Case Study

Aerospace

Honeywell Normalair Garrett Limited

Introduction

Honeywell Normalair Garrett Limited is a pioneer in the development of aircraft cabin pressurisation. The company specialises in the design, development, manufacture and support of systems for environmental control, life support, hydraulic power generation and landing gear control and electronics.

Honeywell Normalair Garrett (HNGL) was selected to supply the power generation and conditioning systems along with a mathematical model of the complete hydraulic system for Nimrod MRA4. The project involved major upgrades to all the aircraft's systems, including a total redesign of the hydraulics. The model was to be capable of predicting system level dynamic performance, e.g. times to extend or retract the landing gear, thermal performance, to allow accurate sizing of oil coolers, as well as component interactions, such as the effect of pressure spikes on uplocks. It was the intention that once written, the model would be employed as a design tool, used for troubleshooting during certification and then be available to assist with the analysis of any in-service problems and the evaluation of any future modifications to the system.

Situation

Computer simulation of complete aircraft hydraulic systems has seldom been undertaken as they are too large and complex both for model creation and analysis. So, a traditional ground test rig (iron bird) approach has been used for design validation.

Many studies have shown that engineers spend a large proportion of the time taken to perform the analysis, perhaps 30-50%, gathering the required data. The large number of suppliers, frequent design changes resulting in data changes and lack of data in the early design stages, further complicates the task.

Also, as the simulation model develops, results obtained and discussed, the data has changed and assumed values for missing data are shown to be inaccurate. So, further data revisions and analyses are required. It soon becomes apparent that data tracking and revision control is a major issue - perhaps as large as the analysis task.

When HNGL began to investigate simulation tools for modelling aircraft hydraulic systems a number of facts became obvious. Firstly, the traditional method of developing in-house bespoke tools was not a viable option due to lengthy timescales and costs. Then, there were no packages that met all of HNGL's requirements. Finally, the data tracking and revision control were beyond anything previously envisaged.

The solution was an informal partnership with one of the simulation software suppliers. This was a fundamental change of approach but was made attractive by the realisation that it would allow the company's analysts to spend their time working on the true problem rather than on developing tools. Also, by working with a supplier a degree of sophistication in analysis and data control capability could be achieved, that had not been possible before.

Flowmaster® was chosen as it came closest to meeting HNGL's requirements and Flowmaster Ltd were prepared to work closely with clients to guide product development.

Data Management

The largest problems HNGL encountered were those of data control:

1. Collection: Data had to be collected from many different suppliers and also sites and departments within BAE SYSTEMS. Once acquired, some data had to be translation to "modelling units".
2. Control: The data obtained had to be held securely under proper configuration control. This not only

allowed the model users to determine the “build state” but also ensured that changes made by suppliers could be incorporated. It also indicates whether the data are: specification values, from calculation or measured from test.

3. Usage: The data must be transferred accurately and quickly to the analysis in a method that avoids the possibility of transcription errors.

The principal method of building Flowmaster models is via its graphical user interface. As each component is added to the model, data may be entered via an associated data input form. The model may then be saved in an integrated database and re-used at a later time. The model build, data entry and security features are adequate for normal use. However, they were not strong enough for a design tool of the complexity that HNGL envisaged.

The solution to the problem was to integrate Flowmaster to a MS® Access database to provide the users with an integrated modelling environment tailored directly to their requirements. The database facility provides the ability to store and maintain all the data to aerospace configuration control standards. The database design eliminates data duplication. Finally, a “wizard” was developed that transfers data from the database to Flowmaster eliminating the possibilities of data misuse and transcription errors.

Database Structure

It was essential when designing the database that the structure was properly designed for the data input and usage. Therefore, some time was spent analysing the various data types and usage.

For example, the Flowmaster database effectively has two sections: one for model component data and the other for analysis run data. The data for each component is input via a component data form. All other data, such as time step, stop and start times, are associated with an analysis run of the model. This structure is quite suitable for many applications. However, it does not meet HNGL desire to store once and to have full configuration control. Therefore, it was decided to replicate the Flowmaster data structures within the MS Access database. Flowmaster UK, worked closely with HNGL to ensure that these database structures were correctly defined.

