Spring back analysis of pipe coil manufacturing using conventional lathe machine

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Abstract The demand for manufacturing to support the food industry, medical industry, infrastructure, energy, and transportation are soaring. Meanwhile, the capacity and capability of conventional lathe machines need to be improved, especially to the manufacturing capability of particular parts. This issue needs to be considered since lots of small manufacturing industries which have conventional lathe machine need to compete to overcome the production demand of unique parts, for example as pipe coil. In large companies, coil manufacturing is produced with a special machine. With this concept, coil manufacturing can also be made in a lathe machine. What needs to be researched is how the good product achieved. In this case, are related to the dimensions laterally and axially, because there is a spring back character on the workpiece to produce. This study analysis the spring-back of the pipe coil in which manufactured using conventional lathe machine. From this research and testing, it was found that the lathe machine can be used to make coils with pipe raw materials. It was also found that there was a size deviation in the diameter and pitch of the coil. The size deviation can be used as a coefficient to compensate for the size of the mandrel and pitch.

Keywords: pipe coil, spring back, lathe machine

1. Introduction
Recently, pipe coil has been used widely in industry, such as at the heat exchanger [1,2]. An example of it is the apparatus of distillation or refrigeration. The use of pipe coil is more preferred compare to the straight pipe since the pipe coil has more heat transfer surface and more compact. It makes the pipe coil has better performance in heat transfer. The pipe coil is required in a wide range of industries, for instance, in the sector of agricultural product processing such as in the distillation industry of lemongrass or eucalyptus oil. As well as in the food industry, this requires
Pipe coils in the cooling evaporation chamber. In addition to the chemical industry, pipe coils are used to obtain pure alcohol in the process of separation from a mixture of alcohol and water. The primary mover in the electric vehicle also needs the implementation of the coil for the cooling system of their electric motor [3].

Pipe coil is a long pipe formed into a spiral helical like a spring using a special machine. Pipe coil can be either a single coil or a double coil inside. Pipe coils can be formed from various types of pipes with variations in length, diameter, and thickness. Coil diameter and pitch coil can also be adjusted according to needs. However, only soft metal pipes can be formed by pipe coils such as copper, stainless steel, aluminum, and galvanized steel. Pipe coil formation through process stages that require controlled operation consistency, namely the three-roller bender method, pitch rolling bender, and Two-Disc Coil Bender. All pipe coil making equipment is operated using hydraulic power and controlled by a computer to get a consistent bend. The method is complex using modern and expensive equipment [4], so it is difficult to do by small and medium industries that have limited equipment and capital.

This research aims to analyses the spring back a pipe coil manufacturing using a conventional lathe machine. This research will get a relationship between operating parameters such as pitch spacing, coil diameter, and pipe diameter to produce suitable quality pipe coils.

2. Literature review

Pipe coil is a long pipe that is bent in the radial direction and, at the same time, toward the axial continuously so that a helical spring is obtained. This pipe coil is widely used for heat transfer needs. In terms of the mechanism of its formation, the pipe coil can be made with a conventional lathes machine. Conventional lathes machines are the most widely used machines in the manufacturing industry. However, it has not been widely used for making pipe coils. By utilizing existing conventional lathes machines to make pipe coils, the process will be far more effective and efficient because it does not require special equipment to make pipe coils.

Conventional lathe requirements that can be used to make pipe coils have automatic feeding and threading. Also, the intermediary mechanism of the spindle drive is the gear. The pulley and belt mechanism carries a small slip and torque risk, although it has no direct effect on the results of the pipe coil. The process of making pipe coils is classified in the non-cutting process where no material is discarded or cut during the process [1]. Thus the "cutting force" required does not exceed its ultimate strength, but up to the plastic area [2]. In the stamping process, the formation is similar to forming.

Material that can form, in general, has good creep ability (not brittle). This stretching ability is usually followed by the ability to return to its position (elasticity) [5, 6]. In the bending or forming process, the material is pressed to the plastic area, but the spring-back phenomenon still occurs. The size of the spring back depends on many things. Some of them are the thickness, direction of plastic load, type of material, and others [7]. Some fatigue factors in the pipe coil must also be considered, such as pre-bending, mechanical defects, and corrosion [8]. Thus, the dimension correction factor is needed to get the appropriate final product dimensions [9].

This pipe bending process is carried out without heating the material or is classified as a cold-forming process. The consideration is that the workpiece is not bent to extremes and sufficient mechanical stretching property. Meanwhile, to determine the coil spring back factor is a function of several parameters, namely the pipe material property, the geometry of the pipe coil, and machine rotation (rpm) [10-12]. There are two spring back analyses, which are radial direction and axial wine. The radial spring back analysis is by comparing the outside diameter of the mandrel with the inside diameter of the pipe coil after it is formed. In comparison, the axial direction spring
back analysis is comparing the lathe spindle distance during operation with the spacing of the pipe coil after it is created.

