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INVESTIGATION OF THE DESIGN PARAMETERS AFFECTING THE SAFETY FACTOR IN FITTINGS BY USING TAGUCHI METHOD

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ABSTRACT

Introduction
In Turkey, it has been observed that unqualified Chinese fittings are used in water and natural gas connections. Domestic production industry of cast iron did not remain competitive. It is thought that due to the production of aluminum pipe fasteners and corrosion resistance, production easiness and low cost, it can be preferred.
Material and methods
For the design of aluminum tee pipe fittings, the authors have proposed a new design. This design incorporates angled inner surface and bracelet design with some standard measurements. In this study, the parameters forming the new type design are determined. Design parameters and their levels are specified. Pressure endurance analysis was performed by using the finite element method. The Taguchi method was used to reduce the number of experiments and to investigate of optimum conditions of the effects of the parameters on the pressure balance.

Results
The results of compressive strength analysis were listed by using the ANSYS program. Variations in weight, elastic deflection amount, vertical and horizontal axis maximum stress amounts were analyzed by Taguchi method andvariance analysis. The percent effect ratios of the design parameters were investigated.
Conclusions
With this work, it is desired to optimize in design and production. Minimum weight and maximum safety coefficient are desired. Although the weight is not much, the parameter values that increase the strength were determined.

Key words: FEM Analysis, Design Parameters, Optimization, Taguchi Method, Fittings.

INTRODUCTION

In water network systems, plastic fittings used with ease of production, low cost and lightness but it shows the carcinogenic effect as a result of researches and can't show the necessary strength at high pressures poses a threat to water health and safety. 80% percent of manufacturers of plastic fittings in our country use scrap-added blends as their raw material.
This mixture affects the quality of the product on the negative side and creates an insecure situation in both health and safety aspects. Alternatively used cast iron materials are required secondary processes such as thermal and galvanizing. For this reason, production difficulty and high cost are the issues.
Low quality and low cost pipe fittings that provided from China are preferred for economic reasons. This choice results in an unhealthy structure in the water network systems. On the other hand, in the case of extraordinary disasters, these poor quality products can't show sufficient strength, causing cracks on the network and even breakage. In this case, the water network system becomes unavailable at the most necessary time.
Aluminum fittings which will solve the problems mentioned do not pose a threat to the health and safety of water, so they can be used without any coating and similar secondary processes and production easiness will be ensured.
Aluminum materials that do not carry an element that negatively affects human health and have high safety in terms of corrosion resistance. Fittings that made of aluminum material provide the required strength properties and leave behind the competitors in extraordinary disasters.In this study, optimization of the design parameters of the aluminum fittings with the necessary qualifications will be made by the Taguchi method and the finite element method.
Reduction and breakage of the tap can be eliminated by tempering.By reducing the hardness of the material, the danger such as earthquake and water pressure can be prevented [1]. The cast iron fittings are galvanized to reduce the corrosion effect. These processes add extra energy and cost. Also, the material tensile strength is decreases proportionally. There is harmful sand waste in sand with iron casting.A variety of chemical materials are needed for the core.
Development of products with high corrosion resistance compared to casting and plastic fittings is important for human health. Obtaining a product with high fatigue strength under high pressures, winter conditions and seismic events will reduce the risks of flood and safety of natural gas installations. Especially in India and America, the use and sale of aluminum fittings have been determined to be widespread [2-5].
The finite element method and special test setups have been used in studies for fittings [6]. The pipe bending process in elbow fittings was investigated using the Ls-Dyna program [8]. The pressure analysis of the pipes of different wall thicknesses was investigated in a special test setup [9].

Force accumulation zones and graph of Te material are calculated by classical theorems [10]. Maximum stress calculations of pipe connection Te element with wall thickness 2.5, 5.5 and 8.5 mm have been made.

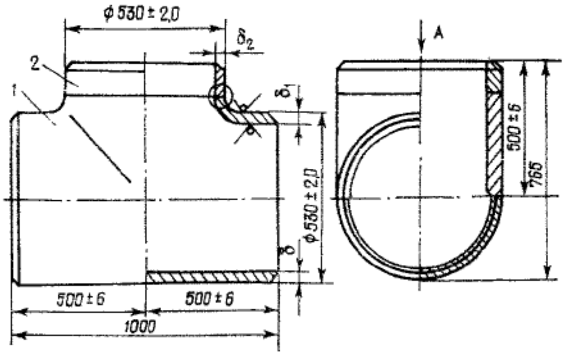

Figure 1.Te material with different wall thickness measure [11]

Fittings are design according to TS 11 EN 10242 Standards (Figure 2.A.). It is suggested to give an angle to the metal core for make it easy to get out the inner core in aluminum die casting and injection molding (Figure 2.B).

