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Material Database for Resistive and Pulse Magnets

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Abstract

This research involved creating a conductor database for building high field magnets for scientists and engineers at the National High Magnetic Field Laboratory (MagLab) to select appropriate materials that enable the magnets to safely achieve the desired magnetic field. Microsoft (MS) Access was utilized to build the conductor database for analyzing and organizing large numbers of data. Additionally, test data organized in Excel is easily compatible with MS Access. Access also allows for cross references between relatable tables to reveal relative data and an approach made by combo boxes was used. The conductor database contains necessary material data (tensile and fatigue test performed since 1994 in MagLab) used to build high field pulse and resistive magnets.

Scientists and engineers at the MagLab can use this conductor database for quick, organized access to the data.

Introduction

For the past twenty-three years, the National High Magnetic Field Laboratory (MagLab) has built high powered world record magnets. The MagLab is operated by Florida State University, University of Florida and the Los Alamos National Laboratory in New Mexico. MagLab employees range from scientists, machinists, and engineers from around the world.

Scientists at the MagLab and from all over the world use the magnets as a research tool to understand materials, energy, and life. Scientists immerse their sample in a high magnetic field with extreme environments to observe how the sample reacts. Extreme environments include either hot and cold temperatures or high pressures. Applying electricity or shooting a laser through a sample is also a common research technique. The results scientists at the MagLab collect from their experiments have global impacts on society. For example, high field research can make the world better by answering questions relating to advancing technology, drug discovery, medical treatments and improving the current environment.

The Magnet Science and Technology department at the MagLab mission involves exploring and discovering how to develop and utilize the world's highest magnetic field resistive and pulse magnets. Resistive magnets are a type of electromagnet that run electricity through Bitter disk to

create high magnetic fields. Pulse magnets are also electromagnets. Instead of a constant electric current running through the windings, a brief current is applied so that a brief but strong magnetic field is created. The pulse magnet at the Los Alamos National Laboratory produces the highest nondestructive field in the world.

In order for MS&T scientists to construct high field resistive or pulse magnets, specific material properties of the magnet are required. A database for building high field magnets is essential for MS&T scientists and engineers to select appropriate materials that enable the magnets to safely achieve the desired magnetic field. The work discussed in this report explains how this database was built and how MS&T scientists and engineers can use this tool as a material reference to build resistive and pulse magnets.

Microsoft (MS) Access was utilized to build the conductor database so large numbers of data could be organized and analyzed. Access can manage data more efficiently than spreadsheet applications like MS Excel and data organized in Excel is easily compatible with Access. Access also allows cross-referencing between relatable tables to reveal relative data to the user. An interface made with VBA ComboBoxes was constructed so the scientist or engineer can easily select a material of their choice. The conductor database contains data (tensile and fatigue test performed since 1994 in MagLab) for materials used to build high field pulse and resistive magnets.

MS&T scientists will have quick, easy, and organized access to prime properties of materials. MS&T scientists will be able to select the best material required for the bitter disk of the resistive magnet and the wires for the pulse magnet. Properties of specific materials can be observed by analyzing fatigue and tensile tests. A fatigue test is conducted by exposing specimens to repeated stresses levels. The procedure is repeated for other specimens at various

stress levels. When specimens are exposed to cyclic stresses they will become fatigued and eventually break. Tensile testing involves operating an apparatus that applies tension to a sample. The specimen is stretched at a constant rate and both applied stress load and displacement are measured instantaneously. The specimen is stretched until it is fractured.

Method for building the conductor database

Step 1. Gather all tensile and fatigue data for the resistive and pulse magnet since 1994 and organize into Excel sheets.

Step 2. Transfer the following data from Excel to Access:

- Pulse Tensile
- Pulse Fatigue
- Resistive Tensile
- Resistive Fatigue

Step 3. A table for each Excel sheet was created in Access. A primary key is a unique identifier for each record. A primary key for each table was defined with a field name as “ID”.

Step 4. Data types were also defined for each field specifying what type of data the field can store. For example, common data types were short Text, AutoNumber and Number. Short Text values store alphanumeric data up to 255 characters. AutoNumbers were defined for the primary keys of each table to distinctively identify each record. Numbers were used to store a numeric value.