The aircraft system consists of a large number of components, eg. pipes, Tees, actuators and the same part may be re-used in several different locations. So the landing gear door actuators may be used in both nose and main landing gear assemblies. The geometric data will be identical but their loads will likely be different. One of the design goals was that data be held once only. Therefore, the geometric or part data is held once only but the component data, which relates to a particular usage of the part, will appear many times.

The component data varies on a case-by-case basis. For example, the loads on the landing gear doors vary with airspeed at atmospheric conditions. Once again careful design is required to ensure that data collection and entry are manageable and subsequent usage is practical. Therefore, the component data are sub-divided into demands, loads, initial conditions and environment. Also, by associating every one of these factors with each other to form a “configuration data group” then consistency is assured and data entry minimised.

For example, the landing gear component data can be sub-divided into loads, demands, initial conditions and environments:

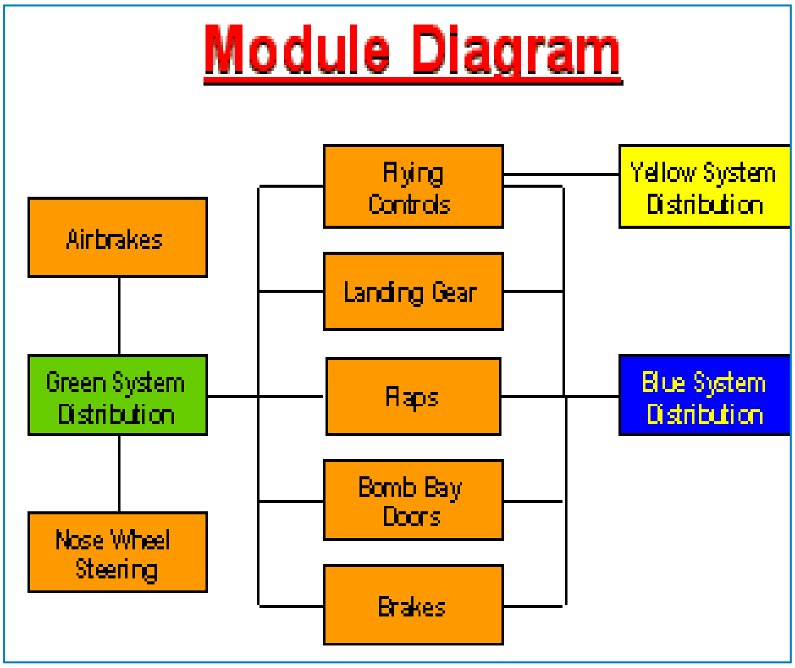
1. Loads: A series of load cases was defined for the landing gear systems as a whole labelled as "hot day, 150 knots" or "standard day, 125 knots".
2. Demands: These specify a particular operation - "gear down" or "gear up".
3. Initial conditions: These are few - generally only "landing gear up" or "landing gear down".
4. Environment: The subsystems do not experience the same environmental conditions - atmospheric pressure and temperature only - for a given case. It varies from bay to bay throughout the aircraft. However, by storing the bay in which a component is located and by grouping the bays by common environments, the pressure and temperatures need be stored once.

The groupings allow models to be set up for analysis runs by defining initial condition, demand, load and environment.

Building the system model

A modular design was chosen for the model due to the large and complex nature of the system. This had beneficial effects of making it easier to edit, manage the results while reducing overall analysis run times.

The aircraft system divided naturally into ten sub-systems. Each was modelled separately and developed with pressure/ flow source boundary conditions. Three of the ten represent power generation systems. Where there was no service selected, loss components were placed between pressure and return manifolds to represent any quiescent flow. Once the individual sub-systems had been developed they were linked together, the boundary conditions removed and the desired analysis performed.



