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Analysis of the operating torques via anfis of stabilizer connection parts that is one of the front suspension equipment

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Abstract
Curve stabilizer connection parts (Link Stabilizer) which is used on front suspension systems that is preferred for new generation vehicles undertake the task of stabilizing the suspension systems during the curves. During the production of this part it is necessary to assemble with a tightness torque value. This is one of the two parameters (geometric tightness and day) influencing the torque of product, experiment is made with different combinations of variables, data according to these results, have been examined on the ANFIS (Adaptive Neuro Fuzzy Interference System) architecture by the Sugeno method. As a result of this learning, the issue of finding the values by calculating which is not measured was investigated.

Keywords: Link stabilizer; antiroll bar connection part; torque; ANFIS; SUGENO; Artificial neural networks

1. Introduction

Steering and suspension systems are components that supply driving safety for vehicles. Ball joint type is commonly used within the structure of these systems and as a stress bearing material, POM (polyoxymethylene) is mostly preferred. The material of the housing which makes task of bearing among the components which we examined is St37-2 steel which formed by cold forging, the material of the bearing is Delrin 7057 produced by plastic injection method, the ball-stud is 41CrMo4 produced by machining.

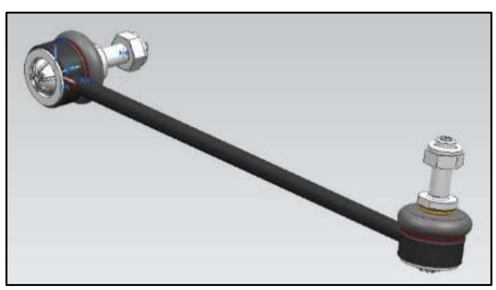

Figure 1. Link stabilizer.

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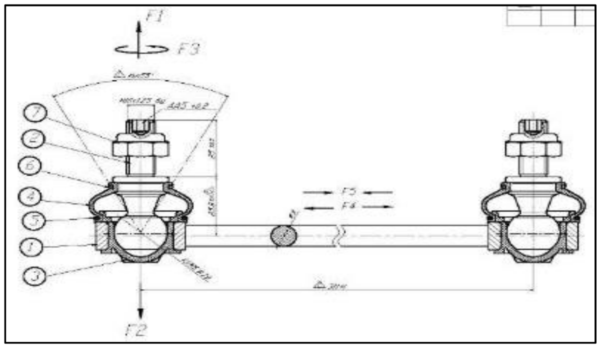

Figure 2. Link stabilizer drawing.

3D model and technical drawing of the component which were examined are shown in figures 1 and 2. Firstly, the ball-stud was lubricated and assembled into the plastic bearing. After that, assembled components were assembled as they were close fit to the body. The body form is presented as assembled bearing and ball-stud in the figures 3 and 4. The plastic bearing was welded over the rear of the body by using ultrasonic welding method. Main factors allowing the formation of torque are; a bearing inner and outer dimension, a ball-stud dimensions, lubrication, a body inner hole dimension, operating temperature and waiting time for this type of mechanisms. An analysis was conducted on the basis of these factors and their effects on the working torque by making various trials: Only two factors were changed while others were constant.

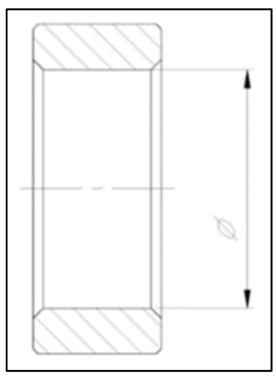

Figure 3. Body of link stabilizer.

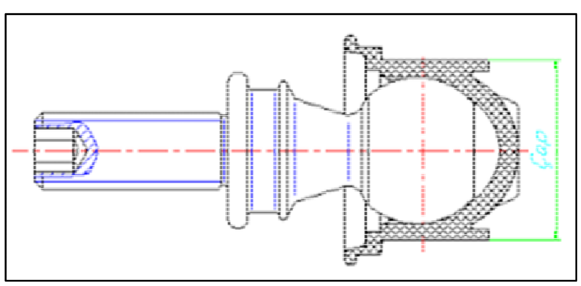

Figure 4. Ballpin and bearing.