PulseTensileTable	
Field Name	Data Type
ID	AutoNumber
Material	Short Text
WorkOrderNo	Short Text
WireDimension	Short Text
RT modulus	Number
77 K modulus	Number
RT-YS	Number
77 K YS	Number
RT-UTS,	Number
77 K UTS	Number
RT elongation	Number
77K elongation	Number
RT area reduction, %	Number
77K area reduction, %	Number
RT-IACS,%	Number
RRR (R295/R77)	Number
Conductivity	Number
MaterialID	Number
WorkOrderNoID	Number

Figure 1: Pulse Tensile Table

The field names are important properties of materials that are analyzed during tensile test for pulse magnet materials.

PulseFatigueTable	
Field Name	Data Type
ID	AutoNumber
WorkOrderNumber	Short Text
Material	Short Text
PulseFatigueSampleNumber	Short Text
Design	Short Text
StressRatio	Number
Frequency	Short Text
MaxStress	Number
CyclesToFailure	Number
WireInventoryNumber	Short Text
InitialFatigueStressMin	Short Text
InitialFatigueStressMax	Short Text
LoadMode	Short Text
AutofrettageStressMax	Short Text
AutofrettageStressMin	Short Text
WorkOrderNumberID	Number
WireInventoryNumberID	Number
LoadModeID	Number
MaterialID	Number

Figure 2: Pulse Fatigue table

The field names are important properties of materials that are analyzed during pulse fatigue test for resistive magnets.

ResistiveTensileTable	
Field Name	Data Type
ID	AutoNumber
Sample Number	Short Text
PO No	Number
PR No	Number
MaterialAndPartNumber	Short Text
Description	Short Text
ReportOrWorkOrderNo	Short Text
Modulus	Number
YieldStrength	Number
TensileStrength	Number
Elongation in 25 mm	Number
Conductivity % IACS Longitudinal	Number
Conductivity % IACS Transverse	Number
Average Conductivity	Number
ReportOrWorkOrderNoID	Number
POID	Number
MaterialDescriptionID	Number
MaterialAndPartNumberID	Number
PRNoID	Number

Figure 3: Resistive Tensile Table

The field names are important properties of materials that are analyzed during tensile test for resistive magnets.

ResistiveFatigue	
Field Name	Data Type
ID1	AutoNumber
ID	Number
RollingOrientation	Short Text
SampleNumber	Short Text
WorkOrderNumber	Short Text
Material	Short Text
Design	Short Text
Thickness (mm)	Number
Stress Ratio	Number
Frequency (Hz)	Number
AmplitudeStress	Number
CyclesToFailure	Number
WorkOrderNumberID	Number
MaterialID	Number
RollingOrientationID	Number
DesignID	Number

Figure 4: Resistive Fatigue Table

The field names are important properties of materials that are analyzed during fatigue test for resistive magnets.

Step 5. Relationships are the connection mechanism between tables in the database. In order for sophisticated searches to be established individual relationships for each table were defined. To create a relationship, the user must go to database tools and select relationships. The user must then select the Show table and begin adding tables for their relationships. The user can drag the primary key field to the foreign key in the other table. The edit relationship dialog box will appear and the user will have the option to enforce referential integrity. Enforcing referential integrity in Access prevents the user from corrupting data relationships.

