SPINDLE DEFLECTION TEST STAND

A thesis submitted to the
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by

EREZ GRENIMAN

Bachelor of Science University of Cincinnati

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Faculty Advisor: Janek Dave, PhD
ACKNOWLEDGMENT

All though this project carries my name there are several individuals that without their guidance and devotion I would not be able to complete this project. First of all I would like to grand my gratitude and respect to Mr. Mick Davies who was my mentor in this entire process, Mr. Davies was always available to guide me whenever I needed it. I would also like to thank Mr. Vick Vogel, without his knowledge and experience it would have been impossible to complete this project. I really want to thank Mr. Jason Reynolds our company’s general manager who made this all happen. And last on the list but always first in my life, my wife Rotem, without your love and support none of this would matter, thank you.
ABSTRACT

Spindle deflection testing is one of the most important procedures when assembling a spindle cartridge, the entire performance of the machine depends on this type of testing. Spindle deflection testing is a simple, easy and fast procedure when the proper device is used, trying to conduct this testing with some made up, out of date equipment can be a long and agonizing process. By combining the desired features of the operator with the proper engineering procedures a new design was born with the ability to change the entire spindle cartridge testing capabilities of MAG – LLC, and at the same time increase production and reduce expenses.
# TABLE OF CONTENTS

- SPINDLE DEFLECTION TEST STAND................................................................. I
- ACKNOWLEDGMENT ......................................................................................... II
- ABSTRACT ........................................................................................................ II
- TABLE OF CONTENTS ..................................................................................... III
- LIST OF FIGURES .......................................................................................... IV
- LIST OF TABLES .............................................................................................. IV
- INTRODUCTION ............................................................................................... 1
  - BACKGROUND ............................................................................................... 1
- EXISTING METHODS OF DEFLECTION TESTING ........................................ 2
  - CATEGORY # 1 – PRECISION DEFLECTION TESTING.............................. 2
  - CATEGORY # 2 – HEAVY DUTY DEFLECTION TESTING........................... 4
  - EXISTING METHODS FOR SPINDLE SHAFT DEFLECTION TESTING........ 6
- CUSTOMER FEEDBACK, FEATURES AND OBJECTIVES ................................ 8
  - SURVEY ANALYSIS ....................................................................................... 8
  - PRODUCT FEATURES AND OBJECTIVES .................................................. 10
- SCHEDULE AND BUDGET .............................................................................. 14
- CONCEPT GENERATION AND SELECTION .................................................. 15
  - DUAL PLATE TESTING DEVICE ................................................................. 15
  - HYDRAULIC LOADING TESTING DEVICE ................................................. 15
  - DEFLECTION TESTER – SELECTED CONCEPT ......................................... 16
  - CONCEPT DESIGN – SUMMARY ................................................................. 16
- CALCULATIONS ............................................................................................... 18
- ASSEMBLY DESIGN DETAILS ....................................................................... 19
- TESTING .......................................................................................................... 24
- PRODUCT FEATURES AND OBJECTIVES – POST TESTING ...................... 27
- CONCLUSION .................................................................................................. 28
- WORKS CITED .............................................................................................. 29
- APPENDIX A – RESEARCH ........................................................................... A
- APPENDIX B – CUSTOMER SURVEY AND RESULTS .............................. B
- APPENDIX C – QUALITY FUNCTION DEPLOYMENT ANALYSIS .................. C
- APPENDIX D – SCHEDULE .......................................................................... D
- APPENDIX E – BUDGET ................................................................................ E
- APPENDIX F – CALCULATIONS ................................................................... F
- APPENDIX G – ASSEMBLY AND DETAIL DRAWINGS ................................. G
APPENDIX H - BILL OF MATERIALS

LST OF FIGURES

Figure 1 - Chatillon TCD 200 Digital Test Stand ................................................. 2
Figure 2 - Indentation Force Deflection (IFD) .......................................................... 3
Figure 3 - Nondestructive Deflection Testing ............................................................ 4
Figure 4 - Q - Impact 25 Pendulum Impact Tester ..................................................... 5
Figure 5 - Current Spindle Deflection Testing Device ................................................. 6
Figure 6 - Deflection Testing Device Mounted onto a Spindle Cartridge ....................... 7
Figure 7 - Concept Drawing ....................................................................................... 15
Figure 8 - Concept Drawing (Selected) ..................................................................... 16
Figure 9 - T Slot Table ............................................................................................... 19
Figure 10 - 10" V Block ............................................................................................. 19
Figure 11 – Key .......................................................................................................... 20
Figure 12 - Slide & Angle Plate .................................................................................. 20
Figure 13 - Slides Assembly ...................................................................................... 21
Figure 14 - Mounting Plate & Load Cell ..................................................................... 21
Figure 15 - Spindle Deflection Test Stand Assembly .................................................. 22
Figure 16 - Spindle Deflection Test Stand Assembly .................................................. 22
Figure 17 - Spindle Deflection Test Stand Assembly .................................................. 23
Figure 18 - Spindle Deflection Test Stand Assembly .................................................. 23
Figure 19 - FTV (Lancer) Spindle Cartridge ............................................................... 25
Figure 20 - Spindle Deflection Test Stand (Fully Assembled) ....................................... 25

LIST OF TABLES

Table 1 - Customer Satisfaction .................................................................................. 8
Table 2 - Customer Importance .................................................................................. 9
Table 3 - Customer Features Ranking ....................................................................... 10
Table 4 – Schedule .................................................................................................... 14
Table 5 – Budget ...................................................................................................... 14
Table 6 - Rated Weight Method ................................................................................ 17
Table 7 - Current Expenses ...................................................................................... 17
Table 8 - Current Total Manufacturing Cost ............................................................. 17
Table 9 - Testing Results ......................................................................................... 26
INTRODUCTION

BACKGROUND

MAG LLS is one of the largest machine tool manufacture companies in the world, with a variety of machines from metal cutting to composites. MAG specializes in designing and building spindle machines such as 10K, U5, and the wide-range. All spindles machines are assembled and tested in house, one of the most important testing is the spindle shaft deflection testing.

The purpose of spindle deflection testing is to check the bearings stiffness located on either side of the spindle shaft; those bearings will dictate the performance of the spindle cartridge and therefore the performance of the entire machine; If the bearings are too tight, that will affect the speed of the spindle, and If the bearings are too loose, that will affect the cutting performance of the machine.

One of the problems spindle assemblers struggle with is the duration of spindle shaft deflection testing, the current testing device uses requires over 2.5 hours of total testing time (including set up time), which results in decrease of production. The main problem of the current testing device is that the device has numerous heavy unrigged parts consist of two steel plates with 4 mounting bolts for the spindle cartridge; the device weighs roughly 60 lbs. making it difficult for the spindle specialist to set it up and test it individually.