2. Methods

Fuzzy inference system is more powerful than Multi-Layer Perceptrona. There are some unique features of ANFIS controllers as follows:

1-Learning ability,
2-Parallel processing,
3-Structured data representation,

4-Better integration with other Controller Design Methods,

Multilayer perceptron does not have 3. and 4. features. Tsukamoto and Sugeno methods (Fig. 5) are the most used methods [1]. We performed our research by using Sugeno method per the reason that multilayer perceptron system does not cover the structured data representation and advanced integration with other design methods.

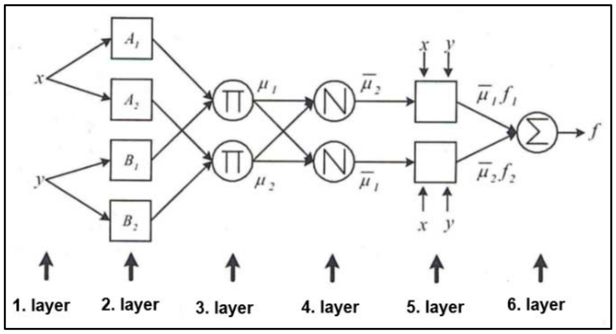

Figure 5. 2 Inputs and 2 rules sugeno [1].

The results obtained from sample test for tolerance study within the company is given in the Table 1. The (X+...) value which is stated in rotation torque shows the measurement time as day, after assembly. The data were uploaded to the system with the anfis editor (Fig. 6). Chosen Anfis Architecture is shown in Figure 7.

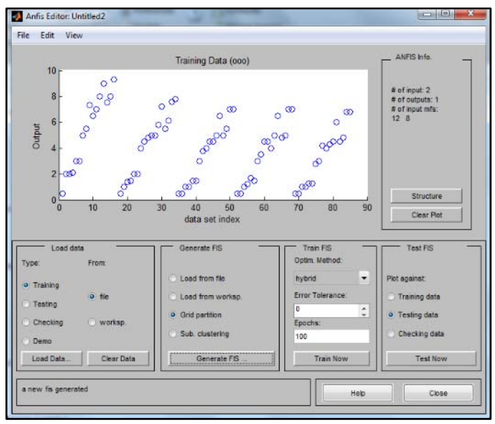

Figure 6. Status of transferred data to Anfis editor.

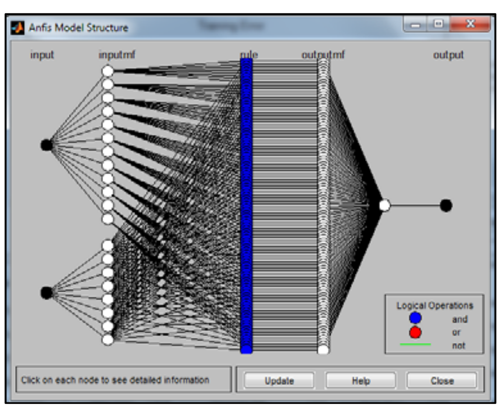

Figure 7. Used Anfis architecture.