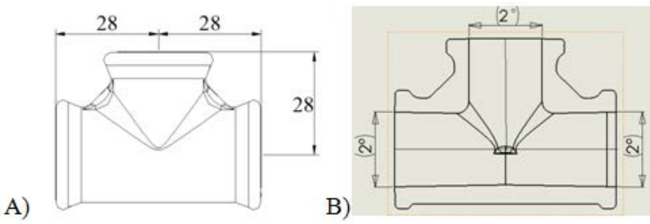

Figure 2.A) TS 11 1/2›› Te dimensions, B) Aluminum Te designs with 2 ° angled inner core design.

The authors previously identified a new type of industrial design in the optimization study of design geometry.A bracelet design has been proposed instead of imported products and cast iron products.Optimization of the geometry is provided as a result of the analyses made by the finite element method.

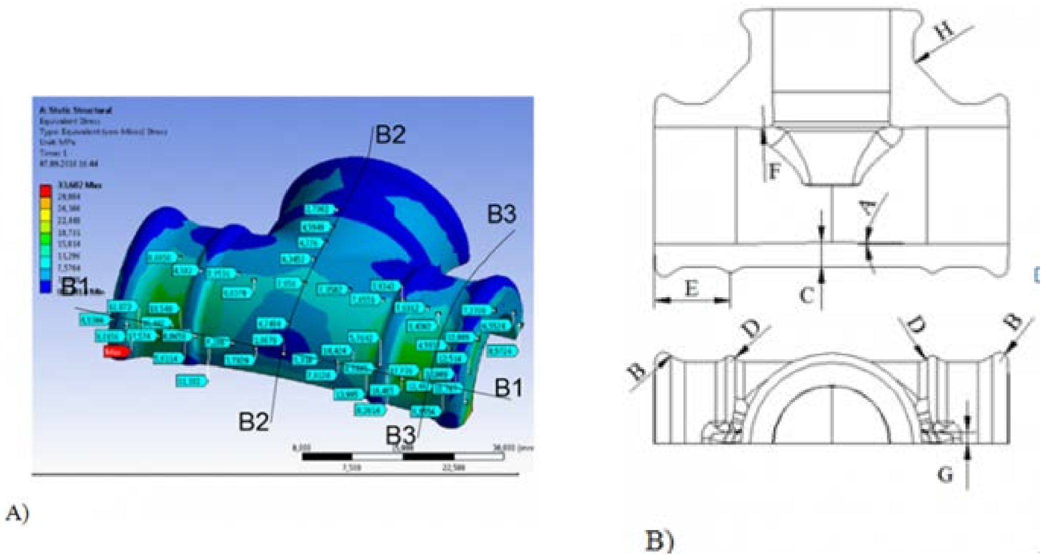

Figure 3. A) Showing of stress concentration regions with lines, B) Design Parameters

TS 11 EN 10242 standard measures only the distance of the axis to the midpoint.The remaining measurement is made with reference to the pipe thread measurements.When looking at Figure 3.B, there are at least 8 design parameters in a fittings design.The change in each parameter causes the change in weight, deformation amount and maximum amount of stress.When the literature is examined, it is seen that there is no research about the effectsof the changes in the design parameters on the strength properties and the weight. Obtaining maximum pressure resistance properties in minimum weight will prevent the use of unnecessary materials.Using the Taguchi method, the test will be applied for determining the optimum levels and the number of analyzes will be reduced.

MATERIALS AND METHODS

Variables have been determined by considering imported products and designs previously made by authors (Table 1).A total of $L_{32}(2^1x4^7)$ Taguchi factorial fractional experiment design and analysis studies was planned for the classical experimental study to calculate the effects of these design variables on weight, stiffness and maximum stress.

The Taguchi parameter options in Table 3 are used for variable selection.In the ANSYS program, 6061-T6 material was selected to perform the analysis with the finite element method.The mechanical properties of 6061-T6 materials are defined in the literature.The pressure resistance analysis was performed by applying a pressure of 10 bar.

Equations used in Taguchi method are used to obtain the graphs of the effects of the parameters on the experimental outputs. According to the result of these equations, the graphsare created by the program [13-14]. How much effect the parameter has on the outputs is calculated by % formula given in literature [15].