In this project the goal is to redesign the deflection test stand by:

i. Designing a rigid and stationary test stand to be at one designated area so no valuable set up time is required.

ii. Placing all associated parts and tools within that area at all time

iii. Designing the deflection test stand so any spindle assembler would be able to complete the entire process individually and with no extra help needed.
EXISTING METHODS OF DEFLECTION TESTING

There are numerous types of deflection testing methods in variety of industries, from testing the deflection on a spring and plastic to testing the deflection on a foam and pavement. Those testing methods can be divided to two main categories:

1. Small scale - Precision deflection testing.
2. Large scale – Heavy Duty deflection testing.

Two testing methods from each category were chosen as examples for illustration, for more details please refer to appendix A.

CATEGORY # 1—PRECISION DEFLECTION TESTING

Chatillon TCD-200 Digital Test Stand

The rugged all-metal construction offers durability for both laboratory and production floor applications. The ball screw drives with dual column alignment ensures precise linear motion as well as a high level of accuracy in the deflection measurement. (1) Dynamic braking provides positive control of the motor. Programming of test speed, high and low digital deflection set points and cycling as well as basic functions are activated via the keypad. "Min speed" and "max speed" functions are also included in order to facilitate test set up. (1)

Figure 1 - Chatillon TCD 200 Digital Test Stand
Two 1/2" high LCD's (see Appendix A3 for complete technical data) display the speed and deflection values along with status indicators of the programmed functions and units of measurement (inches or millimeters); This provides the operator a quick easy to read reference of not only test values but test parameters as well. When using a Chatillon DFGS digital force gauge as the force indicator, the gauge's force set points may be programmed to signal the test stand motor to stop or cycle between the set points. (1) This provides even further automation in product testing.

**Indentation Force Deflection (IFD)**

Indentation Force Deflection or IFD, previously known as Indentation Load Deflection or ILD is a method of testing foam to determine the firmness or stiffness (load bearing capacity). The amount of force, in pounds, required to indent a 50 square inch, round indenter foot (compression platen) into a foam sample a certain percentage of the sample's thickness (see Appendix A4 for complete features). IFD test results are greatly influenced by sample size and thickness of the foam specimen. (2)

![Figure 2 - Indentation Force Deflection (IFD)](image)

Test Resources IFD / ILD Foam Testers are reliable in getting accurate IFD readings for testing many foam and foam products applications. Our IFD test machines are fitted with the proper compression fixtures that will help you meet your requirements. This IFD machine is commonly used foam research or manufacturing for quality. This ILD test standards are used to determine the support factor, sag factor, comfort factor, guide factor, initial hardness factor, hardness index, indentation modulus and modulus irregularity factor of the foam and foam material used in various foam products. (2) A dual column machine with an adjustable crosshead designed for symmetrical loading that has a maximum height of 24" and 15" of
space between columns. The columns are mounted on a 11" wide base.

**CATEGORY #2 – HEAVY DUTY DEFLECTION TESTING**

*Nondestructive Deflection Testing*

Nondestructive Deflection Testing (NDT) as shown in Figure 5 is an integral part of the pavement evaluation, design and management programs used by engineers today. Large amounts of data are collected using NDT without affecting the condition of pavement. The most common method of NDT is the Falling Weight Deflectometer (FWD). (3)

![Falling Weight Deflectometer](image)

Figure 3 - Nondestructive Deflection Testing

The FWD is a device capable of applying dynamic loads to the pavement surface, similar in magnitude and duration to that of a single heavy moving wheel load. The response of the pavement system is measured in terms of vertical deformation, or deflection, over a given area using seismometers. (3) ERI currently maintains and operates two models of Falling Weight Deflectometers, the KUAB Two Mass FWD (2m-FWD) and Dynatest FWD.
**Q-Impact 25 Pendulum Impact Tester**

Q-Impact advanced Pendulum Charpy / Izod Impact Tester shown in Figure 6, is designed to determine the Charpy & Izod Impact strength of plastics and other materials. (4) This pendulum is controlled by a microprocessor which controls all the functions and the test protocols according to major International standards. (4)

![Q-Impact 25 Pendulum Impact Tester](image-url)

**Figure 4 - Q - Impact 25 Pendulum Impact Tester**
**EXISTING METHODS FOR SPINDLE SHAFT DEFLECTION TESTING**

*Deflection (Push-Pull) Test Stand – Interview with spindle assemble specialists*

The Deflection test stand shown in Figure 10 is custom made by one of MAG LLC spindle specialists and has been used by all spindle assembler for the past few years. One of the major downfalls of this test stand is the amount of time it takes for the spindle specialist to set it up onto the spindle cartridge and test the spindle shaft for any deflection. (5) (6)

![Current Spindle Deflection Testing Device](image)

Figure 5 - Current Spindle Deflection Testing Device

This deflection test stand has its advantages, such as light weight not more than 40 lb. (5) It is very simple to operate once it is mounted onto the spindle cartridge, maintenance is minimal and because its dimensions are small it is easy to store it in any cabinet (see Appendix A1 for complete interview)
Figure 11 Shows the deflection test stand mounted onto a spindle cartridge, the indicator is mounted on the actual spindle housing which causes problems in reading since it is not a flat surface. Once the test stand is in place the operator turns the bolt in the middle of the plate which turns the entire fixture to apply the load, it is a manual operation since only a 1000 lbs. of load is needed for this type of testing. The actual requirement is 600 lbs. (5) (6) however MAG standards are 1000 lbs. for each spindle deflection testing.
CUSTOMER FEEDBACK, FEATURES AND OBJECTIVES

Survey Analysis

7 people participated in this customer survey. All 7 people who participated in the survey (see Appendix B for complete Survey Results) are spindle assembler specialists, each one with over 25 years of experience.

Table 1 below shows customer satisfaction ranked on a 1-5 scale, with 5 being the most satisfy. The features are ranked from most satisfy to lease satisfy. Planned satisfaction rating is based on the designer’s personal predication of how satisfy the customer will be with the new product. The improvement ratio is calculated based on planned satisfaction divided by current satisfaction, 1.7 for example indicates an increase of 70% in satisfaction.

