was mine, but later abandoned for a re-write to get better integration into the different flow solvers in use. But we have compared eigenmodes and frequencies and found them to be in good agreement.

2) The later addition of the fuselage substitute might have created areas more difficult to render for the grid deformation tool, so the more rounded appearance of the beam leaving the balance in the later model might be due to this. But this is just an educated guess, I can ask the creator of the beam axis used for the SPT data, but he is not in Aachen anymore. I know that we initially started with the same representation of the wing.

The angle of attack has been removed from the SPT data, so this rotation of the coordinate system cannot be seen in the data anymore.

Subject: Re: Beam model...

Date: Friday, June 10, 2011 12:51 PM

From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>

Conversation: Beam model...

On Friday 10 June 2011 18:22:58 you wrote:

> The E is constant for the balance at 1.81E11

> G varies a lot which means the nu for the material also varies. I guess that is one thing you are using to tweak the beam model to make it work and resemble real life.

yes, there is some tweaking going on. But also please remember that I've written not to look at the singular values of the material and beam data, as I had to be creative with these due to the lack of development in my own software back then. I was able to make sure that the products that define the stiffness and mass matrices are correct - such as $E \cdot I$, $G \cdot J$, $G \cdot A \cdot \kappa$, $\rho \cdot A$, $\rho \cdot I$, $\rho \cdot J$. These are the really important values.

My beam program evolved from one for full, symmetric cross sections and to get it working with the wing at one stage needed this creative definition of the beam. I.e. the J in $G \cdot J$ and $\rho \cdot J$ would take different values in a beam with a cross section like the wing - so I had to take care to get the products right, which meant modifying G and then κ . Later on I did never re-define the properties, as I had a working model.

Subject: Re: Non Structural Mass

Date: Tuesday, June 21, 2011 3:27 PM

From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>

On Tuesday 21 June 2011 00:28:58 you wrote:

> According to the Nastran model I should be using the D points as the ends of each of the beam sections. I'm dealing with coordinate systems and transformations.
> Why does the beam do such weird things near the tip?
>
> What are the quantities supposed to be for the NSM for C points?
>
> How did you get the original beam model? Static load tests? How did you come up with the original Beam Areas, inertias, etc. properties.

Hi Carol,

there are multiple ways to get the local beam properties. Two have been used with similar results:

- a) calculate the values from the local cross section (orthogonal to assumed beam axis).
- b) do simulated static load tests with a beam of a certain length (i.e. 2m) and the local cross section currently of interest with a volume FE model.

Near the tip the neutral line (and centre of gravity) will turn towards the rear tip corner, because the wing is not cut off orthogonal to the beam axis of the last full cross section. If the remaining triangle is assumed to be elastic, the resulting axis will be as given. It is also a valid assumption to model this outer triangle as a solid, non-deformable mass with matching inertia. The beam axis there looks strange, and in the case of large

deformations in this area the result might well be questionable, but the actual deformation is very small and the beams attached in this area mostly add mass in an off-centre position.

I'll now have another look at the nastran definitions and hope to add another mail in a short time.

> On Tuesday 21 June 2011 14:32:31 you wrote:

>> I think we should attempt to modify the solid model to include the NSM.

>> I could use some help in extracting that info from the beam model or be directly provided by you - values of NSM and the locations where they should be applied.

>

> Carol,

>

> if you look at the pictures of the opened wing in the slides I presented to

> you last week (on dashlink), then you'll see the channels inside the wing filled with cables. These are the largest part of the NSM. In the beam model

> I sent you there is a guess about this mass included in each section written in the comment. I added this mass to the mass centre of the beam. For the volume model, I would distribute this mass inside the two channels running along the complete wing. The error will be reasonable small, if you choose to make an even distribution according to each section I have given you.