The parameters and levels used in the studies are given in table 1 and the mechanical properties of the material used are given in table 2.

Table 1.Parameters and their levels

	(A) Angle of inner core	(B) Piping radius dimensions	(C) Wall thickness	(D) Bracelet Radius	(E) Bracelet Axis Length	(F) Intermediate radius	(G) Flag Thickness	(H) Amount of flag radius
1.	1	3	4	2	12	3,5	2	2
2.	2	3,5	4,5	2,5	13	4	2,25	2,25
3.	-	4	5	3	14	4,5	2,5	2,5
4.	-	4,5	5,5	3,5	15	5	2,75	2,75

Table 2. Mechanical properties of 6061 - T6

Type of Material	Density (Kg/m3)	Modulus of Elasticity (MPa)	YieldStrength (MPa)	Tensile Strength (MPa)	Poisson's Ratio
Al 6061-T6	2700	69000	275	310	0,33

RESULTS

The weights of 32 different designs were calculated for 6061-T6 material.The maximum amount of deformation was determined by the finite element method for 10 bar pressure.The maximum amount of stress that occurs in the horizontal axis of the double bracelet shape and the maximum amount of stress that occursvertical axis in the horizontal axis of 90 degrees are measured.Table 3 shows the results of each experimental plan.The intensity of the effect was shown on the result values of the parameters (Figure 4-7).Variance analyses were established. Percentage effect values to analysis results are calculate (Table 4-7).

Table 3.Experiment plan and its ANSYS results

No	Design Variables								Weight (Gr)	Maximum Horizontal Axial Stress (MPa)	Maximum Vertical Axial Stress (MPa)	Maximum Deformation Amount (mm)
	A	B	C	D	E	F	G	H				
01	1	1	1	1	1	1	1	1	53	19,3	15,9	0,0173
02	1	1	2	2	2	2	2	2	60	15,7	12	0,0138
03	1	1	3	3	3	3	3	3	68	13,9	9,9	0,0111
04	1	1	4	4	4	4	4	4	76	12,7	7,6	0,0095
05	1	2	1	1	2	2	3	3	54	19	14,4	0,017
06	1	2	2	2	1	1	4	4	62	15,6	12,6	0,0135
07	1	2	3	3	4	4	1	1	70	13,9	8,6	0,011
08	1	2	4	4	3	3	2	2	56	18,8	12,2	0,0127
09	1	3	1	2	3	4	1	2	70	13,2	10,2	0,011
10	1	3	2	1	4	3	2	1	62	15,7	11,1	0,0135
11	1	3	3	4	1	2	3	4	65	15,9	11,6	0,0127
12	1	3	4	3	2	1	4	3	71	13,5	9,7	0,0108
13	1	4	1	2	4	3	3	4	57	18,1	12,1	0,016
14	1	4	2	1	3	4	4	3	64	15,7	12	0,0133
15	1	4	3	4	2	1	1	2	74	13,5	9,5	0,0104
16	1	4	4	3	1	2	2	1	81	12	8,6	0,009
17	2	1	1	4	1	4	2	3	53	20,6	14,4	0,0174
18	2	1	2	3	2	3	1	4	58	18,2	12,7	0,0145
19	2	1	3	2	3	2	4	1	65	14,9	10,4	0,0119
20	2	1	4	1	4	1	3	2	72	13,2	8,4	0,0102
21	2	2	1	4	2	3	4	1	54	20	13,8	0,0169
22	2	2	2	3	1	4	3	2	59	17	13,1	0,0143
23	2	2	3	2	4	1	2	3	66	14,8	9,5	0,0118
24	2	2	4	1	3	2	1	4	73	13,4	8,9	0,01
25	2	3	1	3	3	1	2	4	53	19,3	12,9	0,0168
26	2	3	2	4	4	2	1	3	61	17,2	10,2	0,0134
27	2	3	3	1	1	3	4	2	67	14,1	12,1	0,0116
28	2	3	4	2	2	4	3	1	75	12,3	9	0,0097
29	2	4	1	3	4	2	4	2	54	19,9	12,7	0,0165
30	2	4	2	4	3	1	3	1	63	16	10	0,013
31	2	4	3	1	2	4	2	4	64	13,9	10,9	0,0115
32	2	4	4	2	1	3	1	3	76	12,4	10,5	0,0095