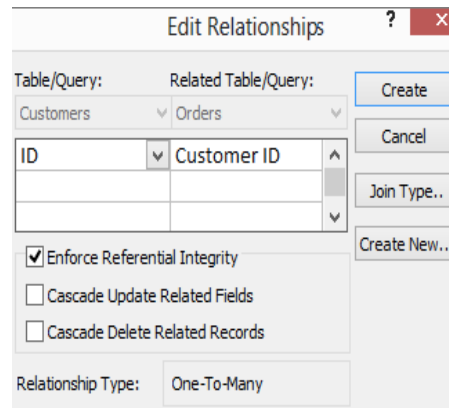


Figure 5: Edit Relationships

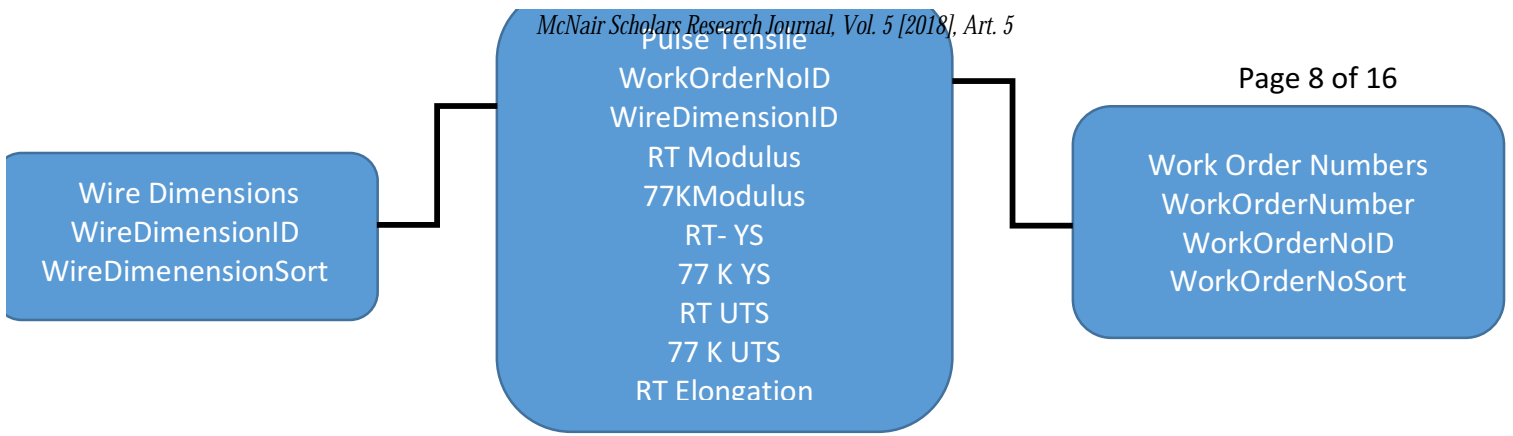


Figure 6: Pulse Tensile Relationship Flow Diagram

The Pulse Tensile table was designed to store information about samples that were tensile tested. Each sample has a specific material, work order number, wire dimension, RT (room temperature) modulus, 77K modulus, RT YS (yield strength), 77 K YS, RT UTS (ultimate tensile strength), 77K UTS, RT elongation, RT area reduction %, 77K area reduction %, RT – IACS%, RRR, and conductivity. Individual tables were designed for the materials and wire dimensions to identify the different types in the pulse tensile test data. Referential integrity was enforced for the relationship between material and wire dimension IDs.