<table>
<thead>
<tr>
<th>Customer Features</th>
<th>Current Satisfaction</th>
<th>Planned Satisfaction</th>
<th>Improvement ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision</td>
<td>3</td>
<td>5</td>
<td>1.7</td>
</tr>
<tr>
<td>Repeatability</td>
<td>3</td>
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<td>1.7</td>
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<td>Ease of operation</td>
<td>2.9</td>
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<td>1.7</td>
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<tr>
<td>One person operation</td>
<td>2.4</td>
<td>4.9</td>
<td>2</td>
</tr>
<tr>
<td>Ease of adjustment</td>
<td>2.4</td>
<td>4.7</td>
<td>2</td>
</tr>
<tr>
<td>Range of operation</td>
<td>2.4</td>
<td>4.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>2.3</td>
<td>4.6</td>
<td>2</td>
</tr>
<tr>
<td>Rigidity</td>
<td>2.1</td>
<td>4.7</td>
<td>2.2</td>
</tr>
<tr>
<td>Tooling compatibility</td>
<td>2</td>
<td>4.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Speed of operation</td>
<td>1.9</td>
<td>4.8</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Table 1 - Customer Satisfaction
Table 2 below shows customer importance ranked on a scale of 1-5, with 5 being the most important. The features are ranked from most important to lease important. The designer’s multiplier column indicates if the designer concurs with the customer by marking 1 in the appropriate column or if the designer disagree with the customer and adjust it accordingly by marking 1.3 for example, which indicates an increase of 30% in the importance.

<table>
<thead>
<tr>
<th>Customer Features</th>
<th>Customer Importance</th>
<th>Designer’s Multiplier</th>
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</thead>
<tbody>
<tr>
<td>One person operation</td>
<td>4.9</td>
<td>1</td>
</tr>
<tr>
<td>Ease of operation</td>
<td>4.9</td>
<td>1</td>
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<tr>
<td>Precision</td>
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<tr>
<td>Repeatability</td>
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<td>Rigidity</td>
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<tr>
<td>Ease of adjustment</td>
<td>4.7</td>
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</tr>
<tr>
<td>Tooling compatibility</td>
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</tr>
<tr>
<td>Range of operation</td>
<td>4.4</td>
<td>1</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>4.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Speed of operation</td>
<td>4.1</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Table 2 - Customer Importance
Table 3 below shows customer features ranked from the most important one to the least important one based on the survey results and the QFD data calculation.

<table>
<thead>
<tr>
<th>Customer Features</th>
<th>Relative weight %</th>
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<tbody>
<tr>
<td>Speed of operation</td>
<td>14%</td>
</tr>
<tr>
<td>Rigidity</td>
<td>11%</td>
</tr>
<tr>
<td>Tooling compatibility</td>
<td>11%</td>
</tr>
<tr>
<td>One person operation</td>
<td>10%</td>
</tr>
<tr>
<td>Ease of adjustment</td>
<td>10%</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>10%</td>
</tr>
<tr>
<td>Precision</td>
<td>9%</td>
</tr>
<tr>
<td>Repeatability</td>
<td>9%</td>
</tr>
<tr>
<td>Ease of operation</td>
<td>9%</td>
</tr>
<tr>
<td>Range of operation</td>
<td>8%</td>
</tr>
</tbody>
</table>

Table 3 - Customer Features Ranking

**PRODUCT FEATURES AND OBJECTIVES**

Each of the product objectives were taken directly from the customer features and survey, those feature are ranked from the most important one to the least important one based on their relative weight (total of 100%). The product objectives shown below will be developed in order to design and create the best deflection test stand suitable for the customer needs and desire.

1. Speed of Operation (14%)

   i. The most important aspect of this entire new test stand design is the ability to gradually reduce the speed of operation. Currently the average speed of operation for any spindle assembler is between 2 to 3 hours, which is extremely high. A company such as MAG produce multimillion dollar company can’t afford to have one manually testing that take that long, it is not
productive and it is bad for business. With the new test stand the speed of operation should not exceed 45 minutes, which gives the spindle assembler a lot more time to be productive.

2. Rigidity (11%)
   i. The new testing design will have a 2200 lbs. T slot table as the base of the test stand. It is 108 inches long and 40 inches wide, it is made out of solid steel and it is as rigid as possible for this type of application.
   ii. The make sure that the new design will solve some of the problems the spindle assembler encounter with; the loading device will be bolted to the spindle cartridge to assure it will not move, and it will be rigid.
   iii. The last part of ensuring rigidity is to mount the indicators to the V blocks using a magnet, the V blocks are solid steel and are placed on the T slot table, by mounting the indicators to the V blocks the operator is confident that the indicator will not move or give inaccurate reading.

3. Tooling Compatibility (11%)
   i. To achieve the goal of the new and improve test stand design all parts must be compatible so the T slot table must be compatible with the V blocks, slides and must have the capability to hold any type spindle manufactured.

4. One Person Operation (10%)
   i. The set up operation should not exceed 3-5 steps, which includes the spindle set up on the V Blocks, the indicators on the slides, and the loading device on the spindle cartridge.
   ii. The test stand will be design so the spindle (weighs roughly 300 lb.) will be transported to the T slot table using a 3 ton electronic crane.
   iii. All parts associated with the test stand including the V blocks, slides, Indicators, load cells and any other standard tools will not weigh more than 20 lb. making it easy to any spindle assembler to use them with no extra help.

5. Ease of Adjustment (10%)
   i. One of the most important features on the new design is to ensure that any adjustment needed on the test stand will be as simple as possible, so in order to adjust a 300 lb. spindle a 3 ton crane that is placed at the testing are will be used to complete the tasks.
   ii. Another important task is to mount the loading device onto the spindle cartridge, to insure easy adjustment 2-3 standard tools will be used.
iii. Indicators are considered very important tools in this testing, due to the fact that based on the indicators the operator knows if he is on the right track or not. Because indicators are extremely gentle the best way to adjust them to the right location in order to receive the best reading is by hand.

6. Maneuverability (10%)

i. The new design of the spindle deflection test stand will also have a new area of operation, one that the spindle assembler can work around with no interruptions and no obstacles.

ii. The goal of the new design is to reduce the time of operation so each spindle assembler will have the ability to test his spindle without any other testing accruing at the same time on the same test stand.

7. Precision (9%)

i. The most important part of the test stand to ensure precision is the T slot table, prior to use it will be balanced and leveled vertically and horizontally with a tolerance of .0005” in both directions.

ii. The test stand will be designed under the expectation that new set of indicators will be purchased to ensure they have no ware, or at least inspect current once to assure device integrity.

iii. Another important part that will decide the precision of the testing is the V blocks, new set is vital to eliminate any concerns as far as dents, cracks and fatigue that will affect testing results.

iv. New load cells are important, however since the load cells will not dictate the amount of precision either way, old load cells are acceptable with the condition that they will be tested and inspected prior to use.

v. To insure the best results a train operator is vital, with at least 6 months of experienced testing spindles.

8. Repeatability (9%)

i. In order to insure the same results over and over test stand parts must be inspected frequently, V blocks are solid steel and will require minimal maintenance due to the mere fact that they are not used intensely throughout the process, however to ensure product integrity V blocks must be inspected by a spindle specialist at his discretion.

ii. To insure that the new design will improve results and maintain those readings all parts on the test stand must be monitored, especially the electric indicators. To assure accurate results indicators must be calibrated at the spindle
specialist discretion.

iii. Some of the parts in the new design are solid steel and rigid parts which will result in fatigue; those parts must be either machined or replaced to insure proper testing results.