The model was to be used for different types of analysis, which require different levels of detail in the models. For example, pressure spike analysis requires very short time steps, of the order of microseconds, with full model detail. Whereas thermal analysis, where the system time constants are in minutes, a much coarser time step to avoid long run times and very large results sets. However, this can lead to instabilities in detailed dynamics component so a less detailed model is needed.

Certain component models were available in the standard database. In some cases, such as a compensated pump, the standard pump could be combined with other components to accurately model desired hardware. If standard components could not be used then code had to be written. In most of such cases an enhancement request was made to Flowmaster Ltd for the desired functionality. This resulted in the inclusion of a number of components and functionality that has greatly improved the overall modelling while minimising overheads.

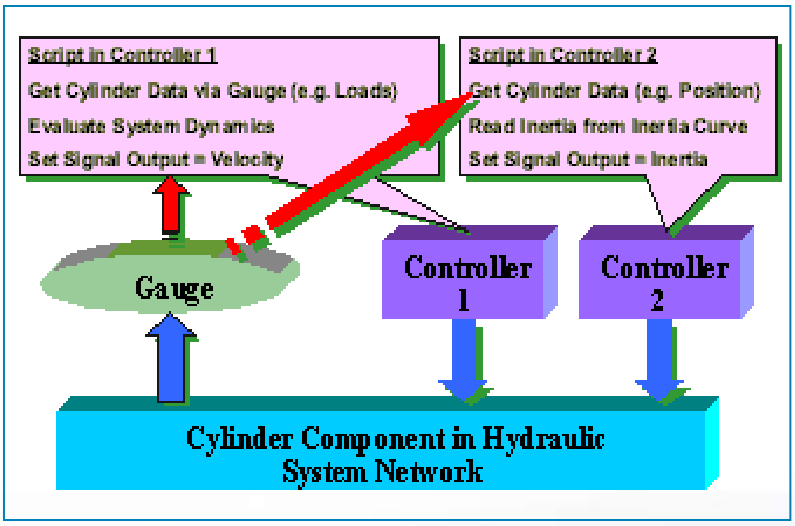
In some instances, such as the bomb-bay doors, where hydraulic cylinders are mechanically linked, code had to be used. In this case, controllers with VBScript were used.

Linking of hydraulics & mechanicals

Flowmaster is designed to simulate problems in the hydraulics fluids domain. Other codes are designed to simulate problems in the mechanical domain. Either code will not be ideal for simulating problems in the other's domain. However, some applications, as typified by HNGL's total aircraft system, requires the interaction of hydraulic and mechanical domains. For example, the aircraft landing gear has mechanical linkages, hydraulic cylinders and valves that interact during operation.

Flowmaster Ltd, working with HNGL, was able to develop new functionality to meet their needs. By working closely with our customers we are able to provide the comprehensive support infrastructure that is needed to maximise return on software investment. This partnership must go beyond the delivery of software and extend to high-quality technical support and technology transfer for best practice.

Tools have been developed within the Flowmaster modelling environment to allow close integration between the hydraulic and mechanical domains. Hydraulic cylinders (actuators) have been enhanced to allow an interchange of data between the hydraulics and the mechanics.