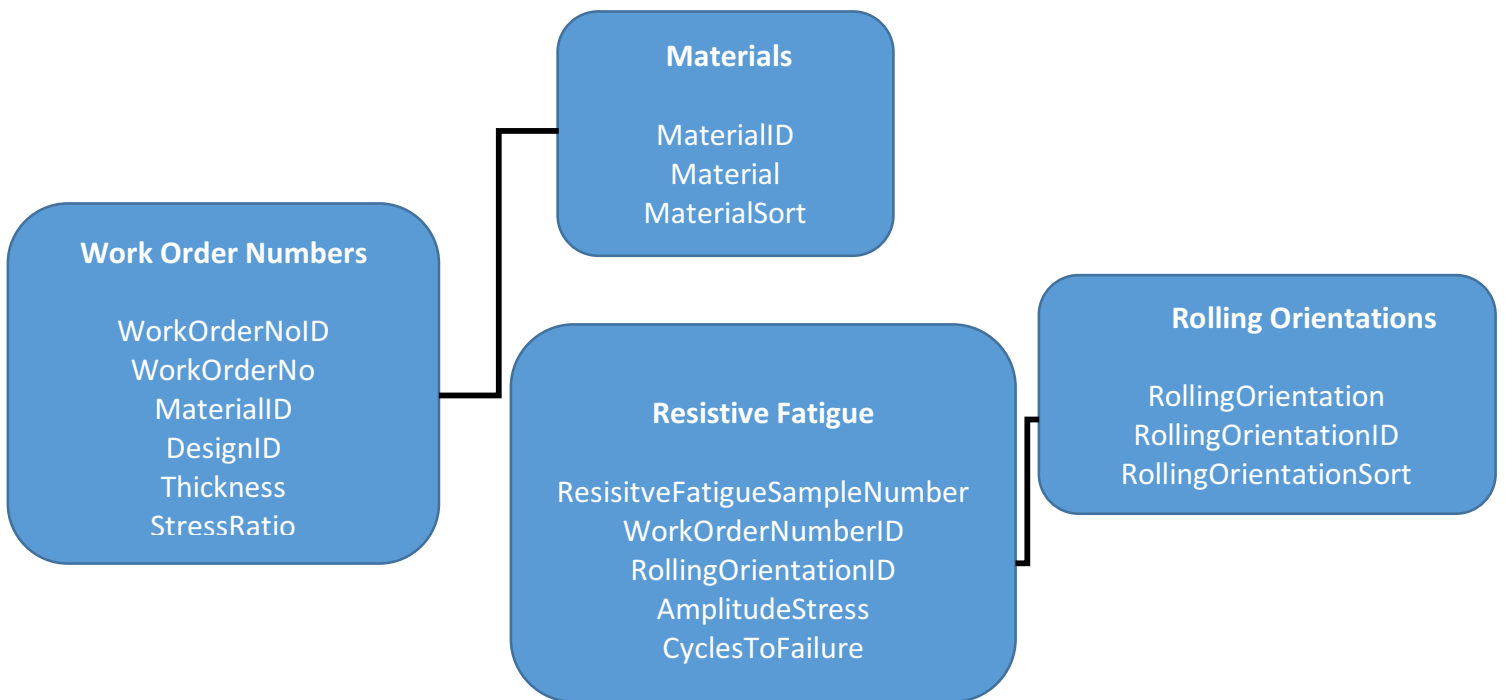


Figure 7: Resistive Fatigue Relationship Flow Diagram

The Resistive Fatigue table was designed to store samples that were fatigue tested. Each sample has a work order number, rolling orientation, amplitude stress, and cycles to failure. The resistive fatigue work order number table was designed to store the experimental design, thickness of sample, stress ratio, and frequency that each work number has. Tables were made for the materials, designs and rolling orientations to uniquely identify the different types in the resistive fatigue data. Referential integrity was enforced for the relationships between work order numbers, rolling orientation and material IDs.

