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# Making Of Pressure Springs From Low Carbon Steel St 37 Material As An Alternative To Standard Pressure Springs In Mold Construction Through Solid Carburation Processes

**Heri Setiawan**
Mechanical Engineering POLMAN Bandung
Email: herisetiawan529@gmail.com
* Correspondence: herisetiawan529@gmail.com

**KEYWORDS**
Compression pring, Low Carbon Steel St 37, Pack Carburizing.

**ABSTRACT**
Compression Spring is one of standard components type that are widely used in machinery construction, as well as in mold construction that serves to restore the position of the ejector mould into position. This study aims to find alternative materials for standard compression spring using specimen test of low carbon steel St 37 in the form of a compression spring is made by using coiling process followed to heat treatment processes such as pack carburizing, hardening, quenching and tempering. To ensure the quality process, the tests should be done in the laboratory such us the hardness test, the distribution of hardness, microstructure and deflection of the spring test. The pack carburizing is done at a temperature of 925ºC with a holding time of 2.5 hours, followed by a case hardening process at a temperature of 870ºC with a holding time of 12.5 minute and quenched on medium oil and tempered at a temperature of 350ºC. The results of this research show that the method used to generate the average value of 456.57 HV and have α – martensite microstructure and also the compression spring deflection average value of 18.625 N/mm on 613.9 N. Those data approache the compression spring standard value of hardness, microstructure and deflection. Based on the data analysis, low carbon steel St 37 can be used as alternative material for standard compression spring



## Introduction

The need for standard machine components such as nuts, bolts and springs will increase from year to year following the need for engineering tools in the manufacturing industry. As with compressed springs, it is one type of standard component that is widely used in mold construction which functions to return the mold ejector position to its original position. The common standard compressed spring material is JIS B 5012. This material is a material that is difficult to find in the market. Conditions like this are a great opportunity for research on the possibility of making alternative components using other types of engineered materials through the heat treatment process (Amaliah & Rumendi, n.d.).

This research was conducted on St 37 low carbon steel material through a heat treatment process method with the type of solid carburizing process. This method is a heat treatment process by adding carbon to low carbon steel by diffusion which aims to increase the surface hardness of the material. The results of this study aim to find alternative materials that can be used for compressed spring products which can be used as alternative compressed springs with product quality close to standard products and can be used in various constructions on machines such as mold construction, methods and materials.