Table 1. 2 Inputs and 2 Rules Sugeno

Sample No	Body Average Diameter (mm)	Bearing Average Diameter (mm)	Interference Fit Bearing to Body (mm)	Rotatition Torque 29.04.2015 (X+1) (Nm)	Rotatition Torque 02.05.2015 (X+3) (Nm)	Rotatition Torque 03.05.2015 (X+4) (Nm)	Rotatition Torque 06.05.2015 (X+7) (Nm)	Rotatition Torque 07.05.2015 (X+8) (Nm)
1	21,89	21,81	-0,0765	0,50	0,50	0,50	0,50	0,50
2	21,88	21,81	-0,0630	0,50	0,50	0,50	0,50	0,50
3	21,86	21,82	-0,0440	0,50	0,50	0,50	0,50	0,50
4	21,85	21,82	-0,0325	0,50	0,50	0,50	0,50	0,50
5	21,84	21,82	-0,0205	0,50	0,50	0,50	0,50	0,50
6	21,83	21,82	-0,0020	0,50	0,50	0,50	0,50	0,50
7	21,81	21,83	0,0125	2,00	1,00	0,50	0,50	0,50
8	21,81	21,83	0,0200	2,00	1,40	1,00	1,00	1,00
9	21,80	21,83	0,0350	2,10	1,50	1,00	1,20	1,00
10	21,78	21,84	0,0597	3,00	2,00	1,50	1,70	1,30
11	21,78	21,83	0,0500	3,00	2,00	1,50	1,50	1,30
12	21,75	21,84	0,0905	5,00	4,00	3,00	3,00	2,80
13	21,75	21,84	0,0915	5,50	4,50	3,80	3,50	3,00
14	21,75	21,84	0,0967	7,30	4,80	4,00	4,50	4,20
15	21,73	21,85	0,1155	6,50	5,00	4,50	4,50	4,00
16	21,72	21,85	0,1255	7,00	5,00	4,50	4,00	4,30
17	21,72	21,85	0,1365	8,00	5,80	5,00	5,00	4,50
18	21,70	21,85	0,1567	9,00	7,20	6,50	6,50	6,00
19	21,70	21,86	0,1618	7,50	5,50	5,00	4,80	4,50
20	21,70	21,85	0,1545	8,00	6,10	5,50	5,00	4,80
21	21,68	21,87	0,1913	9,30	7,60	7,00	7,00	6,80
22	21,67	21,88	0,2120	10,00	7,80	7,00	7,00	6,80

Within Membership function values of two inputs, 12 were chosen for “tightness” and 8 for “day”. “Trimf” is used as type (Fig. 8). “Hybrid” as Method, “0” as fault tolerance, “100” as number of iteration were chosen (Fig. 9). Error value was appeared as 0,059 After program was trained (Fig. 10 and 11). Some of inputs in the value table and the success rate of trails for untaught inputs were shown in the table 2. The maximum error rate is %3,54 and the average error rate is %0,70.

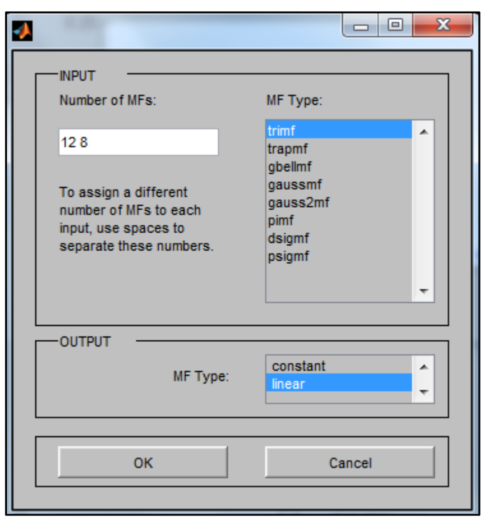

Figure 8. Membership functions selection.

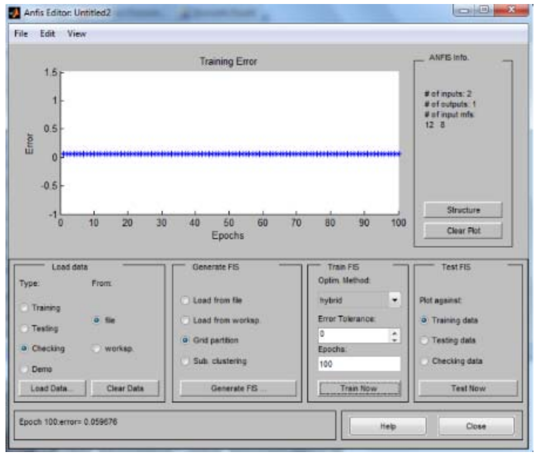

Figure 9. Optimization method selection.

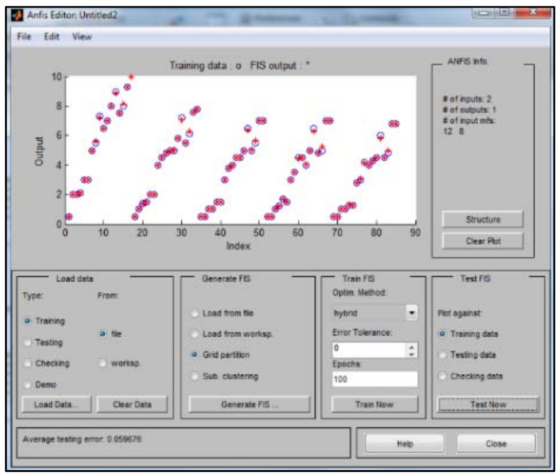

Figure 10. Comparison table of the calculated values with trained values.

