A Study on the Development of Exclusive Sensor for Detecting the Hydraulic Cylinder Stroke

2000
Abstract

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A Study on the Development of Exclusive Sensor for Detecting the Hydraulic Cylinder Stroke

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Abstract

In order to comprise a basic closed-loop control system for hydraulic systems it is necessary to detect the piston rod stroke of hydraulic cylinder. There are many conventional type sensors which have been applied to detect the displacement of cylinders. Several types of LVDTs and magnetic sensors are representative illustrations of them. However, they cannot reveal the original performance normally or they cannot be applied at all where the operating circumstance of cylinders is beyond specifications of sensors. Especially, for the purpose of detecting the strokes of cylinders mounted on heavy equipments, a special exclusive sensor must be used. Because the operating circumstances of heavy equipments are so severe that general purpose sensors cannot endure such circumstance as a shock and a residual vibration induced by rough works.
In the conclusion, an exclusive sensor must be developed to detect the strokes of hydraulic cylinders of heavy equipments.

In this thesis, an exclusive method for detecting the piston rod stroke for heavy equipments is suggested, which adopts a remote detecting technique using optical sensors and optical fibers. To do this, first of all, a kind of scale treatment of piston rod is required and it is also proposed here. An entire implementation procedure of the proposed exclusive sensor is explained concretely. A prototype of the sensor is resulted from the procedure. And then, several experiments using the prototype are executed for verifying the effectiveness of the suggested method and the possibility of the remote detection. Finally, the conclusion is demonstrated based on the experimental results.
housing

1.1 (Heat source)  ........................................................................................................................................................................

... (Bucket) ........................................................................................................................................................................

... (Residual vibration)  .................................................................................................................................................................

Kayaba[1]  ........................................................................................................................................................................

... [2]  ........................................................................................................................................................................

housing[ ]  ........................................................................................................................................................................
プロジェクトは以下の通りです。

1. 原型

2. 原型

3. 原型

4. 原型

5. 原型

6. 原型

- 3 -
### Table 1.1 Performance comparison of sensors

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Operating Temp. (°C)</th>
<th>Vibration (G)</th>
<th>Shock (G)</th>
<th>Resolution</th>
<th>Accuracy</th>
<th>Sensing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heavy Equipment</strong></td>
<td>-40 - 100</td>
<td>25G above</td>
<td>120G above</td>
<td>1mm below</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JC40S [COPAL (Japan)]</td>
<td>-40 - 100</td>
<td>15G</td>
<td>100G</td>
<td>± 0.05%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LP-100FP [MIDORI (Japan)]</td>
<td>-13 - 176</td>
<td>15G</td>
<td>50G</td>
<td>± 1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LP-10FBS-3 [MIDORI (Japan)]</td>
<td>-40 - 212</td>
<td>10G</td>
<td>50G</td>
<td>± 1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LVDT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GYMT C-11 [SANTEST (Japan)]</td>
<td>-5 - 60</td>
<td>6G</td>
<td>20G</td>
<td>less than 0.01%FS</td>
<td>1kHz</td>
<td></td>
</tr>
<tr>
<td>BTL-A [BALLUFF (Germany)]</td>
<td>-20 - 60</td>
<td>50G</td>
<td></td>
<td>12bit</td>
<td></td>
<td>2kHz</td>
</tr>
<tr>
<td>AQLT [Data Instrument (America)]</td>
<td>-40 - 152</td>
<td>20G</td>
<td>50G</td>
<td>± 0.05%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hall Sensor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KSSC-050 [Kayaba (Japan)]</td>
<td>-20 - 75</td>
<td>5G</td>
<td>90G</td>
<td>0.5mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Encoder</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS5000 [TAMAGAWA (Japan)]</td>
<td>-10 - 75</td>
<td>10G</td>
<td>100G</td>
<td>20 - 25,000 Pulses</td>
<td>200 μsec</td>
<td></td>
</tr>
<tr>
<td>A2-E2 [U.S Digital (America)]</td>
<td>-13 - 185</td>
<td>20G</td>
<td>100G</td>
<td>10000rpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE-65-S ISI [TR Electronic (Germany)]</td>
<td>0 - 60</td>
<td>10G</td>
<td>100G</td>
<td>6000rpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Resolver</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TS2013N94E23 [TAMAGAWA (Japan)]</td>
<td>-30 - 100</td>
<td>15G</td>
<td>100G</td>
<td>7290 Pulses</td>
<td>±0.28% for 180°</td>
<td>30 msec</td>
</tr>
</tbody>
</table>
2.1 アイテムの詳細