## Research methods

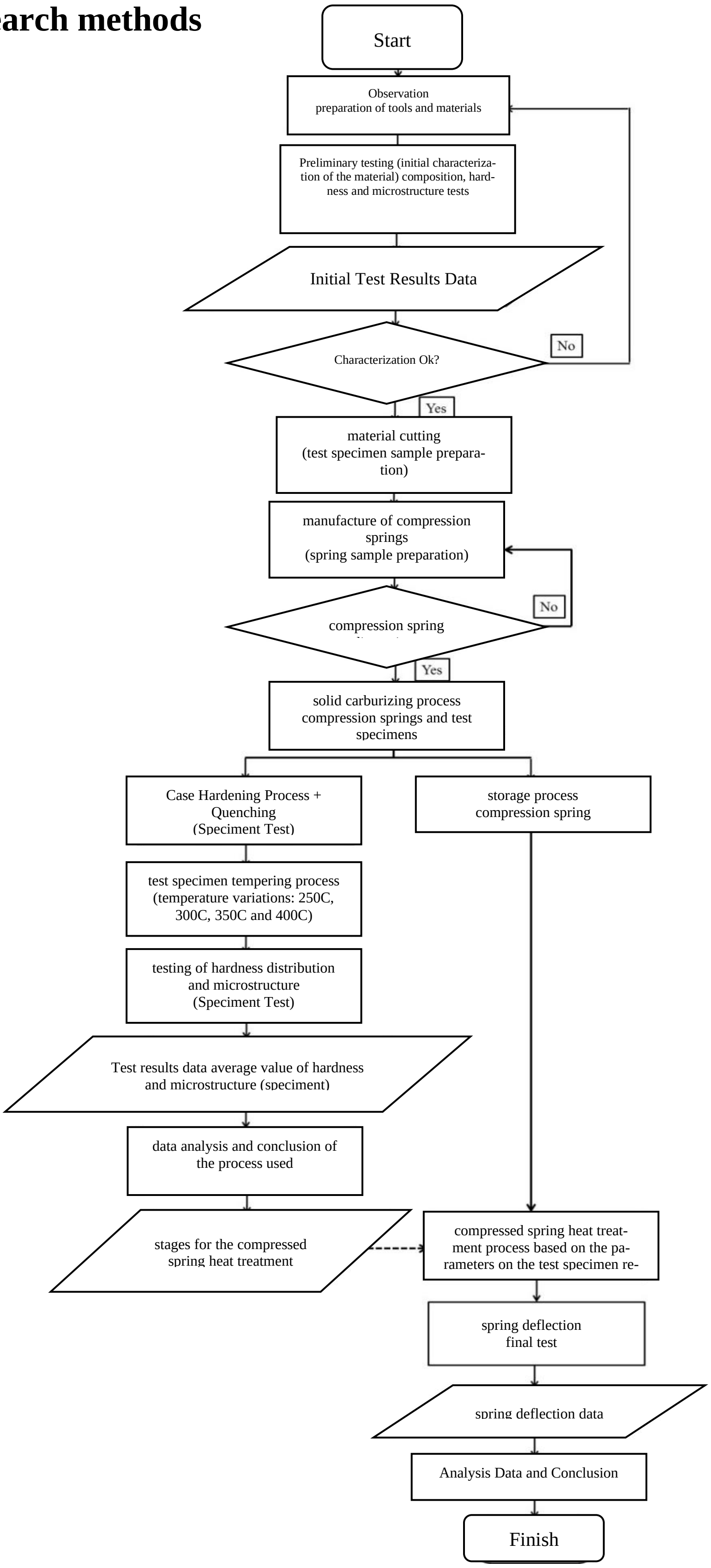


**Fig 2.1** Flowchart Diagram

## Research Preparation

There are two types of samples, namely test specimens and compressed springs. Samples in the form of test specimens are used to determine the parameters of the heat treatment process to be used on compressed springs resulting from the machining process while samples in the form of compressed springs are used as samples for spring deflection testing which were previously subjected to heat treatment processes based on the parameters of the heat treatment process results on the test specimens.

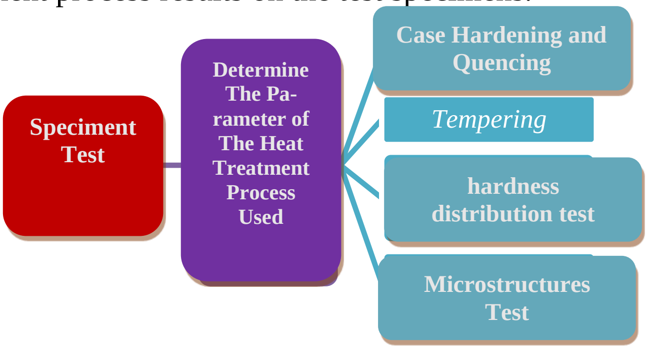



**Fig 2.2** Use of test specimens

**Fig 2.3** test specimen

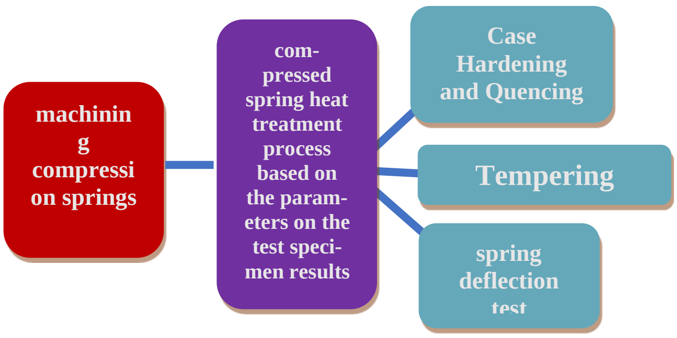



**Fig 2.4** Use of compression springs

**Fig 2.5** result of compression spring

**Making Compressed Springs**

Compression spring specifications are taken from the ACME catalog which is a compressed spring manufacturer. The following are the compressed spring specifications made in this study:

- Diameter of spring wire = 4 mm.
- Inner Diameter in compressed spring = 17 mm.
- Outer diameter of compressed spring = 25 mm.
- Length of compressed spring = 100 mm.
- Pitch = 8 mm.
- Number of windings = 14
- Compressed spring end type = Squared and Grounded Ends left-hand.

