Shipboard Buoy/Cable Deployment System in ADAMS

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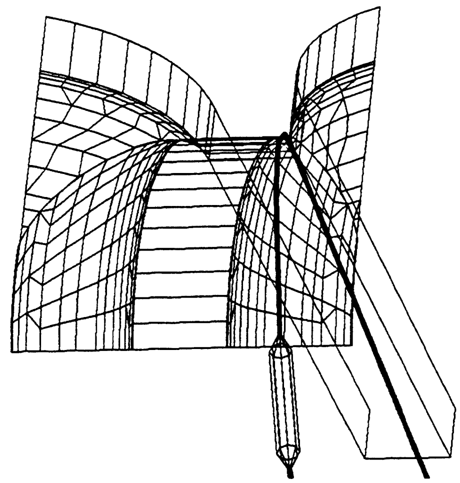

ABSTRACT

ADAMS dynamics simulation software has been used to model and test various buoy and cable deployments systems for Lucent Technologies. The model was used to design a chute which would provide the most effective deployment of the buoy under various sea states. The buoy and the cable were modeled to provide information about the line tensions, strain relief, and operating behavior under typical deployment operation. A custom interface was developed to allow Lucent engineers to rapidly build and test various configurations. The resulting models are used in conjunction with other analytical and available test results to build reliable and efficient buoy deployment systems.

1.0 INTRODUCTION

During ocean deployment of telecommunication cable systems, a failure cannot only be extremely expensive, it can be dangerous for the crew of the ship. Due to the relative infrequency of these operations, it is not feasible to do any extensive testing before the deployment. That leaves computer simulation as an important tool in designing safe and reliable deployment systems.

Previous computer simulations consisted of various in-house codes, component FEA, and MathCAD representation of the system. Lucent Engineers found that this approach took too much time and did not provide the required flexibility and robustness required to complete the designs in time. ADAMS dynamic simulation software was obtained to build this model. It was soon determined that numerous complexities of the model made it necessary to work with MDI consultants to build a model of the system.

Lucent and MDI engineers worked together to create a method by which buoy deployment models could be readily produced. The first task was to create a platform which would simulate realistic ship motions. Then existing Unigraphics CAD geometry was converted in order to define the chute geometry. Then macros were created to create the buoy and the cable. These components employed the 3D contact routines developed by Sam McDonald

[1]. Finally, another macro was created so that analytical representations of the chutes could be readily created.

The result of this work is that Lucent engineers have a tool by which they can rapidly build ADAMS models for different configurations of the buoy deployment system. They can easily change such parameters as chute geometry, buoy geometry, cable stiffness parameters, and sea state. The results of the ADAMS simulations are used to verify existing designs and observe the effects of proposed changes early in the design process.

2.0 APPROACH

2.1 Ship motions

The first task in building the model was to create a platform which would simulate six degree-of-freedom ship motions. This was accomplished by adding a series of intermediary ADAMS Parts to provide the necessary degrees of freedom. Then appropriate constraints were added to connect the parts between ground and the ship in series. First, three translational joints were added in the ship-oriented x, y, and z directions to provide the surge, sway, and heave motions respectively. Next, three rotational constraints were added in series about the x, y, and z axes to simulate the roll, pitch, and yaw motions respectively. Then the six remaining degrees of freedom were defined by the desired ship motions. A graphical representation of the rotational and translational motions are shown in Figure 1. The functions for the motion statements were generally included as simple harmonic motions to provide the frequency and amplitude that the ship would experience under different sea states.

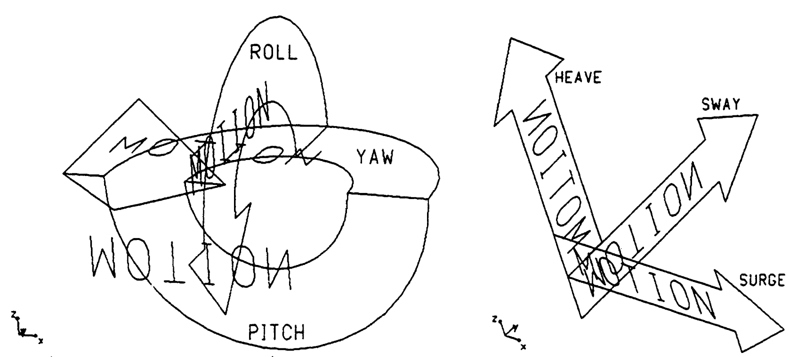

Figure 1: Rotational and translational ship motions

2.2. CAD chute geometry

The shape of the chute geometry is based on many parameters. Among these parameters are the space availability on the ship, the size of the buoys and the allowable bending in the cables. The chute geometry is generally developed in a CAD systems such as Unigraphics. In that environment, the geometric constraints on the chute can be verified with the rest of the CAD model. It was desirable to have the ability to convert the CAD geometry into a format that could be used for the ADAMS simulations. This was accomplished by first converting the chute geometry to IGES format. In this format, it could be imported into ADAMS/View. This provided a visual representation of the chute as well as a means by which to write out a shell (.shl) file required by the 3D contact routines. The shell file is an

ASCII text file which contains the coordinates and connectivity of the nodes in the geometry. The contact routines use this file during the ADAMS simulation to search for, and calculate impacts occurring in the model.

