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DESIGN AUTOMATION OF PRE-SEPARATOR WEDGES FOR FRIB ADVANCED RARE ISOTOPE SEPARATOR*

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Abstract

At the Facility for Rare Isotope Beams (FRIB) unique pre-separator wedges are required for each experiment. As the number of experiments and wedges needed increases every year, reduction in design time and increase in accuracy is critical (FY23 utilized 40 unique wedges, FY24 approx. 60 are planned, and eventually 100 annually).

Design automation is achieved by DriveWorksXpress™, which reduced design/drafting time by 60%. A form was created with parameters (inputs) listed for each component of the wedge assembly (e.g., wedge height, wedge on axis thickness, wedge angle, etc.). The dimensions and file properties of each component are then able to reference the input values for each parameter from the form and automatically adjust the model and assembly accordingly. Automation on drawing drafting is achieved at the same time.

The reduction in design time resulted in completing the design task more efficiently. A reduction in design error and human error was also observed, reducing manufacturing down time and effort required during the release process. These benefits have streamlined the mechanical design process for the pre-separator wedges.

INTRODUCTION

In mechanical design there is constant motivation to reduce design time while also increasing model and drawing accuracy. Reduction in design time allows resources to finish a project more effectively and opens them up for opportunity to work on other projects. Increase in model and drawing accuracy reduces design and human error resulting in a more streamlined manufacturing process.

Design automation tools have been used in many industries to streamline the design process [1-3]. The use of these design automation tools within engineering in the physics sector could be a powerful tool if applied to situations where there is redundancy in a design and a frequent need for the design.

At FRIB, this situation has been presented in the form of needing unique pre-separator wedges for each experiment. The goal of a wedge in an experiment is to deaccelerate down the ions that pass through it and further purify the beam of study. The profile of the wedge is determined based on the position of the particle and its magnetic rigidity after the wedge. Different ions will experience a different amount of deacceleration down, therefore each beam of study requires its own unique wedge profile. A wedge profile impacts three main factors within the design model: wedge on-axis thickness, wedge angle and wedge height. Figure 1 shows a standard wedge design model where the on-axis thickness, angle and height would be modified and its print drawing would update accordingly (Fig. 2). This print drawing would then be sent to the machine shop for fabrication.

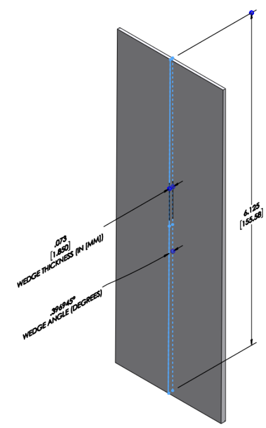

Figure 1: Standard wedge design model.

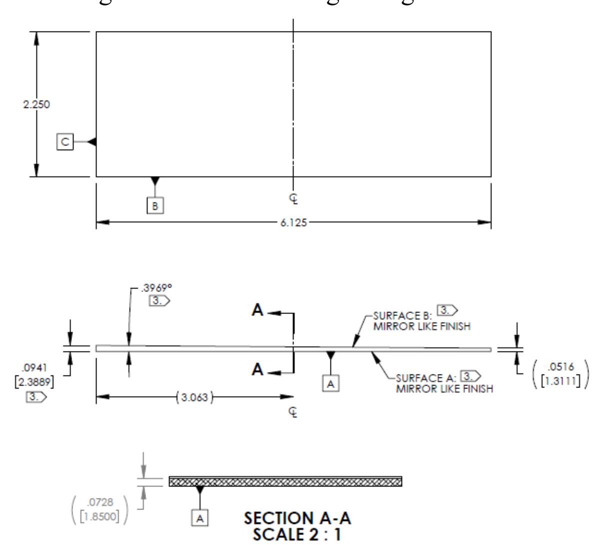

Figure 2: Standard wedge design print.

As the number of wedges has increased over the years with an anticipated annual need of approximately 100 wedges [4-7], it presents the need for a design automation tool. This motivated the search for such design tool that fit the application and could be used universally within the mechanical engineering department for potential future applications.