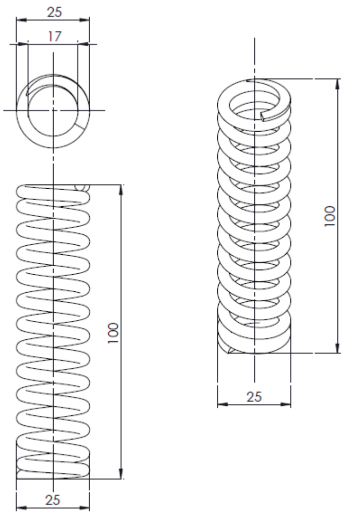



**Fig 2.6** Compression spring specifications

Compression springs are made using a Grazioli Dania 180 machine. The material used is low carbon steel St 37 with a diameter of 4 mm. The process used is in the form of a coiling process, where the material is gripped and directed using a spring guide and wrapped around the shaft of the spring to form a compressed spring according to specifications.

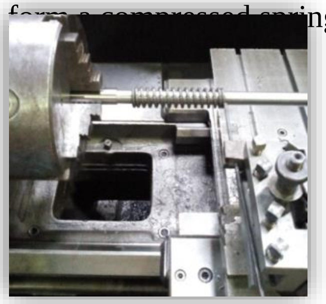


**Fig 2.7** C*oiling process*

## Carburizing Process

This process is carried out using a furnace. The temperature used is 925°C with a holding time of 2.5 hours. The carbon medium used was coconut shell charcoal mixed with 10% $BaCO_3$. The cooling process is carried out in the furnace until room temperature is reached. The following is a schematic of the carburizing process.

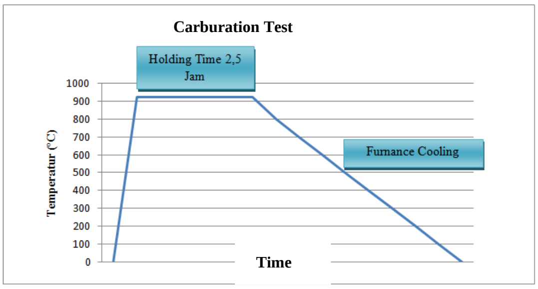



**Fig 2.8** Carburizing process schematic

## Case Hardening Process

The temperature used in the case hardening process is 870°C with a holding time of 12.5 minutes. When the process is completed, the cementation box is removed from the furnace. The specimen was removed from the box and then quenched. The specimens were cooled using water and oil.

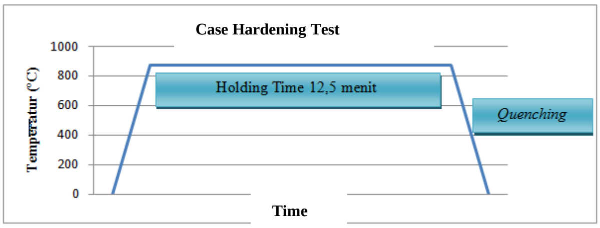



**Fig 2.9** C*ase hardening schematic process*

## Tempering Process

The tempering process is carried out after the hardening and quenching process. The purpose of this process is for stress relieving, namely reducing the brittleness due to the quench hardening process and increasing the toughness of the specimen. This process uses four temperature variations, namely 250ºC, 300ºC, 350ºC and 400ºC with a holding time of 1 hour. The following is a schematic of the tempering process.

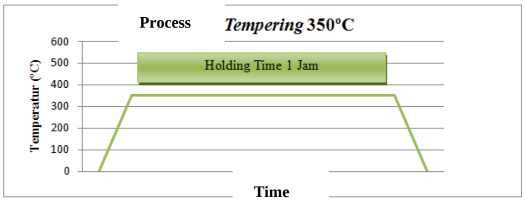



**Fig 2.10** T*empering schematic process*

### Testing Process

The testing process includes:

- Hardness testing and hardness distribution referring to ASTM E18, ASTM E92 – 82 and ASTM 384 standards.
- Microstructure testing refers to ASTM E3 – 01 standards.
- The spring deflection test refers to the Indian Standard Helical Compression Spring {IS 7906 (Part 5): 2004} with four variations of compressive force namely; 613.9 N, 460.9 N and 307 N refer to the ACME (Standard Components for Plastic Mold) catalog.

## Results and Discussions

### Hardness Test Results

Hardness testing was carried out on the initial specimen (low carbon steel St 37 diameter 4 mm) prior to the carburizing process, standard compressed spring specimens, specimens produced from the solid carburizing process and specimens produced from the case hardening-quenching process as well as specimens after tempering.