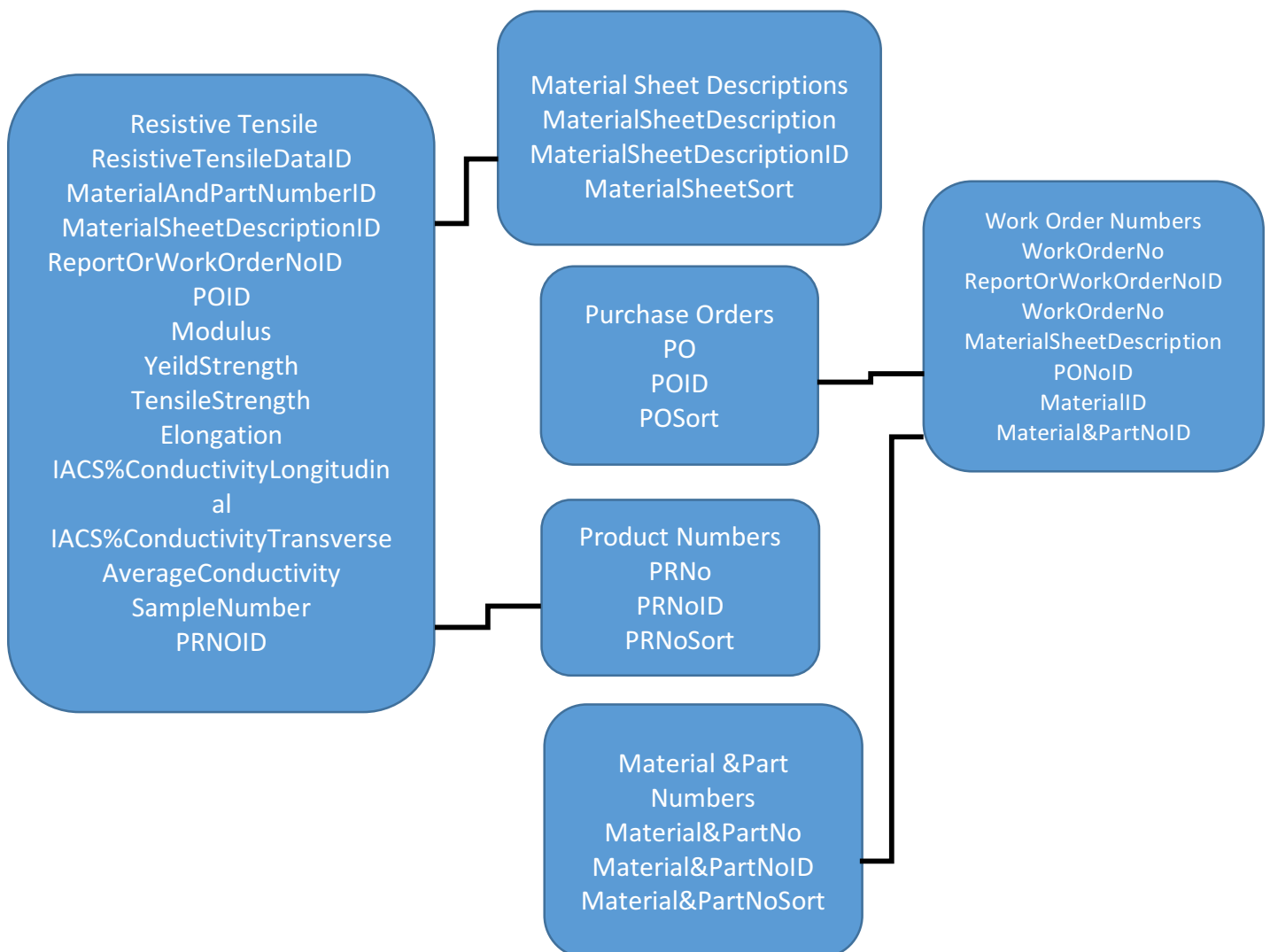


Figure 8: Resistive Tensile Relationship Flow Diagram

The “Resistive Tensile” table was designed to store samples that were tensile tested. Each sample has a material, part number, sample number, work order number, purchase order, product number, modulus, yield strength, tensile strength, elongation, IACS% conductivity longitudinal, IACS% conductivity transverse and average conductivity. The “Work Order Number” table was designed to store the relationship between a sample and their work order number. Each work order number has a material sheet description, purchase number and material. A table was made for purchase orders (PO), product number (PRNo), material sheet descriptions and materials& Part numbers identify the different types in the resistive tensile testing data. Referential integrity was enforced for relationships between work order number, purchase order, material sheet description, material and part number and product number ID’s.