>

>> Re/ Beam model

>> There are still questions re/ the beam model - coordinate system and how to
 >> generate the PBEAM and CBEAM cards to incorporate the B,C and D points.
 >
 >> I have been using the original points (A) as the Grid points.
 >> the Offsets on the CBEAM should be the difference in location between the D and A points- in all 3
 dof's in the correct coordinate system for Nastran.
 >> The PBEAM cards have N1,N2 and M1,M2 to have offsets for the bending and cg but I need to know
 values of NSM.
 >
 > To make life a little easier, please ignore the difference between mass centre C and neutral line B in the
 few places they differ. Assume they are equal (=B) everywhere. By looking at the CBEAM and PBEAM
 definitions you have sent me, I think that you have understood the transformation into NASTRAN right:
 >
 > W?A and W?B describe the offset from my reference axis to the shear centre D.
 > N1 and N2 then describe the offset of the neutral line in reference to the shear centre.
 >
 > If you really want to model the wiring as NSM, then reduce $\rho \cdot A$ by the amount of NSM = (weight of
 wiring) per length (reduce ρ , not Area). And then add NSM with $M1=N1$ and $M2=N2$. But I can't see this
 making an impact on the solution compared to the local varying density as I have defined it. As said earlier,
 ignore the few points where the mass centre differs from the neutral line. If you really want to do these,
 you'll need to define a NSM, so that $NSM + \rho \cdot A$ in NASTRAN = $\rho \cdot A$ in my data and that the centre of
 gravity C (in my data) is replicated by the total centre of gravity of $\rho \cdot A$ at (N1,N2) and NSM at (M1,M2)
 in NASTRAN.
 >
 > Regards,
 >
 > Alexander Boucke

Subject: Re: Beam model
Date: Tuesday, June 21, 2011 5:37 PM
From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>
To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>

Am Tuesday 21 June 2011 schrieben Sie:

> In your beam model text file you said you incorporated the NSM as an increase in ρ . You didn't say
 you added it to the mass center of each beam segment so it was not clear how exactly you incorporated it
 into your beam model based on the file model_input-extract.txt.

Carol,

I thought this was clear when C defines the mass centre and $\rho \cdot A$ the mass per length. By adding extra
 mass to ρ I obviously add this to the mass centre.

What I did not do when adding the mass of the wiring, was trying to estimate if the centre of gravity (mass
 centre, C) moves away. This move away is what can be expressed using (M1,M2) in NASTRAN, and this
 happens if there is non-structural mass...

> I took it literally that you had incorporated the NSM in with the
 > structural mass by modifying ρ of each wing element.

Yes, that's what I did. If the centre of gravity of the non-structural mass and the one of the structural mass
 fall together, it does make no difference
 if I add an additional NSM term or if ρ is modified. It ends up in the same position on the mass matrix.
 The advantage of the approach of NASTRAN is, that the ρ can be a material constant, while I have to add
 local properties into ρ . But this is just a cosmetical difference.

> At this point I have ignored the C points and the B points. The Grid points are the points that are used to define the beam elements, the D points if they exist are used to define the offsets.

>

> I'll have to calculate the N1,N2 and M1, M2 in the element coordinate system.

Make C=B throughout the beam - this will hardly affect the results. But incorporating the correct B should be done. As you've taken over my rho and A values, NSM should be 0.0 and therefor the values of (M1,M2) do not matter.

Subject: Re: Beam model

Date: Tuesday, June 21, 2011 6:30 PM

From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>

Am Tuesday 21 June 2011 schrieben Sie:

> The frequencies I am getting with versions of beam models are: the
> differences between the models involve the coordinate system, include or
> not include kappa, and the implementation of alpha and whether the offset
> is included. I am using the rho in the model of what you sent in your
> description. Ignoring the "incl mass comment"

>

> nca_0_sa_xyz nca_0_sa_xyz_o1 nca_0_sa_xyz_o1_k nca_0_sa_xzy

> nca_0_sa_xzy_o1 nca_0_sa_xzy_o1_k

> 26.1573 26.1756 26.3742 26.1575 26.1755 26.3741

> 81.7480 81.6599 83.6227 81.7489 81.6606 83.6234

> 104.0650 103.7993 118.6205 104.0534 103.7987 118.6193

> 165.9623 166.0375 171.0099 165.9621 166.0377 171.0105

> 243.5511 243.4076 265.5477 243.5769 243.3928 265.5275

> 258.3379 260.4031 273.9994 258.3392 260.4103 273.9074

> 274.9945 273.4003 279.9766 275.0130 273.4226 280.1108

> 376.8331 377.4226 389.8478 376.8272 377.4327 389.8670

> 389.8810 392.9279 443.0927 389.8804 392.9366 443.1164

> 444.0106 443.4791 507.3463 443.9800 443.4815 507.3089

>

> X1=cos(alpha)