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METHOD

The FRIB mechanical engineering department utilizes the 3D computer aided design (CAD) software SolidWorks® for design engineering. DriveWorks™ is a design automation software tool to automate SolidWorks®. DriveWorks™ consists of multiple products, DriveWorksXpress™, DriveWorks Solo™ and DriveWorks Pro™. DriveWorksXpress is an entry level design automation tool that is included within SolidWorks®. This product was chosen for this application due to the early exploration of design automation, cost and availability to SolidWorks® users within the mechanical engineering department.

DriveWorksXpress™' setup is a user submission form style. The form contains a series of parameters (inputs) that are needed in the design (Fig. 3). For example, the parameters that change with each experiment for a pre-separator wedge are on-axis thickness, wedge angle and wedge height. There are also file property parameters that are included in the form such as experiment ID, date, engineer, and part number. All of these parameters influence the creation of the parts, assemblies and drawings within SolidWorks®.

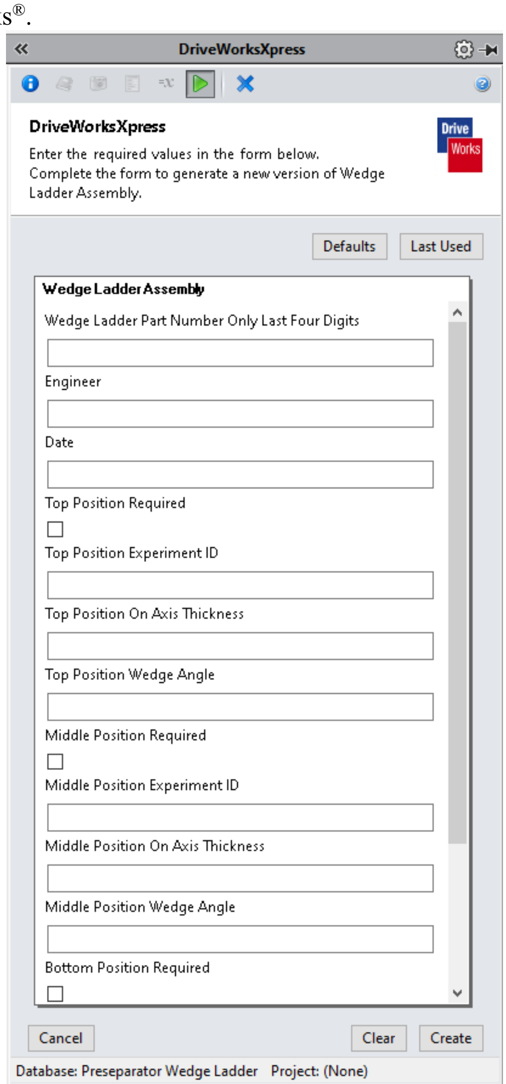

Figure 3: Example of DriveWorksXpress™ Form.

After the parameters have been defined, base models for the parts, assemblies and drawings are connected to the DriveWorksXpress™ program. These base models act as the starting point for the automation tool and the parameters are linked to the base models. Within the base models, dimensions are selected, related to the corresponding input parameters and if needed, if-then statements are used to define the change required (Fig. 4). The if-then statements used in DriveWorksXpress™ resemble the formatting of equations in Microsoft® Excel®.

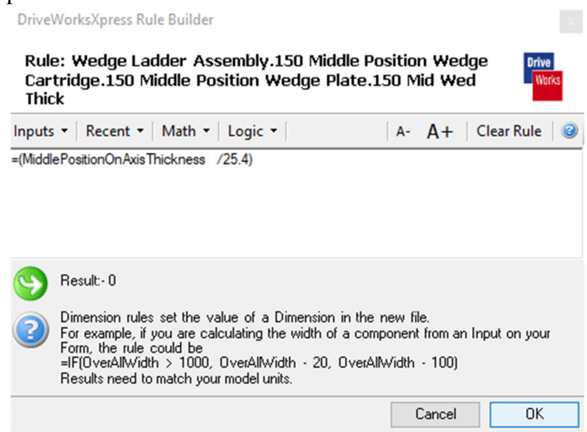

Figure 4: Example of DriveWorksXpress™ If-Then Statement.

Once all the parameters have been linked to the base models as intended, the program is ready for use. When a new experiment is presented with unique parameters, the DriveWorksXpress™ form that was created is filled out with the information. The base models are then automatically modified to match these updated parameters and the output of parts, assemblies and drawings are created unique to the experiment parameters requested.