2.1.1 アイテム1の詳細

2.1.2 アイテム2の詳細

2.1.3 アイテム3の詳細

2.1.4 アイテム4の詳細

2.1.5 アイテム5の詳細

2.1.6 アイテム6の詳細

2.1.7 アイテム7の詳細

2.1.8 アイテム8の詳細

2.1.9 アイテム9の詳細

2.1.10 アイテム10の詳細

2.1.11 アイテム11の詳細

2.1.12 アイテム12の詳細

2.1.13 アイテム13の詳細

2.1.14 アイテム14の詳細

2.1.15 アイテム15の詳細

2.1.16 アイテム16の詳細

2.1.17 アイテム17の詳細

2.1.18 アイテム18の詳細

2.1.19 アイテム19の詳細

2.1.20 アイテム20の詳細

2.1.21 アイテム21の詳細

2.1.22 アイテム22の詳細

2.1.23 アイテム23の詳細

2.1.24 アイテム24の詳細

2.1.25 アイテム25の詳細
Figure 2.1 A basic configuration diagram of sensor for remote stroke detection
2.2 2.2.1 2.2.2
2.3 2.3.1

2.3.2
2.3.3 ¼ö±¤ÀÓ¿¡µû¶ó¼¼¶ó¹Í°úÅ©·ÒÀǽºÄÉÀϷκÎÅ͹ݻçµÈ±¤

ÀǸí¾ÏÂ÷À̸¦Àü¾ÐÀ¸·Îº¯È¯Çϴ¼ö±¤¼¾¼­ÀÇÃâ·Â¿¡ÀÇÇØ½ºÆ®·ÎÅ©¸¦ÃøÁ¤Çϴ°ÍÀ̹ǷÎ。

2.4 ¼/´½¿îÅͺÎ

2°ú±â´ÉÀ»Á¦¾îÇÏ´ÂÇѰ谡ÀÖÀ¸¹Ç·ÎÀûÀýÇÑÆÄÇüºÐÇÒ¹ý[5]
À»µµÀÔÇÔÀ¸·Î½á½ºÆ®·ÎÅ©¿¡´ëÇѵðÁöÅаªÀ»ó¸®ÇÏ¿©»ç¿ëÀÚ°¡¿øÇÏ´ÂÇüÅÂÀǵ¥ÀÌÅÍ·ÎÃâ·ÂºÎ·Î³Ñ°ÜÁÙ¼öÀÖ¾î¾ßÇϰí，º»³í¹®¿¡¼­µµÀԵǴÂÁõºÐÇü
¼¾¼­ÀÇ´ÜÁ¡À»º¸¿ÏÇÒ¼öÀÖµµ·Ïº¸Á¤±â´ÉÀ»°®°íÀÖ¾î¾ßÇÑ´Ù，À̸¦À§
ÇØÀûÇÕÇѹæ¹ýÀºÇÁ·Î±×·¥À̰¡´ÉÇÑÀü¿ëÀÇ
CPU¸¦Ã¤ÅÃÇÔÀ¸·Î½á±¸Çö，2°ú±â´ÉÀ»Á¦¾îÇÏ´Â

2.5 µ¥ÀÌÅÍ󸮺Î

µ¥ÀÌÅÍ󸮺δ¿ø°Ý°ËÃ⽺Ʈ·ÎÅ©¼¾¼­ÀÇÀüü±â´ÉÀ»Á¦¾îÇÒ¼öÀÖ¾î¾ßÇϰí，¾÷/´½¿îÅͺο¡¼­Á¦°øµÇ´Â½ºÆ®·ÎÅ©¿¡´ëÇѵðÁöÅаªÀ»
ó¸®ÇÏ¿©»ç¿ëÀÚ°¡¿øÇÏ´ÂÇüÅÂÀǵ¥ÀÌÅÍ·ÎÃâ·ÂºÎ·Î³Ñ°ÜÁÙ¼öÀÖ¾î¾ßÇϰí，º»³í¹®¿¡¼­µµÀԵǴÂÁõºÐÇü
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ÇØÀûÇÕÇѹæ¹ýÀºÇÁ·Î±×·¥À̰¡´ÉÇÑÀü¿ëÀÇ
CPU¸¦Ã¤ÅÃÇÔÀ¸·Î½á±¸Çö。
2.6  

LCD (Bar)
3.1 食欲値の測定

Fe++ と Cl⁻ を使用した 3.1 枚目の図から、Hunger の値は以下の通りです。

1. …
2. …
3. …

- 11 -
Figure 3.1 A Process of scaling piston rod

1. Surface coating and ceramic coating

2. Chrome plating

3. Scaling after hardening and scale formation

Figure 3.1 A Process of scaling piston rod
Photo 3.1 Ceramic-coated hydraulic cylinder (Hunger Co.)