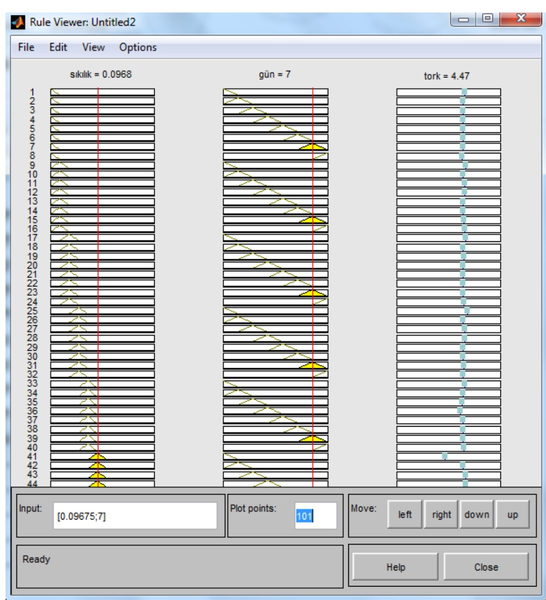

Figure 11. The calculated examples.

Table 2. The calculated values

Tightness (mm)	Day (X+)	Torque (Nm)	Calculated Torque (Nm)	Difference
0,0125	1	2	1,990	0,50%
0,02	1	2	2,010	-0,50%
0,05	1	3	3,00	0,00%
0,0915	1	5,5	5,57	-1,27%
0,09675	1	7,3	7,24	0,82%
0,1365	1	8	8,00	0,00%
0,1545	1	8	8,14	-1,75%
0,0125	3	1	1,000	0,00%
0,02	3	1,4	1,400	0,00%
0,09675	3	4,8	4,80	0,00%
0,1545	3	6,1	6,26	-2,62%
0,0125	4	0,5	0,506	-1,20%
0,02	4	1	0,995	0,50%
0,09675	4	4	4,00	0,00%
0,1545	4	5,5	5,64	-2,55%
0,0125	7	0,5	0,506	-1,20%
0,02	7	1	0,995	0,50%
0,09675	7	4,5	4,47	0,67%
0,1545	7	5	5,22	-4,40%
0,0125	8	0,5	0,509	-1,80%
0,02	8	1	0,992	0,80%
0,09675	8	4,2	4,16	0,95%
0,1545	8	4,8	4,97	-3,54%
0,09675	4	-	4,000	-
0,07	8	-	1,440	-
0,05	3	-	2,000	-
0,05	1	-	3,000	-
0,05	7	-	1,500	-
0,01	3	-	0,878	-
0,02	3	-	1,400	-
0,02	7	-	1	-
0,09	7	-	2,750	-
0,09	1	-	4,75	-
0,1	1	-	8,49	-
0,1	7	-	5,28	-

3. Findings

The first five samples were excluded from the analysis as per the outcomes that they did not affect the torque, as the first five samples among the samples were clearance fit during analysis of data and their error rate were %16 during iterations.

4. Conclusion and discussion

Guang Wang and Shen Yin analyzed the issues of fault diagnosis and monitoring for an automobile suspension system where only accelerator sensors in the four corners of the car body are available by using fuzzy logic. They found that the effectiveness of the fault diagnosis approach is finally demonstrated by the simulation results obtained from a full car suspension benchmark [2].

K.Dhananjay Rao researched the performance of a quarter car semi-active suspension system using PID controller under MATLAB Simulink Model. He found that the performance of body displacement and wheel displacement can be improved by using the proposed PID controller [3].

One of the purposes of performing this research is to find out a method to calculate tightness value to obtain design input of the bearing and the body. It is found out that, current manufacturing tolerances defined as production capabilities are unnecessarily tight. In case of increasing the tolerance limits, it is calculated that, the working torque would be between desired tolerances.

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