3. Methods and material

For the process of pipe coiling using lathe machines to be carried out, a jig and fixture are required on the lathe machine. A jig is a workpiece steering aid, while a fixture is a workpiece grip tool. The mandrel functions as a shaper so that the uniform diameter of the coil meets the standards. As a fixture, a grip is designed at the left end of the mandrel. Feeder functions as a guide so that it can be classified as a jig. The model of jig and fixture as seen in Figure 1.

| No. | Components                      | No. | Components                        |
|-----|---------------------------------|-----|-----------------------------------|
| 1   | Coiling Jig and Fixture         | 6   | Bushing Guide                     |
| 2   | Spring                          | 7   | Bolt - ISO 4762 M6 x 20           |
| 3   | Pipe Clamper                    | 8   | Bolt - ISO 4762 M6 x 10           |
| 4   | Copper pipe                     | 9   | Pipe Feeder Assy.                 |
| 5   | Anti-Flat Rod                   |     |                                   |

Figure 1

Research for spring back analyses on pipe coil was carried out. The conventional lathe machine was used to manufacture the pipe coil. The pipe coil was made by using the various diameters of thin copper, i.e., 8, 10, and 12.5 mm. Three different mandrel diameters were used to form the inside diameter of the pipe coil; those are 59.4 mm, 75 mm, and 88.90 mm. The pitch of the lathe machine was set at 12.7 mm and 15.63 mm.

4. Results and discussions

Experimental works have been conducted for various mandrel diameter dan pipe diameter. The influence of mandrel diameter and pipe diameter on the axial and lateral spring back as shown on the following figures.

4.1. Mandrel diameter to pitch influence to axial spring-back
Axial spring back is the difference in the distance between the pitch of the coil pipe and the pitch of the lathe machine at the forming process. The axial spring back is influenced by the mandrel diameter as shown in Figs. 2 and 3. It is also summarized in Table 1. It can be seen that mandrel diameter increases the actual coil pitch. It means that the axial spring back of the coil is affected by the mandrel diameter. This result has a similar tendency to the study conducted by Olunlade [13].

**Figure 2.** Mandrel diameter to 12.7 mm pitch influence to axial spring-back

**Figure 3.** Mandrel diameter to 15.63 mm pitch influence to axial spring-back

**Table 1.** Mandrel diameter and pitch correlation to the actual pitch

| Mandrel dia. | Workpiece/coil (actual) - Pitch 12.7 | Workpiece/coil (actual) - Pitch 15.63 |
|--------------|-------------------------------------|-------------------------------------|
| Pipe dia. 8 mm | Pipe dia. 9.525 mm | Pipe dia. 8 mm | Pipe dia. 9.525 mm |

13.367 14.217 14.400 14.183
13.383 13.967 14.183 13.0
13.2 13.4 13.6 13.8
59.4 75 88.9

Coil Pitch (mm)
Ø of Mandrel (mm)
Pipa Ø8 (mm) Pipa Ø9.525 (mm)
4.2. Mandrel diameter and pitch correlation to actual coil diameter

Lateral spring back is the difference in the distance between the coil diameter and the mandrel diameter at the forming process. The lateral spring back is influenced by the mandrel diameter as shown in Figs. 4 and 5. It is also summarized in Table 2. It illustrates that mandrel diameter increases the actual inner diameter of the coil. It means that the radial spring back of the coil is affected by the mandrel diameter. This result has a similar tendency to the study conducted by Li [14].

![Figure 4. Mandrel diameter to 12.7 mm pitch influence to lateral spring-back](image-url)
Figure 5. Mandrel diameter to 15.63 mm pitch influence to lateral spring-back

The actual pitch is always smaller than the planned pitch. Thus compensation is required by adding a pitch constant. The results of this research can be developed to determine the formula or constant magnitude of the pitch compensation. Because the lateral spring back is influenced by the material dimensions, mandrel dimensions, and the mechanical properties of the material, further testing with a larger number of specimens is required. This is so that a conclusion can be drawn whether compensation can be formulated or simply by adding or multiplying it by certain constants.

Table 2. Mandrel diameter and pitch correlation to actual coil diameter

| Mandrel dia. (mm) | Workpiece/coil (actual) - Pitch 12.7 | Workpiece/coil (actual) - Pitch 15.63 |
|-------------------|--------------------------------------|--------------------------------------|
|                   | Pipe dia. 8 mm Pipe dia. 9.525 mm    | Pipe dia. 8 mm Pipe dia. 9.525 mm    |
|                   | Dia. Percentage Dia. Percentage      | Dia. Percentage Dia. Percentage      |
| 59.40             | 61.87  4.15%  62.80  5.72%          | 62.28  4.85%  62.43  5.11%          |
| 75.00             | 80.15  6.87%  81.05  8.07%          | 79.78  6.38%  79.88  6.51%          |
| 88.90             | 97.13  9.26%  97.33  9.49%          | 96.98  9.09%  97.83 10.05%          |

5. Conclusions

From these experiments, it can be concluded that the coiling process on copper pipes with various diameter and pitch have dimensional deviations both laterally and axially. It is because copper pipes and similar materials, in general, have elasticity and elongation properties. Therefore, to get a coil with a diameter and pitch close to the nominal size, the mandrel size and pitch size must be compensated.

In this case, the compensation in question is to reduce the size of the mandrel and reduce the pitch. The percentage of the approximation to the reduction in size is, of course, only valid for the above conditions. The spring back or size deviation can also be compared with the elongation of pipe material, which is usually found in the mechanical properties of each material.

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7. References

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