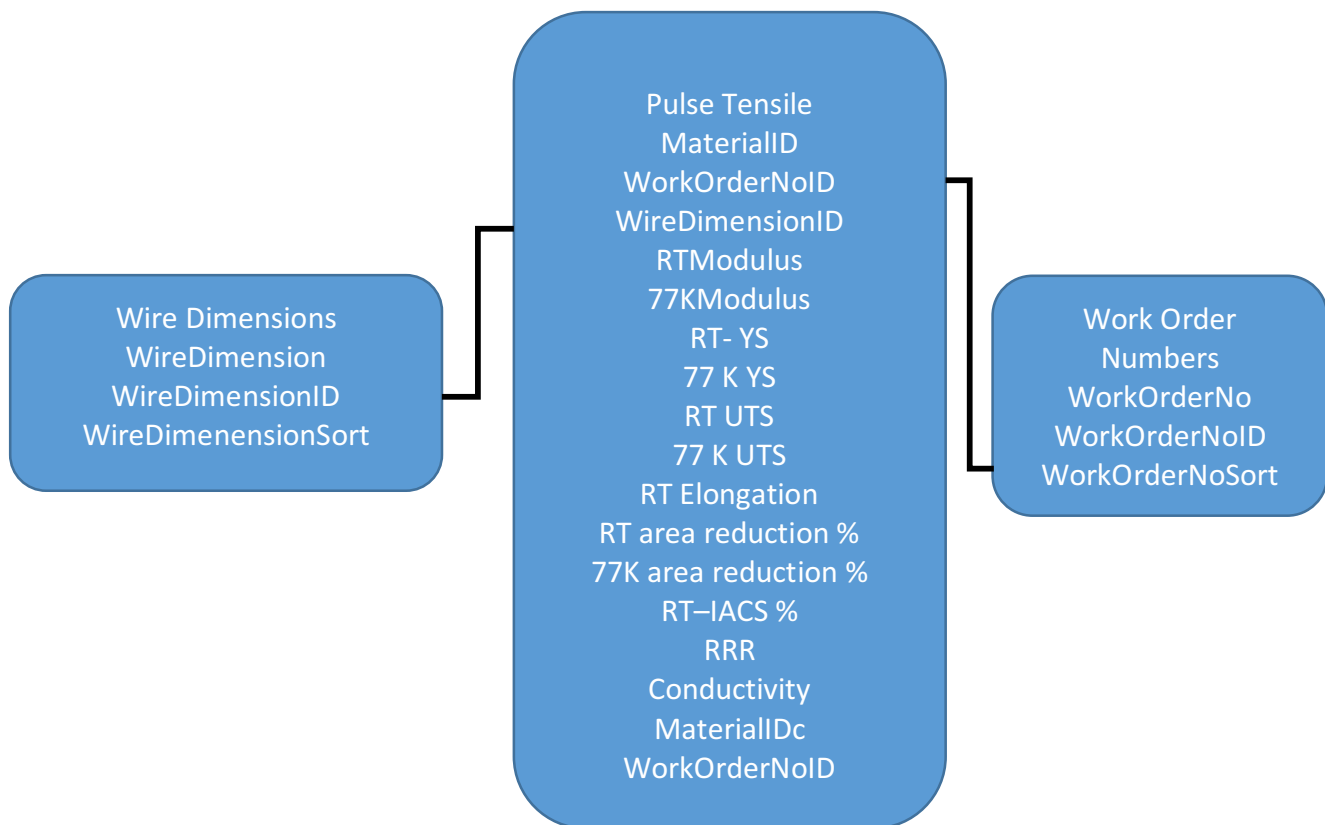


Figure 9: Pulse Tensile Relationship Flow Diagram

The Pulse Tensile table was designed to store information about samples that were tensile tested. Each sample has a type of material, work order number, wire dimension, RT (room temperature) Modulus, 77K Modulus, RT (Room temperature) YS Yield strength, 77 K YS (yield strength), RT UTS (Ultimate Room Temperature Tensile, 77K UTS (Ultimate Tensile Strength), RT Elongation, RT area reduction %, 77K area reduction %, RT – IACS%, RRR, and conductivity. An individual table was designed for the materials and wire dimensions to identify the different types in the pulse tensile testing data. Referential integrity was defined for Material and Wire dimension IDs.