2.3 Buoy modeling

Since no current functionality is available to generate contact forces for axisymmetric to shell contact, the buoy was modeled as a series of shells as seen in Figure 2. A macro was created so that engineers can readily create buoys with various geometric and mass properties. In addition, the engineer can specify the number of spheres to place in the buoy to ensure that the discretization is dense enough to simulate the actual buoy geometry. In addition, the buoy contains markers and contact points at the ends to allow the engineer an easy means by which to attach cables.

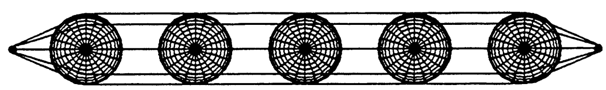

Figure 2: Illustration of contact nodes in buoy

2.4 Cable modeling

Since there is no current means by which to model a continuous cable which can make contact with general surfaces, a discrete cable approach was developed. This approach uses a series of ADAMS Parts connected together with ADAMS Bushings. A graphical representation of a cable fragment is shown in Figure 3. Known information about the stiffness of the cable were implemented into the bushing stiffnesses. This method was also tested with ADAMS Beams and again with ADAMS GFORCE's. There was no appreciable difference in the results, so they can be used interchangeably. As with FEA quality of the results improves with the density of the discretization. Unfortunately, this also significantly increases simulation time.

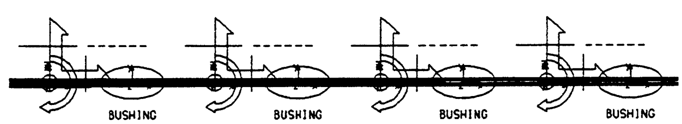

Figure 3: Parts and forces in a cable fragment

The discrete approach also leant itself well to the use of the 3D contact routines used for the buoy. As seen in Figure 3, a GFORCE is specified at the location of each part. The sphere radius for the sphere-to-shell routines were simply set to the cable radius.

A cable macro was created to ease the creation of cables. This was found to be necessary since the cable was subject to many changes, such as size, weight, and diameter, during the design process. Since the parts and forces have almost identical values throughout the cable, variables, could be used to set some, but all parameters. For example, it would be impossible to set a variable for the location of the parts. The panel for this macro is shown in Appendix A. When an engineer wishes to create a new cable he simply provides the properties of the cable and the attachment markers. The macro even connects the cables to the attachment points with universal joints. In addition, the user can specify the discretization of the cable.

This way sparse cables can be used for preliminary models, and dense cables can be used to model cables near the end of the design process.

2.5 3D contact

The contact routines used throughout this model in the buoy and in the cable, are an example of how the sphere-to-shell contact routines developed by Sam McDonald can be used to model more complex contacts. This approach has been used in several areas, such as modeling wire wrapping for electronic devices, and also in biomechanics. Often, the complex geometry of the surfaces in contact can be simulated by use of the sphere-to-surface approach.

The cable application proved to be a challenging application for the sphere-to-surface methodology. Because the shell is only a surface representation (not a solid), the relatively small size of the cables caused the spheres to "pass through" the shell during ADAMS simulation steps. This caused some difficulty because once the sphere passed through, the direction of it's impact normal was reversed. For this reason, the contact routines were modified so that the shell was only one sided, that is, the spheres would not contact the other side of the shell, but act as if they had penetrated into the surface.

Another similar problem was that it was possible of the spheres to possibly fall through a concave juncture between to shell elements. The contact routines search the shell based on the location of the center of the sphere before considering its radius. For that reason, if the center falls into a concave juncture, it can pass through. This was troublesome in this case, because it was desirable to simulate the cable riding into the corner of the chute. This condition exists commonly during shipboard operations du to the fact that the ship has to steer at a different course than it's actual track to offset the effect of the current.

In order to solve this problem, a new way of creating chutes was developed. This also took the form of a macro. Since the chute was constructed of the locus of three planes, and three cylinders, the formulations were fairly straightforward. This macro created an overlap between the parts of the cable, so that there would be no gap for the cable contact points to fall through. This could also be accomplished by drawing the chute geometry with a slight overlap before creating the shell file. The decision was made to go ahead and create the chute macro since it had the additional advantage of being able to create different chute geometry quickly without having to change the CAD model and go through the conversions for every design change. A figure of the chute macro panel is shown in Appendix A.