RESULTS

To review the time saving benefits of using design automation in the creation of pre-separator wedges, a time trial study was conducted. The scenario consisted of creating three wedge parts, one assembly and four drawings (three part drawings and one assembly drawing) using parameter inputs from a previous experiment. Figure 5 highlights the process of the two methods that were used to create the models and drawings.

The first method of creating the parts, assembly and drawings was done by hand. The parameters were manually put into the base models, drawings were updated and once all parts, assembly and drawings were complete they were reviewed for accuracy. The resulting time for this time trial was 41 minutes.

The second method of creating the parts, assembly and drawings was done using DriveWorksXpress™ design automation tool. The parameters were put into the form and the program was used to create the parts, assembly and drawings. Once the files were created they were reviewed for accuracy. The resulting time for this time trial was 13 minutes.

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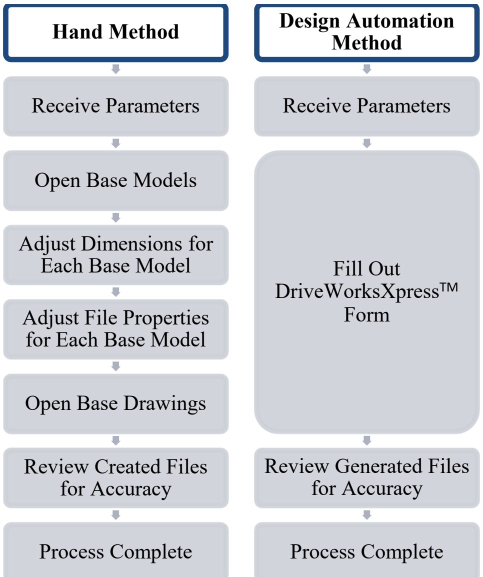

Figure 5: Flowchart of methods used to create models and drawings.

For this one time trial study there was a reduction in design time of 68%. Due to the limited number of time trials conducted and the time trial being previously used parameters it is estimated that the expected design time reduction while using design automation tools could be approximately 60%.

When reviewing the impact of design automation on accuracy, the final review of the parts, assembly and drawings resulted in identical files for both methods. The accuracy check for the first method was more labor intensive and tedious as all dimensions on the parts, assembly and drawings were necessary to review. With the second method only a handful of dimensions were updated based on what was linked to the parameters, therefore when checking for accuracy only the modified dimensions were necessary to review. Therefore, there was an increase in accuracy due to the limitation of what dimensions or items were being changed within the model.

DISCUSSION

For the design of pre-separator wedges where the design is redundant and unique designs are needed on a frequent basis, design automation is a great candidate for reducing the design time and increasing accuracy in the models. From the time trial and experience in using DriveWorksXpress™ in recent applications there has been an average design time reduction of approximately 60%. This has significantly reduced the design load on resources creating these models. There has also been an increase in accuracy which has resulted in a smoother transition to fabrication and streamlining of the manufacturing process.

While design automation is helpful in these ideal applications, challenges have been experienced when one-of-a-kind wedges are requested for an experiment. When a wedge doesn't fit the DriveWorksXpress™ form and is required to be designed by hand, there is an increase in design time required.

Another observation is that the design automation tool is not stagnant, instead it is ever changing and needing to be updated. The design automation tool goes through iterations of base models or parameters listed in the form based on feedback received during experiments. Therefore, time to update the design automation tool is also required on an infrequent basis.

CONCLUSION AND FUTURE WORK

FRIB's mechanical engineering department has experienced a significant reduction in design time from the use of design automation tools, like DriveWorksXpress™, for the design of the pre-separator wedges. This has alleviated resources and made them available for other projects. It has also increased accuracy in the models being created reducing the likelihood of issues arising during the manufacturing process. Although the design automation tool does have limitations, including one-of-a-kind designs and updates required to the design tool itself, the benefits of using the tool outweigh the challenges.

To further utilize design automation tools for this application, exploration into other DriveWorks™ products such as DriveWorks Solo™ and DriveWorks Pro™ could be conducted. These products have additional features, inputs and outputs that could further streamline the design process. The downside of these products is the increase in cost and reduction in universal use among a department. A thorough cost benefit analysis would help highlight if these upgraded design automation programs would be beneficial.

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