> X2=0

> X3=sin(alpha)

>

> Xyz = in your coordinate system

> Xzy = with in our typical coordinate system - xflow,yout span :

> xnew=xold,ynew=zold,znew=yold

>

> o1 = includes offset - Point D - Point A (if Point D) doesn't exist it will

> be 0,0,0

> K = includes kappa

>

> NOTE:

> I don't have M1,,etc N1,etc incorporated yet.

>

Carol,

these frequencies don't look too bad - at least closer than the volume model.
But I am not sure how you incorporated the alpha and think we should wait to

see the frequencies after N1 and N2 have been incorporated

Subject: Re: Beam model

Date: Wednesday, June 22, 2011 11:46 AM

From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>

On Wednesday 22 June 2011 05:34:06 you wrote:

> what would be really nice is if you could calculate the N1,N2 and the NSM associated it with it. It is clear that I didn't understand your "incl... statement" re/ how you did the NSM ($\rho \cdot A$) lumped in with the density of the beam (ρ).

Hi Carol,

as long as the centre of gravity and the neutral line are the same, there is no difference between NSM and structural mass in a beam. In a beam the neutral line and centre of gravity of structural mass will fall together. So the mass per length applied via $\rho \cdot A$ will follow this line. If there is non structural mass, this can be dead mass in the beam (here: wiring) or dead mass due to trying to compensate 3D effects, there are 2 ways to integrate them into a beam model:

1) define a centre of gravity or mass centre line independent of the neutral line and put all mass onto this line. $\rho \cdot A$ then represents the total mass. This is the approach I used.

2) do not modify ρ and A of the structural cross section and elastic material (so the centre of gravity of this part is still the neutral line). Add the non-structural mass by defining the mass (per length) and at least the centre of gravity of this added mass.

When using formulation 2) the combined centre of gravity of the structural and non-structural mass equals the mass-centre line of approach 1).

The only point where the mass centre line differs from the neutral line is near the wing root. The difference is small and stems from adapting the neutral line to follow the neutral line of the 3-dimensional model, instead of the local cross sections. The jump in the cross sections near the clamping area will make parts of the most inboard cross sections effectively non-structural. I doubt that there is any significant change in the computed results, when the centre of gravity in this area is aligned with the neutral line.

So this leaves you with a model where the centre of gravity is equal the neutral line in all points, so there is no need to specify NSM in NASTRAN, as the mass defined by $\rho \cdot A$ is applied to the neutral line.

This is true for the wing without the added mass of the wiring. When adding the wiring, we did not know the exact centre of gravity, apart from the fact that the two channels it is distributed in are roughly symmetric to the neutral line. So the assumption that the centre of gravity of the wiring is the same as the centre of gravity of the local wing cross section. So the mass was simply enlarged (by modifying ρ in my data) and the centre of gravity was not changed. If you transferred the ρ and area-data from my file into the NASTRAN definition, then you already include the mass of the wiring.

I hope this is clearer now.

Subject: Re: Beam model

Date: Wednesday, June 22, 2011 5:57 PM
From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>
To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>
Conversation: Beam model

Am Wednesday 22 June 2011 schrieben Sie:

> Let's take just one example.