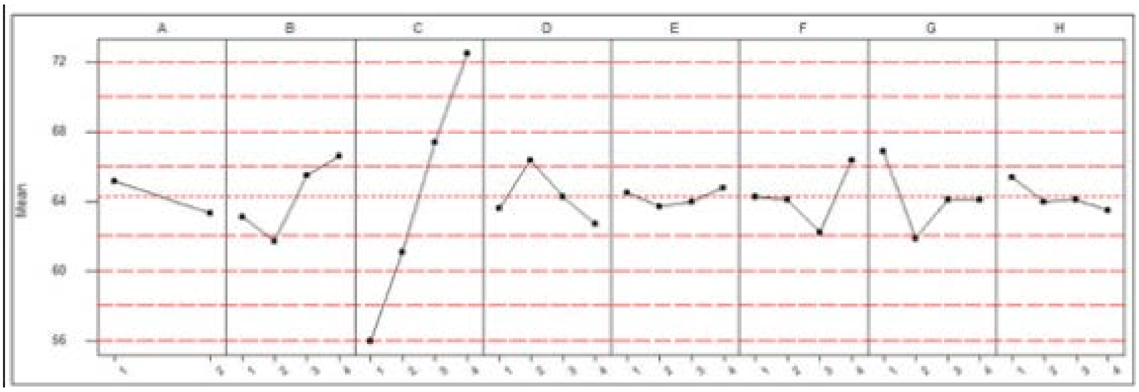

Figure 4. Effects of parameters on weight change

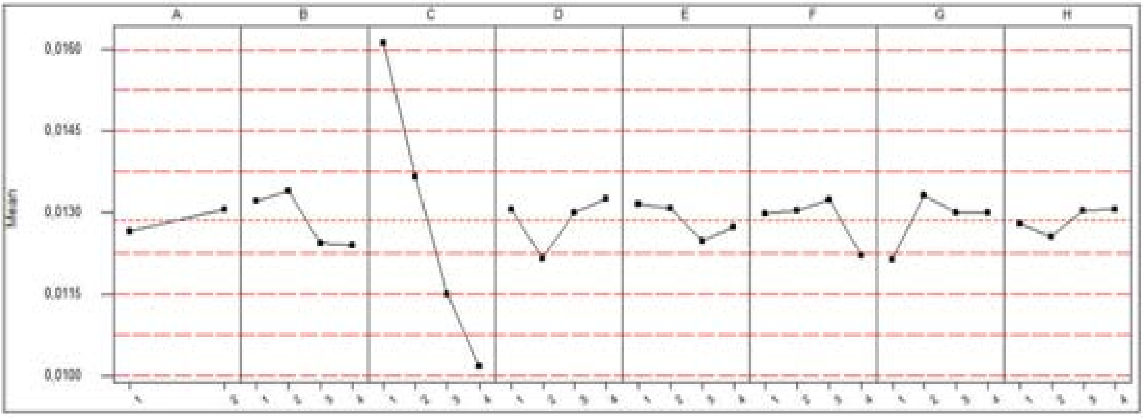

Figure 5. Effects of parameters on the amount of deformation

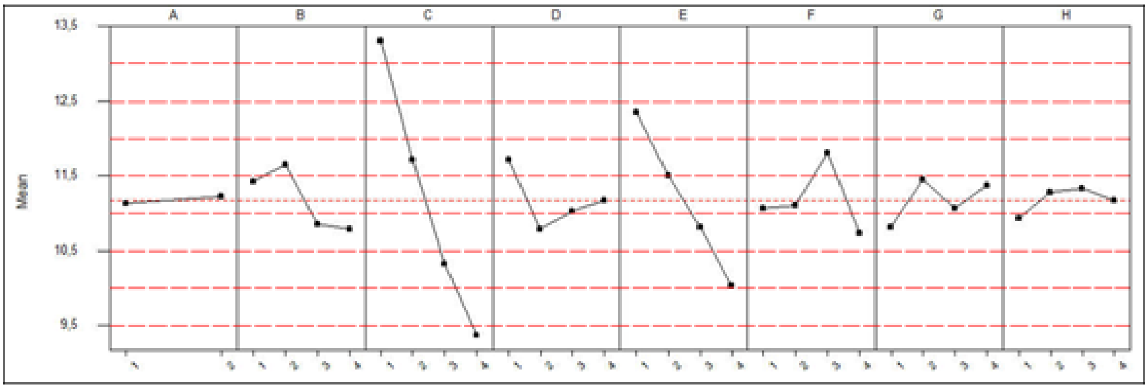

Figure 6. Effects of parameters on vertical axis maximum stress variation

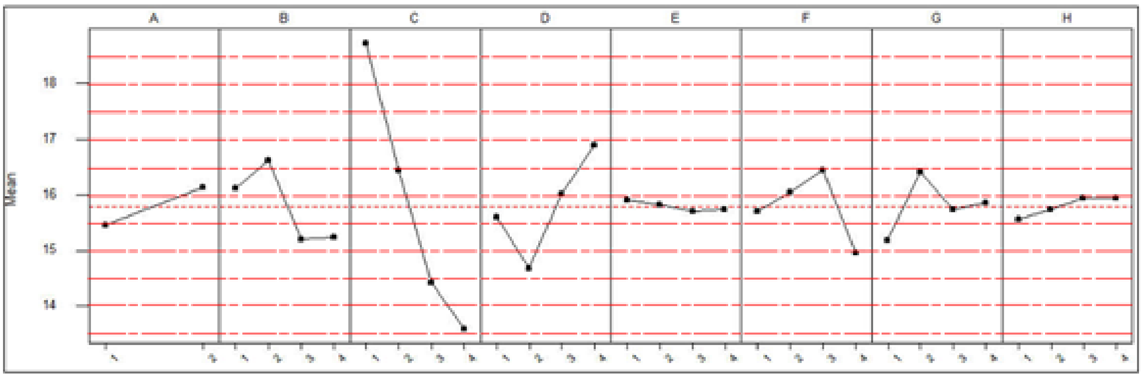

Figure 7. Effects of the variables on the variation of the maximum stress in the horizontal axis

Table 4.Analysis of variance for theWeight and % effect ratio of parameters

Parameter	DF	Seq SS	Adj SS	Adj MS	F	P	% Effect Ratio
A	1	56,25	56,25	56,25	3,53	0,067	4,97
B	3	235,50	235,50	78,50	4,93	0,005	6,95
C	3	2490,50	2490,50	830,17	52,10	0,000	73,46
D	3	114,50	114,50	38,17	2,4	0,082	3,38
E	3	10	10	3,33	0,21	0,889	0,39
F	3	136,50	136,50	45,50	2,86	0,049	4,03
G	3	201,00	201,00	67	4,21	0,011	5,93
H	3	30,50	30,50	10,17	0,64	0,595	0,90
Error	41	653,25	653,25	15,93			
Total	63	3928,00					

Table 5.Analysis of variance for Deformation and % effect ratio of parameters

Parameter	DF	Seq SS	Adj SS	Adj MS	F	P	% Effect Ratio