9. Ease of Operation (9%)

i. Deflection test stand will be design so easy access to the test stand and testing area will be top priority.

ii. Any parts associated with the test stand will be located at the testing area at all time with no exceptions.

10. Range of Operation (8%)

i. The design of a new test stand needs to have the capability of testing any type spindle the company manufactures and that the spindle assembler desire to test.

ii. All parts associated with the deflection test stand needs to have the capability of operating and producing fine results regardless of the type of tools parts or spindle used.
Key Millstone Date:

<table>
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<tr>
<th>Project schedule</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
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<td>26-Jan</td>
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<td>15-Apr</td>
<td>4-May</td>
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<td>Final Report</td>
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<td></td>
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<td>1-Jun</td>
</tr>
</tbody>
</table>

Table 4 – Schedule

The project schedule begins on Dec 10th with the completion of the concept sketches and ends on Jun 1st with the submission of the final report, for a timeline of 25 weeks.

<table>
<thead>
<tr>
<th>Part</th>
<th>Prediction</th>
<th>Actual</th>
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<tbody>
<tr>
<td>T Slot Table</td>
<td>$2,500</td>
<td>$0</td>
</tr>
<tr>
<td>V Block</td>
<td>$700</td>
<td>$0</td>
</tr>
<tr>
<td>V Block Fixture</td>
<td>$100</td>
<td>$0</td>
</tr>
<tr>
<td>Slide (Horizontal)</td>
<td>$1,400</td>
<td>$3,866</td>
</tr>
<tr>
<td>Slide (Vertical)</td>
<td>$2,500</td>
<td>$0</td>
</tr>
<tr>
<td>Angle Plate</td>
<td>$1,000</td>
<td>$1,106</td>
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<tr>
<td>Load Cell Fixture</td>
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<td>Load Cell</td>
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<td>$0</td>
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<tr>
<td>Electronic Indicator</td>
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<td>$0</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$9,800</strong></td>
<td><strong>$4,972</strong></td>
</tr>
</tbody>
</table>

Table 5 – Budget

Schedule and budget are two vital components in the success of a project. In order to utilize the time frame and budget given to the maximum, a schedule breakdown of each assignment...
fulfillment corresponding to a certain date and constant supervision of expenses are required. Schedule and budget identify and manage risks associated with managing schedules and costs.

CONCEPT GENERATION AND SELECTION

**DUAL PLATE TESTING DEVICE**

The first concept generated shown in figure 11 will be referred to as the dual plate testing device. The bottom plate will be mounted onto the tail end of the spindle cartridge, the fixture mounted on top of the upper plate is the loading device, and the proper socket wrench is used to turn the loading screw until a 1000 lb. load detected by the load cell attached to the spindle shaft surface. The load applied is in 200 lb. increments to insure accurate results.

![Figure 7 - Concept Drawing](image)

**HYDRAULIC LOADING TESTING DEVICE**

The hydraulic loading testing device is similar in design to the dual plate testing device. However when using the dual plate device the load is applied manually by using a loading bolt and a socket wrench, where in the hydraulic designs the load is applied using a hydraulic
pump. On the upper plate there is a nozzle which is attached to the tip of the pump hose, when applying the load using the pump the load cell mounted to the spindle surface will indicate the amount of loading applied.

**DEFLECTION TESTER – SELECTED CONCEPT**

The deflection tester consists of several main parts. The 10” V blocks are mounted on the T slot table using either keys (tight fit) on both sides of the V blocks or ½”-13 screw (2 on each side). There are two slides, a vertical and a horizontal. The horizontal slide is 20” long, it has 12” of travel and 6” saddle; it is used to apply the load on the spindle shaft. The vertical slide is 16” long with 8” of travel and 8” saddle; it is used to align the loading device that is mounted onto the horizontal slide to be center with the spindle shaft.

![Figure 8 - Concept Drawing (Selected)](image)

**CONCEPT DESIGN – SUMMARY**

There are two main reasons for choosing the deflection tester (figure 12), to save time and money. The other two design concepts works and they will accomplish the task in hand the question is, at what cost; using either the dual plate or the hydraulic loading devices for testing the spindle shaft for deflection will take roughly 2.5 – 3 hours, ridicules amount of time for this type of operation, and with manufacturing cost of $75 per hour it is a waste of money. Another disadvantage is that in most cases for some portion of the testing two assemblers will be required, especially during setup, which results in more manufacturing cost. By using the deflection tester the amount of time required for testing will not exceed 60 minutes, and as a result manufacturing cost will be reduced by about 60%.
All three concepts were evaluated using rated weight method with a five point scale. The score ranged from 0-4 where 0 is unsatisfactory and 4 is very good. The criteria were taken from the customer features. Each criteria carries different weighted factor based on customer importance, the rating given to each criteria was multiple by its weighted factor then added together to determine the total rating of each concept.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>rating</th>
<th>wt. rating</th>
<th>rating</th>
<th>wt. rating</th>
<th>rating</th>
<th>wt. rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>One person operation</td>
<td>20%</td>
<td>3</td>
<td>0.6</td>
<td>4</td>
<td>0.8</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Ease of operation</td>
<td>15%</td>
<td>2</td>
<td>0.3</td>
<td>3</td>
<td>0.45</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>Ease of adjustment</td>
<td>8%</td>
<td>2</td>
<td>0.16</td>
<td>4</td>
<td>0.32</td>
<td>3</td>
<td>0.24</td>
</tr>
<tr>
<td>Speed of operation</td>
<td>22%</td>
<td>2</td>
<td>0.44</td>
<td>4</td>
<td>0.88</td>
<td>2</td>
<td>0.44</td>
</tr>
<tr>
<td>Range of operation</td>
<td>10%</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Precision</td>
<td>15%</td>
<td>4</td>
<td>0.6</td>
<td>4</td>
<td>0.6</td>
<td>3</td>
<td>0.45</td>
</tr>
<tr>
<td>Repeatability</td>
<td>10%</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
<td>0.3</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100%</td>
<td>2.7</td>
<td><strong>3.65</strong></td>
<td>2.43</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6 - Rated Weight Method

Tables 7 and 8 show MAG’s expenses using the current spindle deflection method:

<table>
<thead>
<tr>
<th>Manufacturing Cost</th>
<th>Testing Duration (min)</th>
<th># of Testing per Month</th>
<th>Total Testing Time per Month (hrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$75</td>
<td>150</td>
<td>20</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 7 - Current Expenses

Table 8 - Current Total Manufacturing Cost
CALCULATIONS

To assure the success of this design one main calculation must be applied, the allowable horizontal force on the V blocks fixture and the slides fixture. The horizontal load is applied gradually in 200 lb. increments for a total applied load of a 1000 lb. the purpose of this calculation is the proof that there is enough load to resist the horizontal load applied on the spindle shaft, and that there will be no movement on the V blocks and slides fixtures.