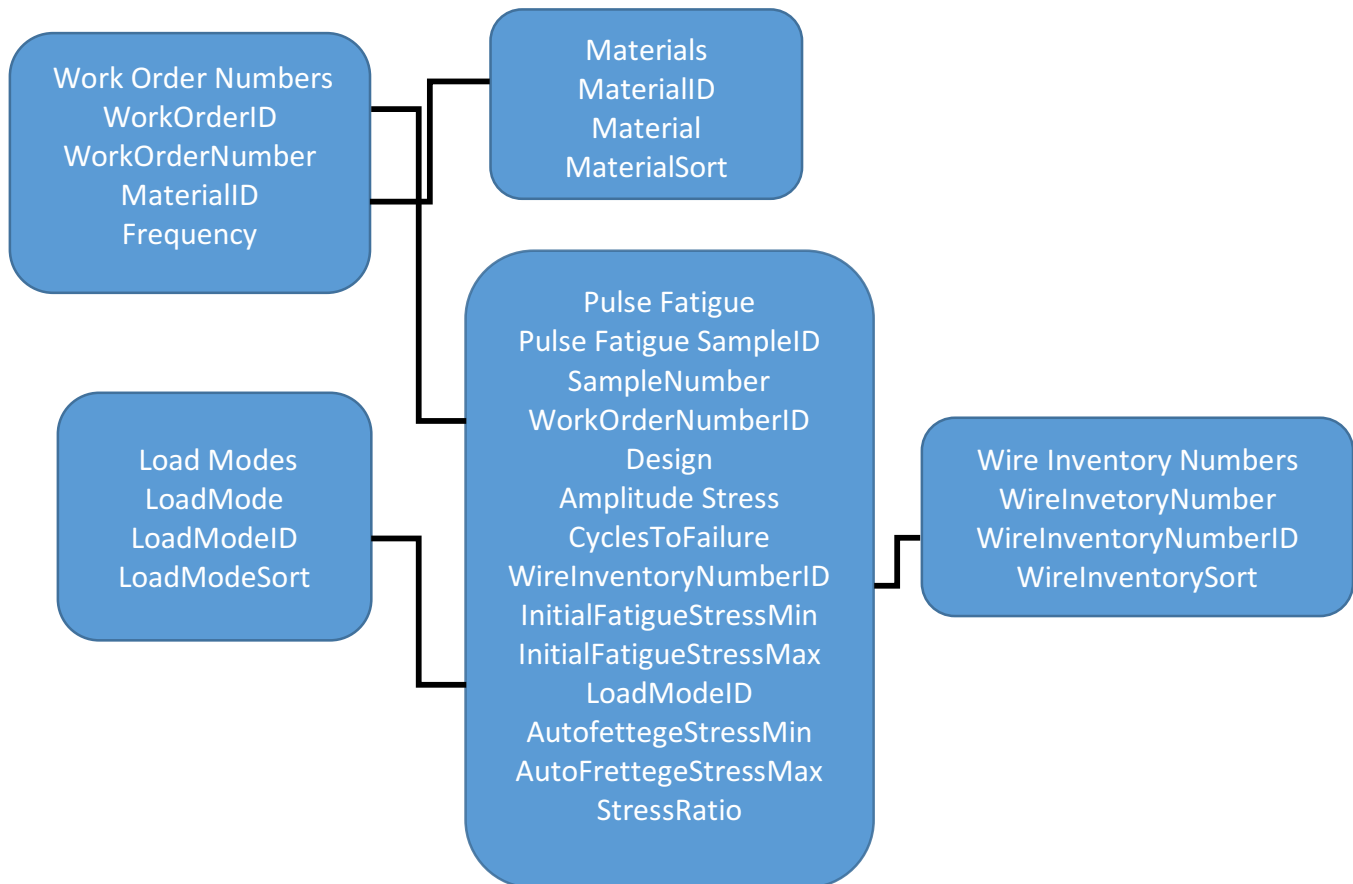


Figure 10: Pulse Fatigue Relationship Flow Diagram

The pulse fatigue table was designed to store information about samples that were fatigue tested. Every sample has a sample number, work order number, design, amplitude stress, cycle to failure, wire inventory number, minimum initial fatigue stress, maximum initial fatigue stress, load mode, auto frettage stress minimum, auto frettage stress maximum, and stress ratio.

Referential integrity was defined for the load mode, wire inventory number, work order number, and material ID's. An individual table for the work order number, wire inventory number, load mode and material was designed to identify the different types in the pulse fatigue testing data.

Step 6. Convert each table into an individual form in MS Access. This allows for a more effective interpretation of data for the user.

Step 7. Define a material selection for each form with bound ComboBoxes. The user can now select a value directly from a list that is linked to the specific table.

Results

Tables converted into forms: All ComboBoxes on forms prompt the user to select a material based on mechanical properties. Once the selection is made, properties on each form are updated.

PulseTensileForm	
PulseTensileTable	
Select Material, RT and 77K Tensile Strength: <input type="text" value="CuNb"/>	
ID	148
Material	CuNb
WorkOrderNo	17-001
WireDimension	5.2x7.2 mm2 Reduced x-section
RT modulus	132
77 K modulus	140
RT-YS	837
77 K YS	849
RT-UTS,	1083
77 K UTS	1285
RT elongation	4.8
77K elongation	6.1
RT area reduction, %	12.8
77K area reduction, %	15.3
RT-IACS,%	77.75
RRR (R295/R77)	5.39
Conductivity	419.07
MaterialID	6
WorkOrderNoID	232

Figure 11: Pulse Conductor Table and Form. Users can select a material with a specific max stress.