A	1	0,0000026	0,0000026	0,0000026	2,98	0,092	1,96
B	3	0,0000129	0,0000129	0,0000043	5,00	0,005	3,30
C	3	0,0003245	0,0003245	0,0001082	125,72	0,000	82,97
D	3	0,0000114	0,0000114	0,0000038	4,41	0,009	2,91
E	3	0,0000048	0,0000048	0,0000016	1,87	0,151	1,23
F	3	0,0000096	0,0000096	0,0000032	3,70	0,019	2,44
G	3	0,0000123	0,0000123	0,0000041	4,75	0,006	3,13
H	3	0,0000027	0,0000027	0,000009	1,03	0,389	0,67
Error	41	0,0000353	0,0000353	0,0000009			
Total	63	0,0004159					

Table 6. Analysis of variance for Vertical axis maximum stress and % effect ratio of parameters

Parameter	DF	Seq SS	Adj SS	Adj MS	F	P	% Effect Ratio
A	1	0,1406	0,1406	0,1406	0,19	0,667	0,19
B	3	8,4169	2,8056	2,8056	3,76	0,018	3,83
C	3	141,3369	47,1123	47,1123	63,70	0,000	64,97
D	3	7,3869	2,4623	2,4623	3,30	0,030	3,36
E	3	47,0419	15,6806	15,6806	20,99	0,000	21,40
F	3	9,7819	3,2606	3,2606	4,36	0,009	4,47
G	3	4,0769	1,3590	1,3590	1,82	0,159	1,85
H	3	1,5219	0,5073	0,5073	0,68	0,570	0,69
Error	41	30,6272	0,7470	0,7470			
Total	63						

Table 7. Variance analysis for Horizontal axis maximum stress and % effect ratio of parameters