### 3.1.1 Original Specimen Hardness Test Results

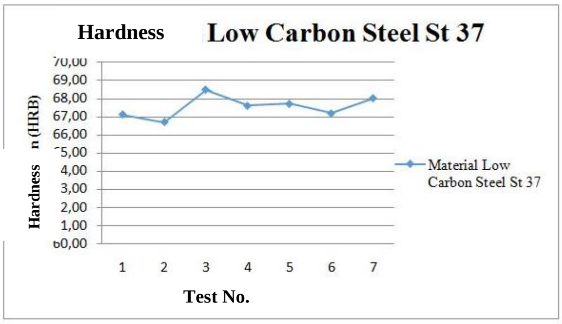



**Fig 3.1** Original Specimen Hardness Test Results

Based on the results of hardness testing using a rockwell B hardness testing machine and using a load of 100 kgf, the low carbon steel St 37 material has an initial hardness with an average of 67.54 HRB or the equivalent of 120 HV. This shows that the material tested is a low carbon steel that has low hardness (ductile steel).

### 3.1.2 Standard Compressed Spring Hardness Test Results

Based on the results of hardness testing at 10 test points using a micro vickers hardness testing machine with a load of 200 gf (HV 0.2), standard compressed spring specimens have an average hardness of 455.71 HV which produces a stable hardness graph as show below.

**Standard compressive spring hardness**

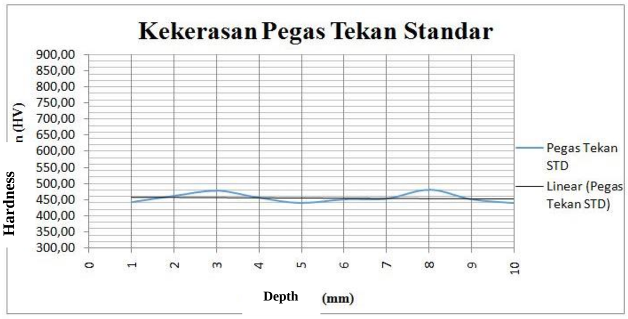



**Fig 3.2** Graph of standard compression spring hardness test results

### 3.1.3 Hardness Test Results of Solid Carburizing Process Results

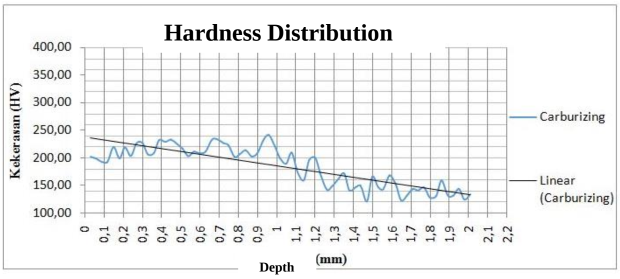



**Fig 3.3** Graph of hardness distribution resulting from the solid carburizing process

Based on the results of the hardness distribution test at 67 test points with a depth range of 0.03 mm to a depth of 2.01 mm using a Vickers hardness testing machine and using a load of 200 gf (HV 0.2), the specimens resulting from the solid carburizing process have an average hardness [illegible] 83.9 HV with a case depth of 1.47 mm. Graph 3.3 shows the distribution of hardness which tends to decrease from the surface to the core. The hardness on the surface has a higher hardness than the hardness on the core. This is caused by carbon diffusion during the carburizing process.

### 3.1.4 Hardness Test Results for Oil and Water Quenching on Hardening Process

Based on the results of the hardness test, the specimens resulting from the case hardening and quenching process in oil media had a hardness with an average hardness value of 708.67 HV, while the case hardening and quenching process specimens in water media had an average hardness of 642.99 HV.

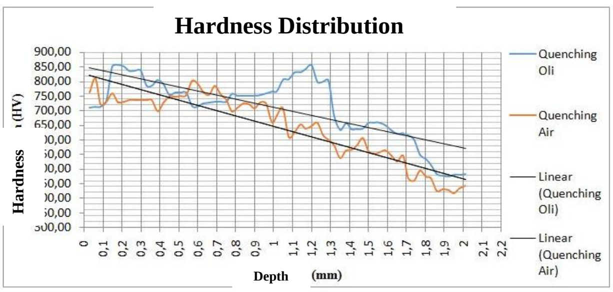



**Fig 3.4** Graph of hardness distribution resulting from oil and water case hardening quenching process

Based on graph 3.4, the use of these two media has an equal distribution of hardness which tends to decrease in hardness values from the surface to the core. While the difference between the two is that the use of water media has a hardness distribution with a tendency to decrease in hardness values which is more stable than the use of oil media.