>

> -----

> -- Wing Element 4

> -- Span from 0.15476·m to 0.20436·m

> -- Length 0.053618·m

> -- Mass 3.4204·kg

>

> Elastic_Material => Mat 4

> Rho => 8186.3·kg/m³;

> -- incl. 2.32kg/m for wiring

> E_Mod => 186110000000·kg/m·s²

> G_Mod => 5344100000·kg/m·s²

> kappa => 10.906;

>

> Cylindric_Module => Wing Beam 4

> Node_1 => Wing Node 3

> Node_2 => Wing Node 4

> Material => Mat 4

> Area => 0.0080545·m²

> I_Yy => 0.000084573·m⁴

> I_Zz => 0.0000018226·m⁴

> Alpha => -0.010752

> J => 0.000086396·m⁴

>

>

> Node => Wing Node 3; 0.31591·m; 0·m; 0.15476·m;

> Node => B Node 3; 0.33410·m; 0.0017307·m; 0.14729·m;

> Node => C Node 3; 0.34343·m; 0.0017147·m; 0.14346·m;

> Node => D Node 3; 0.32245·m; 0.0018564·m; 0.15208·m;

> Node => Wing Node 4; 0.33629·m; 0·m; 0.20436·m;

> Node => BC Node 4; 0.35584·m; 0.0026841·m; 0.19632·m;

> Node => D Node 4; 0.34288·m; 0.0027776·m; 0.20165·m;

>

> I want to implement just that element into nastran.

> The GA and GB correspond to:

> Wing Node 3, and Wing Node 4

> W1A-W2A-W3A - is the difference between D Node 3 and Wing Node 3 points

> W1B-W2B-W3B - is the difference between D Node 4 and Wing Node 4 points

Ok, Carol, lets see this through...

The above is correct.

> The element x-axis goes from the D Node 3 to the D Node 4 points.

The shear centre, yes. NASTRAN defines this as the main axis of the beam element.

> The structural density is going to be

> $\text{Rho} = (\text{Rho} * \text{Area} - \text{NSM density}) \text{ divided by Area}$
 >
 > $\text{Rho} = 8186.3 * 0.0080545 - 2.32$
 > $\text{NSM} = 2.32$
 >
 > $\text{N1}, \text{N2}$ and/or $\text{M1}, \text{M2}$ = Still needs to be calculated – needs to be in element
 > coordinate system at each of the beam ends.

As these are the differences from the shear centre, this is the vector of BC-node - D-node at each end, rotated into the local coordinate system of the NASTRAN beam. If we talk my coordinate system - as seen in the above example, we need an assumption on the local NASTRAN beam's coordinate system. If we x-y-plane so that it is orthogonal on the global x-z-plane (plan view plane of the wing), then my definitions of I_{yy} , I_{zz} and Alpha will hold, as this is how I defined it.

$\text{M1} = \text{N1}$ and $\text{M2} = \text{N2}$ will hold everywhere with $\text{B} = \text{C}$ in my beam definition. And if NASTRAN does not do something strange, the complete NSM-thing can be ignored in this case! Just leave rho unmodified. I would not bother with this! The pair N1 and N2 NEEDS to be introduced though, as this is essential. As I said, in the case of B not equal C I still maintain that there will be no big difference in the modes that interest us, if you move C to B and then do as above. This is because the only point where this is actually the case is near the wing root and any mode shape showing a large deflection in this area will be of a very high frequency and not of interest here (these will not resemble the 'real' modes anyway).

If you really want to establish C not equal B in Nastran, you'll need to define a point M' so that $\text{C} = 1/(\text{rho} * \text{A}) * (\text{B} * (\text{rho} * \text{A} - \text{NSM}) + \text{M}' * \text{NSM})$ with all quantities as given in my data and NSM still to be determined. M1 and M2 will then be the result of rotating $\text{M} - \text{D}$ into the local beam coordinates. NSM for the original definition of my data will not be the mass of the wiring in this case, but was a part of the mass of the wing not considered not contributing to actual stiffness fore and aft of the clamping area. As I have not determined these data myself, I cannot quickly tell you a value to choose for NSM in this case.

> How to incorporate Alpha still
 > needs to be confirmed.

In one of my last e-mails I actually sent you the formulae how to incorporate alpha. This is the rotation of the main axes of the beam's cross section against the local beam coordinate system. Alpha only changes the I_{yy} , I_{zz} and introduces I_{yz} . The results of the formulae I sent you can immediately be put into the PBEAM card. Here they are again:

```
I_YY_New :=
  0.5 * (Beam_I_Yy + Beam_I_ZZ) +
  0.5 * (Beam_I_Yy - Beam_I_ZZ) * Cos(2.0*Beam_Alpha);
I_ZZ_New :=
  0.5 * (Beam_I_Yy + Beam_I_ZZ) -
  0.5 * (Beam_I_Yy - Beam_I_ZZ) * Cos(2.0*Beam_Alpha);
I_Yz_New :=
  0.5 * abs(Beam_I_Yy - Beam_I_ZZ) * Sin(2.0*Beam_Alpha);
```

The *_New values go into the PBEAM card, the BEAM_* values are the ones from my data.