Parameter	DF	Seq SS	Adj SS	Adj MS	F	P	% Effect Ratio
A	1	7,156	7,156	7,156	4,75	0,035	5,74
B	3	22,942	22,942	7,647	5,08	0,004	6,14
C	3	252,512	252,512	84,171	55,86	0,000	67,59
D	3	40,612	40,612	13,537	8,98	0,000	10,86
E	3	0,422	0,422	0,141	0,09	0,963	0,10
F	3	19,137	19,137	6,379	4,23	0,011	5.11
G	3	11,887	11,887	3,962	2,63	0,063	3.18
H	3	1,592	1,592	0,531	0,35	0,788	0,37
Error	41	61,776	61,776	1,507			
Total	63	418,034					

CONCLUSIONS

In this experimental study, optimization of the design parameters for the use of aluminum fittings, which are more successful in strength, corrosion and health, have been achieved in place of conventional plastic and cast iron fittings. When we bring water and health to the foregrounding, the choice of aluminum material fittings is inevitable. It is aimed to get the best product result in aluminum material fittings by foreseeing this choice. In line with this objective, optimization has been made with the methods mentioned above also each parameter that makes up the design have been considering

Figure 8 shows the% effect graph for the results of each variable parameter that makes up the design. C; as the wall thickness increases, the weight and strength properties increase in the same order.

E; Although the effect of weight change on the axis distance of the bracelet was 0.39%; The effect on the vertical axis maximum stress amount is 21,40%. The results of the authors' previous work and these calculations show similar results.

A; The effect of the internal angle value on the horizontal maximum stress value was observed. The effect of the D parameter on the maximum stress results in the horizontal axis was determined to be 10.86%. It has been determined how much the amount of bracelet radius is for strength. In selecting the final design parameters, the weight of the design / pressure resistance ratio is important.According to the evaluations, it has been decided to take optimum values of parameters A1, B3, D2, E3, F2, G1, H1. By choosing these variables, maximum strength can be exhibit at minimum weight.

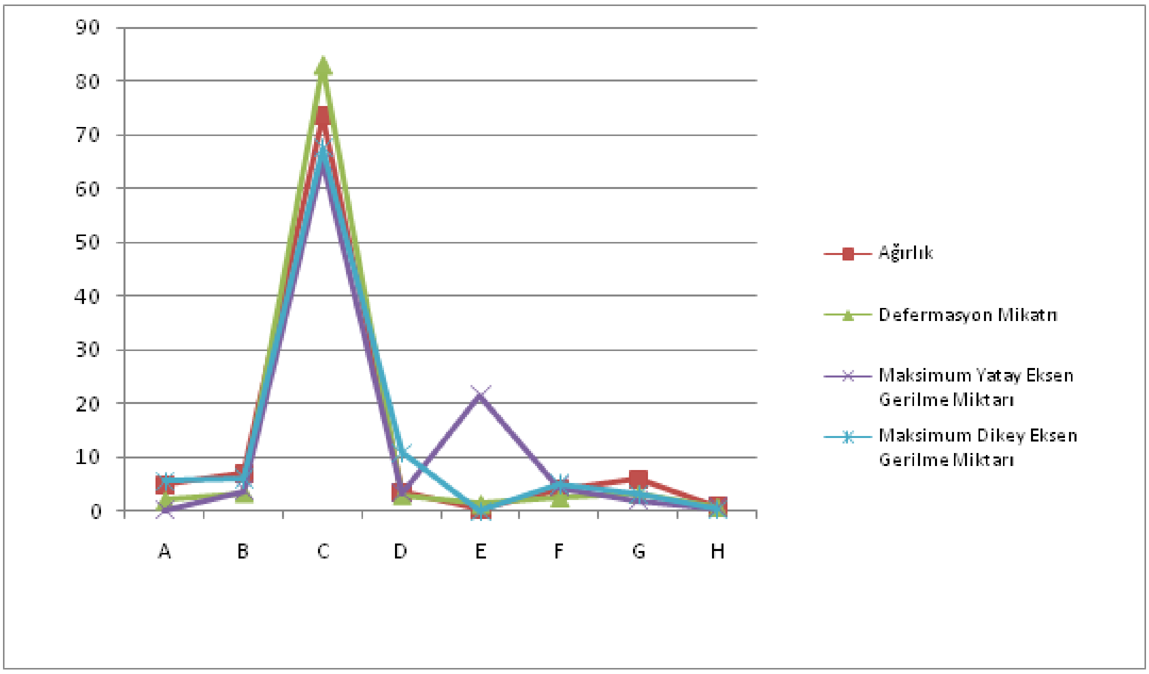

Figure 8. Examination of comparative effect ratios of parameters

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