➢ Allowable Horizontal force (on the spindle):

\[ Fa = (\mu s) \times (F_N) \]

Where, \( Fa \) is the allowable force to be applied, \( \mu s \) is the coefficient if friction for steel on aluminum and \( F_N \) is the normal force.

\[ Fa = (0.45) \times (\Sigma W) = (0.16) \times (W_{spindle} + WVb + WVb) \]
\[ Fa = (0.45) \times (350 \text{ lb} + 50 \text{ lb} + 50\text{lb}) = 202.5 \text{ lb} \]

The allowable force to be applied on the V blocks fixture is 202.5 lb. not nearly enough to resist a 1000 lb. load applied. To accomplish that resistant the V blocks must be mounted to the T slot table using 5/8” bolts.

➢ Shear Force Allowable on a 5/8” Standard Bolts (the lowest max allowable load):

\[ Shear\ Force = 6102 \text{ lb} \]
\[ Fa = 6102 + 202.5 = 6304.5 \text{ lb} , \text{ total allowable force to be applied} \]

Based on the calculation above, while the V block is mounted to the T slot table using the 5/8” bolts, a max of 6304.5 lb. can be applied, which results in a design factor of 6.3045.

➢ For extensive calculations please refer to appendix H
ASSEMBLY DESIGN DETAILS

Figure 12 shows a solid modeling of a T slot table. It is made out of solid steel, the table is 60” long by 20” wide by 15” height; the slots are 1.5” wide and 2.5” deep. This table is the base of the entire test stand all other parts will be mounted to the T slot table.

Figure 9 - T Slot Table

Figure 13 shows the 10” V blocks, the size of the V blocks is based on the size of the spindle cartridge which depends on the type of machine. The V blocks are mounted to the T slot table using a set of keys (tight fit) for alignment and by 5/8” bolt to mount the V blocks to the T slot table (using standard T shape keys). The 10” V blocks were manufactured in house using a vertical milling machine; manufacturing time for each V block was about 4 hours for a total 8 hours.

Figure 10 - 10” V Block
Figure 14 shows the key to be mounted at the bottom of the V blocks. The key is 1.5” long by 0.80” wide by 0.50” thick. It is used to align the V blocks into the slot of the T slot table. A total of 4 keys were manufactured using a vertical milling machine, manufacturing time for each key was roughly 45 minutes for a total of 3 hours.

![Figure 11 – Key](image)

Figure 14 shows the slide. The vertical and horizontal slides are the same model slide; the slides have 16.00” long Base, 8.00” long saddle and 8.00” available travel. The horizontal slide is used to apply the 1000 lb. load onto the spindle cartridge, the vertical slide align the load cell to canter it with the tooling inside the spindle shaft. The vertical and horizontal slides are mounted together using the angle plate, as shown in figure 15. The slides assembly is mounted to the T slot table using four ½ - 13 screws. The slides and angle plate were purchased from SETCO.

![Figure 12 - Slide & Angle Plate](image)
Figure 17 shows the load cell attached to the mounting plate. The mounting plate is a solid aluminum 8” wide by 8” long and 1” thick. The four holes on each corner are used to mount this plate onto the vertical slide using four ½ - 13” screws. The three holes in the center of the plate (where the load cell is attached) are for extra maneuverability when testing different size spindle cartridge. The mounting plate was manufactured using a vertical milling machine, manufacturing time for this part was about 3 hours.
Figure 15, 16, 17 and 18 shows the entire spindle deflection test stand assembly.

Figure 15 - Spindle Deflection Test Stand Assembly

Figure 16 - Spindle Deflection Test Stand Assembly
Figure 17 - Spindle Deflection Test Stand Assembly

Figure 18 - Spindle Deflection Test Stand Assembly
TESTING

The purpose of spindle deflection testing is to check the bearings stiffness inside the spindle cartridge.

These bearings will dictate the performance of the spindle cartridge and therefore the performance of the entire machine.

- If the bearings are too tight, that will affect the speed of the spindle.
- If the bearings are too loose, that will affect the cutting performance of the machine.

The testing process consists of two parts:
I. Set up the spindle cartridge for testing
II. Collecting the data (the total amount of deflection on the spindle shaft)

The set up process includes several steps.
1. The first step is to insert the tooling (taper) into the spindle cartridge using a press, this tooling simulates the cutter head of the spindle cartridge.
2. The second step is to set the spindle cartridge onto the V blocks using a crane and mounting the spindle cartridge surface to the V blocks using two ½ - 13 bolts.
3. The third step is to screw the load cell into the mounting plate (the mounting plate is mounted onto the vertical slide)
4. The fourth step is to align the load cell to the tooling (which is inside the spindle cartridge) using the hand wheel of both the horizontal and vertical slide. Once the load cell and the tooling are aligned they are locked together using a pin.
5. The last step is to set the dial indicator on top of the spindle cartridge with the needle of the dial indicator touching the spindle shaft (the dial indicator is set on top of the spindle cartridge to assure accurate reading in case there is any movement in the V blocks).

At this point the spindle cartridge is ready to be tested.

The second part of the testing process is the data collection which is the actual testing of the spindle shaft. The testing is basically applying a 1000 lb. load horizontally onto the spindle shaft (using the hand wheel of the horizontal slide); the load is measured using the load cell monitor. This type of testing has two parts the “push” part, when the 1000 lb. load is applied (in 200 lb. increments) and it is pushing on the spindle shaft (by turning the hand wheel of the horizontal slide clockwise) and the “pull” part when the 1000 lb. load is applied (in 200 lb. increments) and it is pulling the spindle shaft (by turning the hand wheel of the horizontal slide counter clockwise).
The testing was conducted on an FTV (Lancer) spindle cartridge. FTV machines carry five heads (five spindles) and are used to cut various types of metal (Aluminum, Titanium, Steel).

This type of spindle cartridge is not very common in today’s industry since it is an older model of the FTV machine, this particular spindle cartridge is a rebuild, which means the spindle housing is not replaced but all the other components get replaced (such as the bearings, spacers, nuts).
Set up time for this spindle cartridge was roughly 30 min. since the spindle cartridge consist of different diameter (as shown in the picture above), mounting the spindle cartridge surface onto the V blocks was more complicated then common spindle cartridges (such as the U5 and the wide range). Once the spindle cartridge surface is mounted to the V blocks and the dial indicator is mounted onto the spindle cartridge the operator takes the first reading, and then applies the 1000 lb. load in 200 lb. increments, the operator takes the reading every 200 lb. of increasing load. Once the entire reading is done the process must be repeated three times to assure reliable results.

