Paper Feeding System Tutorial (AutoDesign)
# Table of Contents

**Paper Feeding System Design Problem** ............................................................. 4  
Loading the Model and Viewing MTT2D model .................................................. 5  
Defining the design variables ............................................................................. 6  
Defining the analysis responses .......................................................................... 7  
Running a design optimization problem ........................................................... 9  
Comparison of analysis results ......................................................................... 11
Outline of Tutorial

<table>
<thead>
<tr>
<th>Model</th>
<th>Paper Feeding System Design Problem:</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample_E</td>
<td>When a paper feeds through the roller system-2 and pass through the roller system-1. In a given time, the roller system-1 rotates reversely. Then, the paper runs the roller system-1 backward. The design goal is to minimize the slip between roller-system and paper while satisfying the nip force limitation. <strong>Key Point:</strong> Study the Expression for representing the slip phenomenon. Also, note the design modeling approach to use the guide position as design variable.</td>
<td>4</td>
</tr>
</tbody>
</table>

**Note**
The default value of digits is changed in V7R3. The V7R2 used ‘8’ but the V7R3 uses ‘10’. The following examples are solved in V7R3. Thus, their optimization results may be different from those in V7R2. This digit change can affect on the analysis and design optimization results.

**Tools/Setting/Model Settings/Option1**
Paper Feeding System Design Problem

A paper feeds into the roller system-2 and runs through the roller system-1. When the end of paper passes at the event sensor position, the rotation direction of the roller system-1 is changed as reverse direction.

The design objective is to minimize the slip amount between the paper and the fixed roller in the roller system-1 while satisfying the nip forces of two roller systems for their limits. The design variables are the stiffness, damping and pre-load of nip springs and the rotation angle of the guide attached in the green colored dummy body.

<table>
<thead>
<tr>
<th>Import files related in Sample-E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample</strong></td>
</tr>
<tr>
<td><strong>Solution</strong></td>
</tr>
</tbody>
</table>

*Note: If you change the file path at discretion, it can be located in any folder that you specify.*
Loading the Model and Viewing MTT2D Model

To load the base model and view the animation:

1. On your Desktop, double-click the RecurDyn tool.
2. RecurDyn starts and the New Model window appears.
3. Click Cancel to exit the New Model dialog box. You will use an existing model.
4. In the toolbar, click the Open tool and select ‘Sample_E.rdyn’ from the same directory where this tutorial is located.
5. The paper feeding system appears in the modeling window. Click the center of model to switch model as MTT2D.
6. Click the Analysis button.
7. Click the Play button.
8. The paper moves from left upper end to the right bottom end. The paper will hit the guides during it progresses.
Defining the Design Variables

When you see the parametric Value in the Subentity menu, the following 13 parameters are listed. Among them, parameters 1~6 and 10 are the design variable.

The nip spring properties are linked to the parametric values as follows: Check Nip Spring. Then, Nip Spring Property button is activated. Then, click the button. The right window will be shown. Then, define the Stiffness, Damping and Pre Load by using the parametric values.

Next, create the dummy body as ‘Body2’ and attach the Linear Guide to the dummy body.
And define the rotational joint at the right end of Body 2. This is used only to define the Motion. The parametric value of ‘Guide_Control’ is used to describe the Motion expression. When the analysis start, the body is rotated with the magnitude of ‘Guide_Control’(deg.). Then, the guide will rotate with the same degree because it is attached to the Body2.

**Defining the Analysis Responses**

Although MTT2D provides the mean slips of each roller, they can not be directly controlled in the Expression, which represents that they are not Analysis Response. Thus, we make the slip amounts by using the Expression. The right expression is the slip amount between the paper and the Fixed_roller body in 0.35 second.

The Nip force can be represented by using the spring force.
The analysis responses are defined as the right figure. AR1 is the maximum value of the nip spring force. AR2 and AR3 are the absolute maximum and the RMS of the expression, EX3.

For the initial design, the expression EX3 gives the following result, which may be highly nonlinear to the change of design variables.
Running a Design Optimization Problem

The optimization problem is defined as:

Minimize the Maximum Peak of Slip and the RMS of Slip
subject to

\[ \text{Nip Force} = \leq \text{Limit} \]

1. In the **Design Optimization** menu, the **Design Variable** tab shows the list of design variables.

2. In the **Performance Index** tab, the above design formulation is defined as right. In this study, the limit of Nip force is used as 0.025(N/mm).

3. In the **DOE Meta Modeling Methods** tab, Auto Selection recommends ‘Discrete Latin Hypercube’ and RBF with multi-quadratics as the initial DOE and metamodel. The general guideline for selecting the initial DOE and metamodel is explained in the manual **Part II: Guideline for AutoDesign**. The initial DOE selection for this problem however does not follow the guideline because the expression EX3 seems to be nonlinear.
4. In the **Optimization Control** tab, the convergence tolerances use the default values.

5. Next, check the **Result Sheet** after the optimization is completed. SAO1 gives nearly converged result. The relative deviation between SAO1 and SAO2 satisfies the convergence tolerance. Thus, AutoDesign is converged in 2 iterations. In the final design, the nip force is 0.02432 and the slip amounts such as the maximum peak and the RMS value are 7.732 and 1.767.
6. The Following figures compare the guide positions for the initial and the final designs. When the paper is reversely feed, the initial design hits the guide marked ‘A’ but the final design does not. Thus, the final design can reduce the slip.

![Initial Design vs Final Design](image)

**Comparison of Analysis Results**

Now, we compare the analysis responses. First, compare the nip forces. The blue color line is the initial design and the red color line is the final design. This comparison shows that the final design satisfy the limitation.

![Comparison of Nip Forces](image)
Next, let’s compare the slip amounts. The final design (red color line) is much less than the initial one (blue color line). From our empirical experience, the maximum slip peak, shown as sharply shaped mountain, is highly nonlinear. Thus, it’s approximation requires many sampling points. Although the shape of the nip forces seems to be sharp, it is however slightly nonlinear because their shapes have same trends according to the changes of design variables. The reason of non-smoothness of the maximum peak of slip amounts is due to the position of guide (DV7). Compare the guide position for the initial and the final design, which explains the non-smoothness.