PulseFatigueForm			
PulseFatigueTable			
Select Material and Max Stress: <input type="text" value="CuNb"/>			
ID	<input type="text" value="28"/>	InitialFatigueStressMin	<input type="text" value="-424"/>
WorkOrderNumber	<input type="text" value="EM 08-003 09-003"/>	InitialFatigueStressMax	<input type="text" value="447"/>
Material	<input type="text" value="C107"/>	LoadMode	<input type="text" value="displace"/>
PulseFatigueSampleNumber	<input type="text" value="072-8b"/>	AutofrettageStressMax	<input type="text"/>
Design	<input type="text" value="cryostat"/>	AutofrettageStressMin	<input type="text"/>
StressRatio	<input type="text" value="-0.949"/>	WorkOrderNumberID	<input type="text" value="1514"/>
Frequency	<input type="text" value="5"/>	WireInventoryNumberID	<input type="text"/>
MaxStress	<input type="text" value="447"/>	LoadModeID	<input type="text" value="1"/>
CyclesToFailure	<input type="text" value="292"/>	MaterialID	<input type="text" value="5"/>
WireInventoryNumber	<input type="text"/>		

Figure 12: Pulse Fatigue Table and Form. Users can select a material with a specific max stress.

Field Name	Value
ID	300
Sample Number	R838-L38
PO No	
PR No	
MaterialAndPartNumber	C15100
Description	SHT, CuZr, 0.77
ReportOrWorkOrderNo	1999-015
Modulus	117
YieldStrength	479
TensileStrength	491
Elongation in 25 mm	5.0
Conductivity % IACS Longitudinal	91
Conductivity % IACS Transverse	90
Average Conductivity	90
ReportOrWorkOrderNoID	357
POID	
MaterialDescriptionID	24
MaterialAndPartNumberID	12
PRNoID	

Figure 13: Resistive Tensile Table. Users can select a material with a specific yield and tensile strength

Field Name	Value
ID1	
ID	1
RollingOrientation	Longitudinal
SampleNumber	FTG#L1
WorkOrderNumber	MTS 94-002
Material	CuAg
Design	Obround
Thickness (mm)	0.4
Stress Ratio	0.1
Frequency (Hz)	5
AmplitudeStress	828
CyclesToFailure	3358
WorkOrderNumberID	14
MaterialID	1
RollingOrientationID	1
DesignID	1

Figure 14: Resistive Tensile Table and Form. Users can select a material with a specific room temperature and 77° K tensile strength

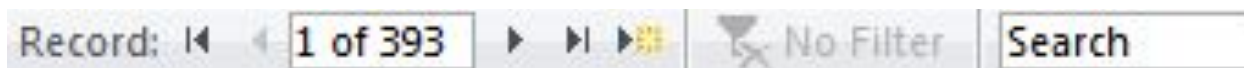


Figure 15: Search Tab on the Pulse Tensile Form

DISCUSSION

Building the conductor database with MS Access is an efficient method for organizing fatigue and tensile data of materials for the resistive and pulse magnet. Scientists and engineers at the MagLab can use the conductor database as a material reference to building desired pulse and resistive magnets. Combo boxes on each form enables scientists to quickly access specific materials by selecting mechanical properties. The work order numbers on each form inform the user on which year the fatigue or tensile test was conducted. For example, work order number 17-001 means the tensile test was conducted in 2017. On the bottom of each form the user can use the search tab to browse through different materials and can add new test data to the specific form.

MS Access is a quick means of preparing a database; permits using commonly-available graphical tools; and is almost universally available to personal computer users. However, scalability is only moderate – for larger data sets performance is hindered. Also, sharing of data sets is impractical since the localized database means files must be shared. As this is a tool to be utilized by researchers, a consideration is how to make it more available. Conversion to an SQL database with a web interface is the natural progression after this draft-level tool has been constructed.

Acknowledgements

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