Testing results are shown in table 9

<table>
<thead>
<tr>
<th>Push</th>
<th>Load (lb)</th>
<th>Deflection (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>-200</td>
<td>-0.00005</td>
<td></td>
</tr>
<tr>
<td>-400</td>
<td>-0.00005</td>
<td></td>
</tr>
<tr>
<td>-600</td>
<td>-0.0001</td>
<td></td>
</tr>
<tr>
<td>-800</td>
<td>-0.0001</td>
<td></td>
</tr>
<tr>
<td>-1000</td>
<td>-0.00015</td>
<td></td>
</tr>
<tr>
<td>-800</td>
<td>-0.00015</td>
<td></td>
</tr>
<tr>
<td>-600</td>
<td>-0.0001</td>
<td></td>
</tr>
<tr>
<td>-400</td>
<td>-0.00005</td>
<td></td>
</tr>
<tr>
<td>-200</td>
<td>-0.00005</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>-0.00005</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pull</th>
<th>Load (lb)</th>
<th>Deflection (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>-0.00005</td>
</tr>
<tr>
<td>200</td>
<td>0.00005</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>0.00015</td>
<td></td>
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<td>800</td>
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<tr>
<td>200</td>
<td>0.00005</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table 9 - Testing Results

The results show a total deflection of .00035” which is acceptable since the total tolerance for this testing is .0007”. 
PRODUCT FEATURES AND OBJECTIVES – POST TESTING

The final piece of the puzzle is to insure that the initial product features and objectives were successfully met.

1. Speed of operation – using the new design the speed of operation was decreased by about 60% from 150 minutes to 60 minutes (with about 15 minutes of potential improvement).
2. Rigidity – with the new design the test stand is stationary and rigid, and no heavy lifting is required.
3. Tooling compatibility – the new design does not require any tooling, since all parts are mounted and are ready to be used.
4. One person operation – simple set up, no heavy parts, all parts are at a designated area.
5. Ease of adjustment – the V blocks and slides allow the operator easy adjustment.
6. Maneuverability – the test stand and all parts are at a designated area with enough clearance to move around.
7. Precision – testing results show quality reading; however this objective will be evaluated in time.
8. Repeatability – this objective will be evaluated in time, once several spindle cartridge assemblers have used this test stand.
9. Ease of operation – I was able to use this testing device with no problems, then so will the spindle cartridge assemblers.
10. Range of operation – there is no problem testing all types of spindle cartridge, the only requirement is to manufacture several more V blocks with different sizes, and since it is done in house it is only a matter of time.

The new spindle deflection test stand is a success, since is being operational MAG – LLC have saved an average of 10 hours of manufacturing cost per week. Within about 4 months MAG will reclaim their initial investment and from that point on its all gain. The new design assured an increase in productivity and decrease in manufacturing cost (of about 60%).

<table>
<thead>
<tr>
<th>Manufacturing Cost</th>
<th>Testing Duration (min)</th>
<th># of Testing per Month</th>
<th>Total Testing Time per Month (hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$75</td>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Total Manufacturing Cost per Month

$1,500
CONCLUSION

MAG – LLC is a world leader in the machine tool business, a company of this caliber strives to perfection in all areas of the industry. MAG – LLC takes pride in building some of the most technologically advanced machines in today’s world. The new spindle deflection test stand design will assist MAG in maintain those high standards by allowing its employees to assure that every single spindle that leaves the shop floor will be at perfect condition, and ready to be utilize to its best.
WORKS CITED
APPENDIX A - RESEARCH

Interview with a costumer, October 13th 2011
Mick Davis, Spindle Assembler Specialist at MAG, 2200 Litton Lane, Hebron KY 41048
email address: mick.davis@MAG-IAS.com
Mick Davis has been a Spindle assembler specialist for over 30 years.
It takes him about 40 hours to assemble an entire spindle cartridge.
Some preliminary testing involves: bearing diameter, housing boars, shoulders squareness.
Some post assembly testing such as: taper run out, pull force, spindle run off.
Extremely important to monitor the temperature of the spindle while testing it.
Vibration must be at minimum.
Monitor the lubrication of the spindle to avoid over heating when not enough lubrication or over flooding the spindle with too much lubrication.
The spindle weighs about 300 lb. depends on the type, and must be handled with care, as a result the test stand must be easy to use and easy to access.
Testing the spindle must reflect “real life” application therefore the duration of testing and the speed of operation should meet those applications.

Interview with a costumer, October 13th 2011
Jay Henggeler, Spindle Assembler Specialist at MAG, 2200 Litton Lane, Hebron KY 41048
Email address: jay.henggeler@MAG-IAS.com
Jay has been a spindle assembler specialist for over 30 years.
He works on particular spindles such as 10K and U5.
It takes him about 30 hrs.to assemble these types of spindles.
Very important to have accurate results
Extremely important teat the spindle right and fast and continue productive work
Features:

Digital control with programming capability
Bi-directional RS232 interface
Digital deflection set point capability
Cycling capabilities: programmable up to 1000 cycles between digital deflection set points or force set points when used with a Chatillon DFGS digital force gauge
Ball screw drive with dynamic braking
Manually adjustable upper and lower travel limits
Vertical travel distance: 0-18" x 0.001" (0-457.2 mm x 0.01 mm)
Travel speed: programmable 0.5 - 12.5 x 0.01 inches/min (12.7 to 317.5 x 0.1 mm/min)
2-1/4" (57 mm) horizontal clearance between platform centerline and column
Standard mounting for Chatillon DFS, DFS-R, DFS-R-ND, DFA, DFGS, and DFIS gauges.

Options:

50" (1270 mm) column (18" travel)
Slow speed: 0.02 to 0.5 inches/min (0.5 to 12.77 mm/min)
Medium slow speed: 0.1 to 2.5 inches/min (2.5 to 62.5 mm/min)
Medium High Speed: 1 - 25 x 0.1 inches/min (25 - 635 x 1 mm/minute)
High speed: 2 to 50 x 0.1 inches/min (50 to 1270 x 1 mm/min)
Interface cables
Gripping fixtures are available to fill a wide range of needs.