### 3.1.5 Tempering Process Hardness Test Results

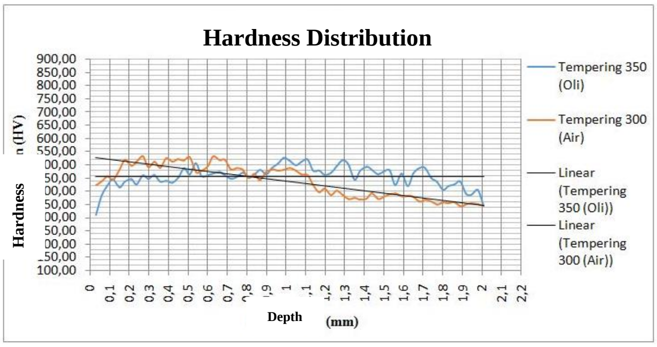



**Fig 3.5** Distribution of the hardness of the tempering process

Based on the test results for the distribution of hardness at 67 test points with a depth range of 0.03 mm, it shows that the case hardening process specimens quenched with oil and tempered at 350ºC have a more stable hardness distribution with an average hardness of 456.57 HV compared to the hardened specimens. water quenching hardening process and tempered at 300ºC with an average hardness of 435.59 HV. Both of these results have an average hardness value that is close to the average hardness value of a standard compressed spring, it's just that specimens from the hardening process of oil quenching and tempering at 350ºC have a smaller difference in hardness compared to specimens from the hardening process of water quenching and tempering. at 300ºC. The effective depth of hardness using the case hardening technique for specimens tempered at 350ºC was obtained 0.99 mm while for specimens tempered at 300ºC it was found at a depth of 0.27 mm. From the results of this comparison, the heat treatment process method is taken in the form of a solid carburizing process followed by a hardening process and quenching in an oil medium then tempering at 350ºC.

## 3.2 Microstructure Test Results

### 3.2.1 Original Specimen Microstructure Test Results

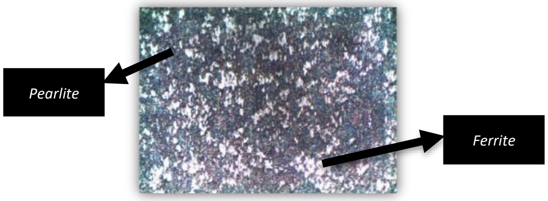
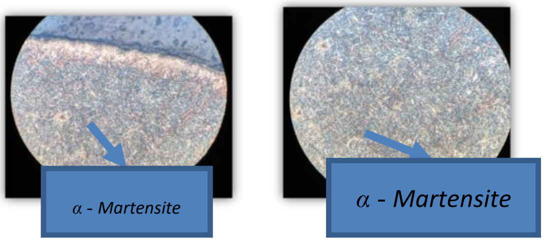



**Fig 3.1** Microstructure of the original material, 1000x magnification

Based on the results of microstructure observations shown in Figure 3.1, there are ferrite structures and pearlite structures. Judging from the average hardness value and microstructure, the initial specimen is a low carbon steel material.

### 3.2.2 Microstructure Test Results for 350°C Tempering Process




(a) (b)

**Fig 3.2** Microstructure of case hardening-quenching process in oil tempered at 350°C

(a) Surface microstructure 400x magnification
(b) Microstructure of the core section magnification 400x

As shown in Figure 3.2 (a), the microstructure on the surface of the specimen formed from the results of the tempering process is an α-martensite structure that is evenly distributed. This happens because the tempering process makes the microstructure of the specimen smoother and more even than the microstructure of the previous process.

As shown in Figure 3.2 (b), the microstructure on the core of the specimen formed from the results of the tempering process has the same microstructure as the microstructure on the surface of the specimen. This happens because the tempering process makes the microstructure of the specimen smoother and more even so that the specimen has tough and ductile properties.