2.6 Dynamic equilibrium

Once the models were built and the engineers began to run static simulations, it was quickly determined that static equilibrium was going to be difficult to find. ADAMS finds static equilibrium by slightly moving the parts around until the forces are all in balance. The cables were created along straight lines and the static solution was known to be with the cable "wrapped" around the bottom of the chute. This solution was relatively large compared to the small radius of the spheres used in the cable. In addition, the distance by which ADAMS could change the position of the parts during each static iteration (tlim) had to be set to a number smaller than the cable radius to ensure that it would not find a solution on the wrong side of te chute. For these reasons, a method by which a dynamic analysis was used to find the static solution. An animation of the model finding this equilibrium is shown in figure 4.

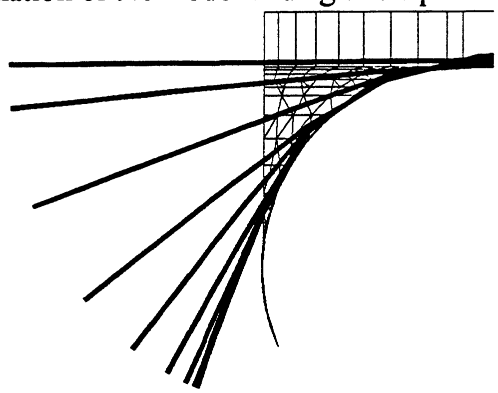

Figure 4: Superposition of cable dynamic equilibrium

This was accomplished by creating an extra part attached to the ship with a translational joint and a motion statement. That part was connected to the end of the cable with a constant tension SFORCE. During the first two seconds of the simulation, the extra part "pulls" the end of the cable down around the end of the chute. The two seconds at the beginning of the simulation are considered as a preprocessing step and are not considered in the analysis of the results. After the two second preprocessing, the part is held in place in order to give the cable an anchor point during the deployment. This proved to be an invaluable tool in the modeling process. It provided a good static solution in a short period of simulation time.

3.0 RESULTS

Due to the proprietary nature of this work, no numerical or graphical results can be provided. From a modeling standpoint, The results can be expressed in terms of the relevant locations, velocities, accelerations, and forces for all of the components of the model. These results can be imported into other software tools, such as MATLAB, for comparison to the analytical results. Preliminary comparison to analytical values were found to be in good correlation.

In addition, the visual representation of the model provides important information about how the model will behave. This can save time and money by visually observing the animations in order to make qualitative judgments. For example, the engineers can change the size and weight of the buoy so that it will not "slap" the side of the chute too much during deployment. Alternatively, the friction coefficient can be modified to observe how different coatings and or materials will affect its deployment behavior.

4.0 CONCLUSIONS

This work served to show several useful techniques for modeling complex systems. The sphere-to-shell contact routines can be used to provide general contact capabilities in many cases. The dynamic equilibrium approach can be used to save time by letting the software put everything in place, thus relieving the engineer of the burden of having to calculate the exact positioning of modeling elements. The connections of several intermediary parts with constraints in series can be used to formulated complex defined motions up to six degrees of freedom. Finally, the creation of customized interface elements and macros can increase effectiveness by automating repetitive tasks.

5.0 FUTURE WORK

There are many possibilities for enhancements to this work. The current model can be improved in several ways. Real ocean data can be incorporated into the ship motions through a subroutine. As more specific cable properties become available, beams can be used instead of bushings to get better cable behavior. The steps involved in converting a CAD file over to a shell file can be made more automatic. More work can be done to better simulate the payout of the cable from the ship. This can be done by constraining the actual motion or, modeling the mechanics of the system farther up the line.

Modeling the cable/buoy system before the chute is the next step in the modeling effort. This will include modeling the racks which hold several buoys and all of the mechanisms required to deploy them to the chute. This task has many elements to consider. The cable with contact method can be used to "wind up" the cable around some roller. The cart to deck constraints will be an important design criteria since it will help determine if it is safe and feasible to deploy the system in different sea states.

The conclusion of this work will be to have a virtual prototype of the complete bouy deployment system. This way Lucent engineers and technicians can work with the ship builders to develop an effective and safe buoy deployment system.

6.0 REFERENCE

McDonald, Samuel, "Three-Dimensional Surface Contact," 1995 International ADAMS User's Conference, P. 383.

Appendix A: Customized View Interface Panels

buoy — DESIGN VAR | EDIT | DONE | SUBMIT | QUIT

LOCATION	14.0.6	MASS	1400	COLOR	maize
ORIENTATION	0.0.0	IXX	100		
TOTLEN	6	IYY	1000		
CYLLEN	4.5	IZZ	1000		
DIAM	.75	NUM_CON	6		

cable — DESIGN VAR | EDIT | DONE | SUBMIT | QUIT

NAME	test	COL	blue_gray
ATM1	one	UMAS	.122
ATM2	two	SEED	
NPARTS	10		
DIAM	.027		

chute — DESIGN VAR | EDIT | DONE | SUBMIT | QUIT

NAME	TEST	SIDE_RAD	6.0
WIDTH	2.0	COLOR	.colors.MAIZE
HEIGHT	1.35	VISIBLE	yes
LENGTH	17.0		
BOTTOM_RAD	7.0		