Range of operation
Accurate
Easy to use
Heavy
Expensive
Appendix A

Specifications:

Capacity: 200 lb or 1000N (high speed: 100 lb or 500 N)
Accuracy: ±5% of max speed
Deflection accuracy: ±0.1% of reading or ±0.004 inches (±0.1 mm)
RS232: 9 pin "D" connector: Transmission parameters user selectable. Baud rate selectable from 300 to 19,200
Analog Output: 0.056 Volt per inch ±3%
Stand dimensions: 35" H x 14 W x 16-1/2" D (889 mm x 356 mm x 419 mm)
Power requirement: 110 Vac (220 Vac available)
Weight: Instrument: 42 lbs

Indentation Force Deflection (IFD)
http://www.testresources.net/material-test-applications/foam-test-equipment/ild-indentation-load-deflection-ifd-indentation-force-deflection-foam-testing/

Large
Requires experienced operator
Precise
Maintenance required

Indentation Force Deflection or IFD, previously known as Indentation Load Deflection or ILD is a method of testing foam to determine the firmness or stiffness (load bearing capacity). The amount of force, in pounds, required to indent a 50 square inch, round indenter foot (compression platen) into a foam sample a certain percentage of the sample's thickness. IFD test results are greatly influenced by sample size and thickness of the foam specimen.
IFD Foam Tester or Test Machine (model 120M) is a dual column machine with an adjustable crosshead designed for symmetrical loading that has a maximum height of 24” and 15” of space between columns. The columns are mounted on a 11” wide base.

IFD Features:

- 390 mm x 400 mm (model 2000M) Base Plate with 6.5 holes on 20 mm centers and is made specifically for ASTM D3574 B1 and ASTM D5672.
- Modular electromechanical actuator that is rated 500 lbs and 10 ipm for performing tension and compression. Has a 12" (300 mm) power stroke, 0.02 micron of position control resolution and a user settable speed of 0.0005 to 10 ipm.
- Compression Platen Model G223 that is 8" (203 mm) in diameter and specifically designed to meet ASTM D3574 IFD test method.
- High accuracy load cell that has a static rating of 500 lbs (2.2 kN) and a deflection under fill load of 0.006”.
- USB standalone closed loop controller with a LCD display, keypad and emergency stop button. (M controller)
- Windows based IFD software package designed for ASTM D3574 and ASTM D5672. (M software)
- Optional: a general purpose test control and data acquisition software with capabilities beyond the IFD Software package is available but not necessary for IFD foam testing. It provides a great deal of power and versatility to the IFD foam test machine.
SPRING TESTERS - Deflection spring testing is the process whereby the spring testing system supplies deflection data as a result in response to input force data requirements. The spring tester crosshead begins at a predetermined “start” position and then moves to a predetermined “end” position. A spring that is located between the spring tester load cell and the spring tester crosshead will then be either extended or compressed, producing an increasing reaction force as the crosshead continues to move. The spring tester acquires both force and position data simultaneously for every point between the start and end positions. Extension/Deflection data is then available for any spring Force. Furthermore, the acquired data is used to present the results of the spring free length, initial tension (for extension springs) and the spring constant.

Features:

- 0.4-10000N Servo driven, PC controlled programmable spring tester
- Φ200 mm Testing platen
- 400mm Standard Stroke, Strokes up to 1000mm available
- Unique spring design module integrated with the system test results to enhance coiler setup efficiency and facilitate spring reengineering, (optional).
- Excellent R+R performance
- Optional SPC control charts, capabilities tests and detailed report creation software
- Programmable for automated testing with spring test setups stored in files for quick recall and test
- Includes automatic Self Calibration Routines
- Fully Microsoft Windows, 2000, ME and XP compatible.
Deflection testing is a mechanical tuning process that is taken from techniques used by the violin masters. Unlike Chladni testing or tap tuning which deal with the frequencies found in a plate, deflection testing instead measures the mechanical properties of the plate. The stiffness of a violin plate can be analyzed by twisting the plate with your hands and removing wood until it twists just the “right” amount. This method of deflection tuning can require years of practice and has limited accuracy. The method of deflection tuning we used involved putting a known load on a certain point and then measuring how far the plate would deflect. This method was developed in the 1970's by Roger Siminoff.

Nondestructive Deflection Testing (NDT) is an integral part of the pavement evaluation, design and management programs used by engineers today. Large amounts of data is collected using NDT without effecting the condition of pavement. The most common method of NDT is the Falling Weight Deflectometer (FWD).
Falling Weight Deflectometer

The FWD is a device capable of applying dynamic loads to the pavement surface, similar in magnitude and duration to that of a single heavy moving wheel load. The response of the pavement system is measured in terms of vertical deformation, or deflection, over a given area using seismometers. ERI currently maintains and operates two models of Falling Weight Deflectometers, the KUAB Two Mass FWD (2m-FWD) and Dynatest FWD.

Features

The KUAB 2m-FWD is a trailer mounted dynamic impulse loading device which can be towed by any suitable towing vehicle. The equipment is completely enclosed by a metal housing for protection against harmful elements, and testing can be performed with all protective features in place. Bay doors on the bottom of the housing open automatically during testing, eliminating the need for the FWD operator to leave the tow vehicle. The KUAB 2m-FWD meets or exceeds all of the requirements of ASTM Standard Test Method D 4694-96 and the SHRP calibration protocol for FWD equipment. Following are a few of the unique features of KUAB 2m-FWD:

• Two Mass Configuration: the most significant factor in the production of a load pulse that simulates the actual effects of a moving vehicle

• Segmented Load Plate: which ensures an uniform pressure distribution over the full area of the plate.

• Seismometers: the deflection measuring sensors with a range of 0 to 200 mils (0 to 5080 microns).
Q-Impact advanced Pendulum Charpy / Izod Impact Tester, available with energies from 1.75 to 25 Joules, is designed to determine the Charpy & Izod Impact strength of plastics and other materials. This sophisticated pendulum is controlled by a microprocessor which controls all the functions and the test protocols according to major International standards.

Features:
• Pendulum with capacity from 1 to 25 J
• Suitable for Izod, Charpy and tensile impact tests
• System controlled by microprocessor

Range of operation
Rigid
Easy to operate
Accurate

Q-Impact 25 Pendulum Impact Tester
http://www.worldoftest.com/q-impact.htm
The Falling Weight Impact Tester is used to perform impact tests on plastic pipes, conforming to ISO 3127, EN744 and EN1411. Test pieces are subjected to blows from a falling striker, of specified mass and shape, dropped from a known height onto specified positions around the circumference of the test piece. The true impact rate of the batch, or production run from an extruder, is estimated.