Photo 3.2 Process of ceramic coating on piston rod (Hunger Co.)
3.2 

3.2.1 

① 

② 

③ 

- 15 -
Figure 3.2 Amplifier circuit
3.2.2 ±¤ÆÄÀ̹öÇìµåÀǼ³Ä¡¹æ¹ý

3.3 ±¤ÆÄÀ̹öÇìµå¼³Ä¡¹æ¹ý

Figure 3.3 A setting method of optic fiber head
3.2.3 Output of optic fiber amplifier for chrome and ceramic scales

Figure 3.4 Output of optic fiber amplifier for chrome and ceramic scales
3.3 3.3.1 A, B と A, B の形状

A, B の形状は以下の通りです。A, B の形状は、ストロークの増加方向に対して示されています。

Figure 3.5 Shapes of A and B phase for stroke increasing direction
Figure 3.6 Shapes of A and B phase for stroke decreasing direction
Figure 3.7 Counting method of scales by 1/4 partition of one period
3.3.3

NEC PD4701

CPU

350ns

CPU

Figure 3.8 Block diagram of up/down counter PD4701
Figure 3.9 A phase and B phase signal outputted from optic fiber amplifiers
3.4 80C196KC

3.4.1 80C196KC

Figure 3.10 The schematic diagram for data processing using 80C196KC
3.4.2 機械的動作

Figure 3.11 Flow chart of data processing

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4 Prototype Configuration

4.1 LVDT

LVDT is used in the test setup. The LVDT used is the SANTEST LVDT GYMT-C-11-A-600-24S-D.

### 3.1 SANTEST LVDT

Table 3.1 Characteristics of SANTEST LVDT

<table>
<thead>
<tr>
<th>Articles</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonlinearity</td>
<td>0.05% below</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.01% below</td>
</tr>
<tr>
<td>Hysteresis</td>
<td>0.01% below</td>
</tr>
<tr>
<td>Sampling frequency</td>
<td>1kHz standard</td>
</tr>
<tr>
<td>Output signal (voltage)</td>
<td>0-10V or 10-0V</td>
</tr>
<tr>
<td>Output signal (current)</td>
<td>4-20mA or 20-4mA</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>+15V ±5%</td>
</tr>
<tr>
<td>Operating Temp.</td>
<td>Probe -5°C ~ +60°C / Controller 0°C ~ +60°C</td>
</tr>
<tr>
<td>Vibration</td>
<td>6G Max</td>
</tr>
<tr>
<td>Shock</td>
<td>20G Max</td>
</tr>
</tbody>
</table>
4.2 Configuration

4.1 The prototype is presented in this section. The prototype is a SANTEST LVDT equipment.
Figure 4.1 Configuration diagram of a prototype developed in this thesis
Photo 4.1 Developed prototype for remote detection of stroke
4.3 

Photo 4.2 Real setting between scaled piston rod and optic fiber head
4.4 データ処理ボード

4.3 で使用した 80C196KC を用いたデータ処理ボードを以下に示す。LVDT と LVDT を用いた LCD ディスプレイを蔽い、10cm の変位を計測する。

Photo 4.3 Data processing board using 80C196KC
5.1 挠度仪

itivity. 5.1.1 测试范围 0.5mm LVDT 由 0.5mm 记录。同样，挠度仪的分辨率 0.5mm
(a) In case of increasing the stroke
(b) In case of decreasing the stroke

Figure 5.1 Output comparison of the stroke sensor with LVDT

- 34 -
5.2

(a) In case of increasing the stroke
(b) In case of decreasing the stroke

Figure 5.2 Relation between the stroke sensor and LVDT for verifying the linearity
5.3 agrid acceleration

...
(a) Output of the stroke sensor with LVDT for verifying the bidirectional repeatability

(b) Error of stroke sensor and LVDT

Figure 5.3 Output comparison of the stroke sensor with LVDT for verifying the bidirectional repeatability
6.  

¿¡¼­º¸´Â±¤ÆÄÀ̹ö¾Ú ÇÁ·Î¼­»ó¿ëÈ­µÈÁ¦Ç°À»»ç¿ëÇÏ¿´Áö¸¸, prototype ¿¡¼­´Â±¤ÆÄÀ̹ö¾Ú ÇÁ·Î¼­»ó¿ëÈ­µÈÁ¦Ç°À»»ç¿ëÇÏ¿´Áö¸¸.


Appendix prototype

A.1 80C196KC
A.2  

Diagram of A/D converter.