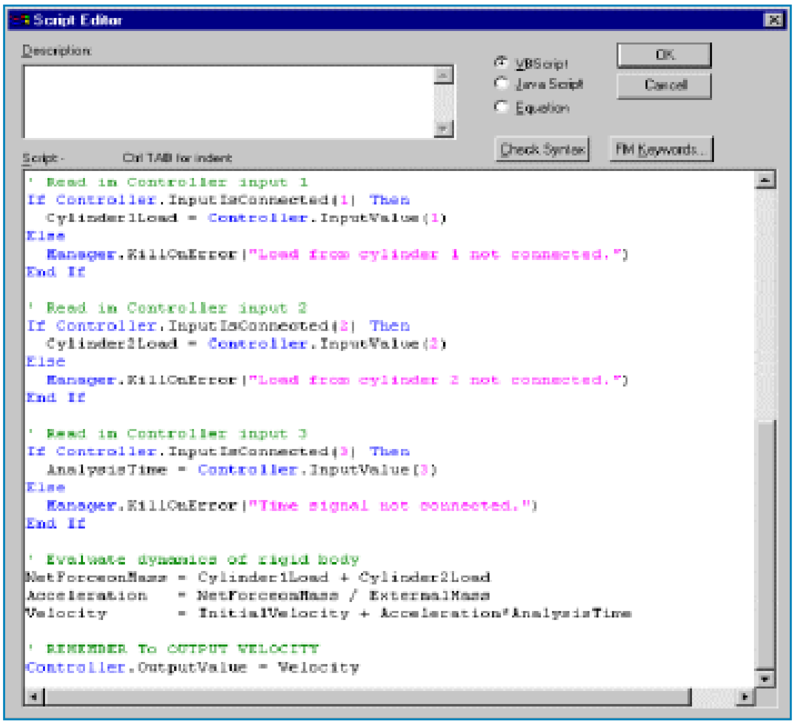


An example of the application of the new tools is Nimrod MRA4 main undercarriage. In Nimrod MRA4, the fuselage dimensions are such that a single actuator large enough for the landing gear loads cannot be fitted in the available space, so dual actuators are required. The functioning of the dual actuators and the mechanisms connecting them is simulated by a gauge component measuring actuator position and internal pressure. These values are input via a controller to the other actuator. Equations, written in a scripting language such as Visual Basic or JavaScript, representing the system dynamics are embedded in the controller. These are interpreted as the simulation proceeds. For a complex system such as Nimrod MRA4 a number of controllers and scripts are used to represent:

- Mechanism variable inertia
- Actuators with different hydraulic and mechanical links
- Actuators with mechanical latches that prevent motion in certain cases.

One controller is used to determine the inertial loading during extension/ retraction by reading a curve that defines the inertia as a function of position. Two further controllers, one linked to each actuator, determine the logic state of the mechanical latches and the linking mechanism. The controllers are modelling the rigid mechanical link between the two actuators and the uplock/ downlock logic.

For this particular case the use of scripts is sufficient, flexible and allows customisation. In more complex cases the data can be passed to and received from a specialised mechanical simulation code. As the data exchange occurs during the analysis a tightly coupled and integrated simulation is obtained.



Conclusion

HNGL has created a data management infrastructure and integrated it with Flowmaster. This design tool has been developed to a level that allows simulation of a complete aircraft hydraulic system. Additionally, a link has been created that allows rapid, accurate and traceable transfer of data from the database to the analysis system.

HNGL, Flowmaster UK and Flowmaster Group have worked in partnership to develop the MS Access database, the database wizard and to extend Flowmaster functionality to provide a truly integrated design tool. Customers are seeking such partnership agreements and comprehensive support infrastructures to ensure that they maximise the return on their investment in software.

Currently, the simulation is being used to supplement the ‘iron bird’, flight testing and certification, but HNGL believe that computer simulation could replace the majority, if not all, the ‘iron bird’ testing. It is also felt that a large portion of certification could eventually be done with simulation.

Finally, HNGL believe that the cost savings gained through the use of simulation are significant.

Acknowlegement

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Development of the Modelling Environment for the Simulation of an Aircraft Hydraulic System.

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As Prime Contractor for the Nimrod MRA4, BAE SYSTEMS is design authority for the hydraulic power generation system and its client services. Technical authority for part or all of some of these systems has been sub-contracted to Airbus UK. Honeywell Normalair Garrett Ltd are contracted to supply the majority of components of the hydraulic power generation and distribution system. As part of BAE SYSTEMS' long-term commitment to cost and cycle time reduction through the use of an integrated set of modelling and design tools, Honeywell were also contracted to produce a model of the entire system using the Flowmaster tool and data from their own and other suppliers' components. This is intended as a risk reduction measure, with the bulk of integrated qualification testing being performed on the most capable Iron Bird ever built. Whilst BAE SYSTEMS is pleased to allow visibility of this effort to a wider expert audience, the views expressed are those of the authors and should not be considered as representing those of BAE SYSTEMS or Airbus UK.

Nimrod MRA4 image courtesy of BAE Systems.