Technical Parameters
• Working environmental temp.: room temp.
• Max. falling height: 2000mm
• Max. lifting speed of the strikers: 12m/min
• Resolution of displacement: 1mm
• Height error: +/- 2mm
• Noses of the strikers: d25 and d90
• Rs: 50
• Specimen Length: 300mm
• Dimensions: 1100mm (D) 600mm (W) 4500mm (H)
• Weight: 300kg
• Diameter of test pipes: 10mm-630mm
• Voltage: 220 VAC/ 50 Hz, single phase or 110 VAC/60 Hz ?
Pneumatic air supply: working pressure = 0.4-0.8 MPa

Temperature restrictions
Limited range of operation
Portable

Falling / Drop Weight Impact Tester
for Plastic Pipes
http://www.worldoftest.com/dropweightimpact.htm
The CHATILLON® LTCM-100 Series motorized tester, combined with a Chatillon gauge, is perfect for applications requiring an economical solution to tensile or compression testing. The LTCM-100 motorized test stand has a large work area making it ideal for production environment or applications with large test samples. Crosshead movement is operator controlled using a switch that can be set to move the crosshead up or down at a specified speed. Speed is user-selectable. Positive braking and high and low limits are standard.

Force Capacity - 110 lbf (500 N)

Features:

- Selectable Speed Control with LED Indicator; 0.2 - 20.0 in/min (5.0 - 500 mm/min)
- Independent Return Speed
- Mechanical Deflection Limits
- 15-inches (380mm) Travel
- Large Working Area
- Lightweight, Portable Design
The custom made deflection test stand is consider obsolete, it is complicated to mount on the spindle, it is not rigid so different spindle assembler takes different approach on how to set it up therefore they might get different results and one might not be as accurate is the other. It takes a long time to set it up on the spindle, which results in the spindle assembler time away from continuing on with his work.

- Weighs roughly 60 lb.
- 2 ft. high.
- 9 in. plate diameter.
- Takes about 2-2.5 hrs. to set up and test the spindle.
- Require load is a 1000 lb.
- Using the center screw as a load screw.
APPENDIX B - CUSTOMER SURVEY AND RESULTS

Deflection Test Stand

In this survey our company is hoping to gather information regarding the best features any spindle assembler will desire on a deflection test stand.

**How important is each feature to you for the design of a new deflection test stand?**

Please circle the appropriate answer.  
1 = low importance  
5 = high importance

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**How satisfied are you with the current deflection test stand?**

Please circle the appropriate answer.  
1 = very Unsatisfied  
5 = very satisfied

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Appendix B1
Based on your experience and the importance of the deflection test stand to your work, how much would you recommend the company to invest in this project? $1000- $3000(1), $3000-$5000(2), $5000-$7000(3), $7000-$10000, Over $10000(1)

Thank you for your time.
## APPENDIX C – QUALITY FUNCTION DEPLOYMENT ANALYSIS

Erez Greniman  
Spindle Deflection Test  
Stand  
9 = Strong  
3 = Moderate  
1 = Weak

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## APPENDIX E - BUDGET

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<tr>
<th>Part</th>
<th>Prediction</th>
<th>Actual</th>
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<tbody>
<tr>
<td>T Slot Table</td>
<td>$2,500</td>
<td>$0</td>
</tr>
<tr>
<td>V Block</td>
<td>$700</td>
<td>$0</td>
</tr>
<tr>
<td>V Block Fixture</td>
<td>$100</td>
<td>$0</td>
</tr>
<tr>
<td>Slide (Horizontal)</td>
<td>$1,400</td>
<td>$3,866</td>
</tr>
<tr>
<td>Slide (Vertical)</td>
<td>$2,500</td>
<td>$0</td>
</tr>
<tr>
<td>Angle Plate</td>
<td>$1,000</td>
<td>$1,106</td>
</tr>
<tr>
<td>Load Cell Fixture</td>
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<td>$0</td>
</tr>
<tr>
<td>Load Cell</td>
<td>$1,000</td>
<td>$0</td>
</tr>
<tr>
<td>Electronic Indicator</td>
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<td>$0</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$9,800</strong></td>
<td><strong>$4,972</strong></td>
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</table>
APPENDIX F – CALCULATIONS

Applied Horizontal Force = 1000 lb.

Coefficient of friction for steel on steel, \( \mu_s = 0.09 - 0.19 \) (for lubricated and grease surface)

Coefficient of friction for steel on steel, \( \mu_s = 0.57 \) (for clean and dry surface)

Coefficient of friction for steel on aluminum, \( \mu_s = 0.45 \)

Allowable Horizontal force (on each V block):

- \( Fa = (\mu_s) \times (FN) \)
- \( Fa = (0.45) \times (\sum W) = (0.45) \times (W_{spindle} + WVb + WVb) \)
- \( Fa = (0.45) \times (350 \text{ lb} + 50 \text{ lb} + 50lb) = 202.5 \text{ lb} \)

Shear Force Allowable on a 5/8” Standard Bolts:

- \( Shear Force = 6102 \text{ lb} \)
- \( Fa = 6102 + 202.5 = 6304.5 \text{ lb}, \text{ total allowable force to be applied} \)

Allowable Horizontal force (on the slides):

- \( FN = \sum W \)
- \( FN = (W_{hs} + W_{vs} + W_{ap} + W_{lc}) \)
- \( FN = (30 + 30 + 30 + 20) = 110 \text{ lb} \)
- \( Fa = (\mu_s) \times (FN) \)
- \( Fa = (0.16) \times (110) = 17.6\text{lb} \)
- \( Shear Force = 1470 \times 4 = 5880 \text{ lb} \)
- \( Fa = 5880 + 17.6 = 5897.6 \text{ lb}, \text{ total allowable force to be applied} \)

Safety Factor:

- For each V block
  - \( N = 6.3045 \)

- For the slides assembly
  - \( N = 5.897 \)
Appendix G1
Mounting Plate

Dimensions:
- Width: 8.00
- Height: 8.00
- Depth: 0.62
- Side: 2.50
- Top: 4.00
- Left: 5.50
- Right: 7.37

Title: Appendix G1
## APPENDIX H - BILL OF MATERIALS

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<thead>
<tr>
<th>Item</th>
<th>Part Name</th>
<th>Qty</th>
<th>Description</th>
<th>Part #</th>
<th>Estimated Cost</th>
<th>Actual Cost</th>
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<tbody>
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<td>1</td>
<td>T Slot Table</td>
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<td>60&quot; long x 20&quot; wide</td>
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<td>2</td>
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<td>3</td>
<td>Key</td>
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<td>Dovetail Slide with the following features:</td>
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<td>• 8.00&quot; Wide x 3.00&quot; High</td>
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<td>• 16.00&quot; Long Base</td>
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<td>• 8.00&quot; Long Saddle</td>
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<td>• 8.00&quot; available travel</td>
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<td>• Straight flat gib − LH side looking into hand wheel end</td>
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<td></td>
<td>• Standard mounting holes in base</td>
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<td>• (4) 1/2&quot;-13 tapped holes in saddle</td>
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<td>• 3/4&quot;-10 acme thread leadscrew</td>
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<td>• Micrometer dial -.001 graduations</td>
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<td>• 5&quot; diameter hand wheel</td>
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