### 3.2.3 STD Compression Spring Microstructure Test Results

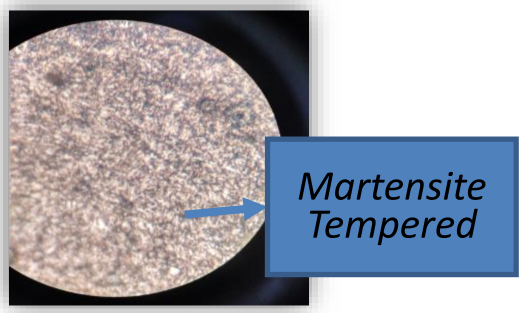



**Fig 3.3** Standard compression spring microstructure 1000x magnification

Based on the results of the microstructure analysis carried out, the microstructure of the specimens resulting from the solid carburizing process, hardening quenching oil for the heat treatment process used in the compressed spring was taken. This is due to the microstructure of the specimens resulting from the solid carburizing process, hardening quenching oil which has a finer microstructure than the microstructure of the specimens resulting from the solid carburizing process, hardening quenching water. To obtain a finer and more even microstructure, the specimens resulting from the solid carburizing process, hardening quenching oil were then tempered at 350°C.

### 3.3 Spring Deflection Test Results

### 3.3.1 Standard Compressed Spring (STD)

The standard compressed spring deflection data is taken from the ACME compressed spring catalog. At a load of 613.9 N the spring deflection shows 32 mm while at a loading of 460.9 N the spring is deflected by 24 mm and at a loading of 307 N, the spring is deflected by 17 mm. Based on the data in table 3.1 using the formulation :

$$F = k\ \Delta x \quad\text{.....................................................(1)}$$

then a standard spring constant of 18.82 N/mm is obtained.

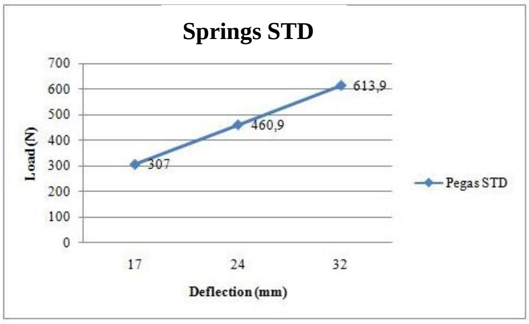



**Fig 3.6** Standard compression spring deflection diagram

### 3.3.2 Compressed Spring Results from Study

The spring deflection test was carried out in the Production Engineering-ITB laboratory using a compression testing machine. The results of the 6 springs that were made, 4 springs were taken to do the spring deflection test. The test was carried out 4 times for each spring. As shown in graph 3.7 at a load of 613.9 N the spring deflection shows 32.22 mm while at a loading of 460.9 N the spring is deflected by 25.13 mm and at a loading of 307 N the spring is deflected by 17 mm. From the test results, a compression spring constant of 18.52 N/mm was obtained. This shows that the average deflection value and compressed spring constant from the research results are close to the standard compressed spring deflection constant values so that the compressed spring from the research results can be used as an alternative to standard compressed springs.

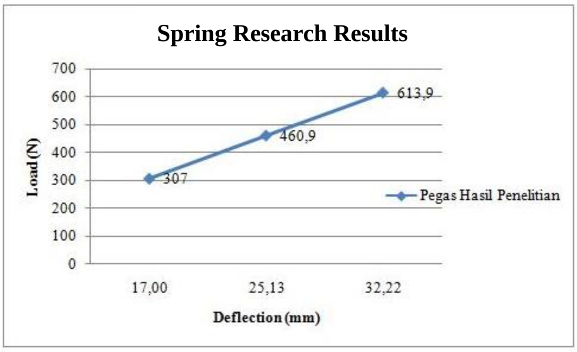



**Fig 3.7** Compressive spring deflection graph of study results

## Conclusion

Based on the data and analysis obtained, the following conclusions can be drawn. 1. After the process of solid carburizing, hardening, quenching in oil media and tempering at 350ºC, there was an increase in the hardness of the low carbon steel St 37 material from 120 HV 0.2 to 456.57 HV 0.2. This data is close to the standard compressed spring hardness value of 455.71 HV 0.2. 2. Compressed springs from research studies with standard compressed springs have the same microstructure, namely α–martensite produced from tempered martensite. 3. The compressed spring deflection value of the research study is 32.22 mm at 613.9 N loading close to the standard compressed spring deflection value of 32 mm at the same loading and the compressed spring constant value is 18.52 N/mm close to the compressed spring constant value standard, which is 18.82 N/mm. 4. Through a solid carburizing process at 925ºC followed by case hardening at 870ºC, and quenching in an oil medium and tempering at 350ºC for 1 hour, low carbon steel St 37 can be used as an alternative material for standard compressed springs.

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