>
 > Corresponding grid cards are:
 > GRID,25,,0.31591,0.15476,0.0
 > GRID,1025,,0.3341,0.14729,0.0017307
 > GRID,2025,,0.34343,0.14346,0.0017147
 > GRID,3025,,0.32245,0.15208,0.0018564
 > GRID,26,,0.33629,0.20436,0.0
 > GRID,4026,,0.35584,0.19632,0.0026841
 > GRID,3026,,0.34288,0.20165,0.0027776

>
>
> The 4000 points are BC points.
> If there is no D point do I assume that the shear center is at the A
> location? The grid #s that are greater than 1000 are not used in the FEM.

Correct, same of B or C if left off. In fact I had a rule to leave these definitions out when the points have been closer than 0.5mm.

Subject: Beam Model

Date: Friday, June 24, 2011 1:31 PM

From: Wieseman, Carol d. <carol.d.wieseman@nasa.gov>

To: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

Conversation: Beam Model

I think that if X1, X2 and X3 are correct (accounting for alpha) then I don't have to modify the Inertias. But are they correct?

But I think this also impacts the values of N1,N2,M1,M2. Although I am calculating them I'm not sure that I have them correct.

If I use the equations to modify the inertias - what are X1,X2,X3 supposed to be for the orientation vector?

Could you please help me with this.

Subject: Re: Beam Model

Date: Friday, June 24, 2011 2:06 PM

From: Alexander Boucke <Alexander.Boucke@itam-gmbh.de>

To: "Wieseman, Carol d." <carol.d.wieseman@nasa.gov>

Conversation: Beam Model

On Friday 24 June 2011 19:31:39 you wrote:

> I think that if X1, X2 and X3 are correct (accounting for alpha) then I
> don't have to modify the Inertias. But are they correct?

Hi Carol,

no, the inertias are independent of the coordinates. The coordinates are a geometrical property, while the main or principal axis are a property of the shape of the cross section. The Alpha describes an additional rotation of the tensor of inertia around the beam's longitudinal axis. This does not impact any of the other values or coordinates!

Just calculate the new inertias by putting them through my formulae. More here:

http://en.wikipedia.org/wiki/Moment_of_inertia#Principal_axes_of_inertia

On Friday 01 July 2011 21:45:43 you wrote:

> What exactly is Kappa and how does it match to K1, K2.

> Our nastran expert says that they are usually between 0 and 1.

Hi Carol,

he is certainly right! The 'strange' values are due to the fact that I had to meddle with the individual values to get all the needed products right. I think I have explained this to you before: When I started modeling this wing model, my own program was in the transition from one for point symmetric (circular) shapes to one being able to cope with general shaped beams. I had J used for the torsional stiffness as well as for the rotational momentum around the longitudinal axis - which is fine for circular sections. And by being creative with the individual values, I was able to get all the important products that define the stiffness and mass-momentum of a beam right before the program was developed further. In retrospective, I should possibly have converted the data to the 'real' G-mod and kappa values back again before sending them out to you.

Values affected are J, G_mod and Kappa. To return to 'traditional' values the following will work:

$$G_mod_new = E_mod / 2.66$$

$$J_new = J_old * G_mod_old / G_mod_new$$

$$kappa_new = kappa_old * G_mod_old / G_mod_new$$

The products $E \cdot I$, $G \cdot J$, $G \cdot A \cdot kappa$, $\rho \cdot A$, $\rho \cdot I$ would stay the same. Only $\rho \cdot J$, which holds for circular and other symmetric cross sections will be replaced with $\rho \cdot (I_{yy} + I_{zz})$, which can be assumed to be done right by NASTRAN.

I'm afraid I'll be confusing you even more...