

# Simulation Study of Flange Characteristic at Various Operating Condition

Amirul Iezlan Ismail<sup>1</sup>, Norrizal Mustaffa<sup>1\*</sup>

<sup>1</sup> Department of Mechanical Technology, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

\*Corresponding Author: [norrizal@uthm.edu.my](mailto:norrizal@uthm.edu.my)

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## Abstract

Flanges are integral components in piping systems, their advantages in terms of easy maintenance and installation, however, come with challenges, particularly in their ability to withstand pressure and ensure durability. This study focuses on investigating the durability of DIN 2633 PN16 Weld Neck Raised Flanges (WNRF) under various operating conditions. The problem statement of this study was to determine the breaking points in connectors especially under higher pressure. Besides that, it is also difficult to determine suitable dimensions for operational needs. Lastly, the problem statement was flange failure risks may lead to accidents and productivity loss. Objectives of this study are to compare flange durability under specific operating conditions and to evaluate the ability of DIN 2633 PN16 flanges to withstand pressures beyond the nominal pressure of 16 bar. This study employs SolidWorks Software for comprehensive simulation testing to evaluate the performance and durability of DIN 2633 PN16 Weld Neck Raised Flanges (WNRF). The research focuses on the coupling of weld neck raised flanges, examining three different types with 4-point, 8-point, and 12-point bolts under varying pressures of 16, 18, and 20 bar. Steam serves as the working fluid, and the study emphasizes the influence of flange diameter (DN) on the results. The materials used for the flanges were cast carbon steel, and the applied torque for bolt tightening was determined according to the specified table. This study methodology was utilizing SolidWorks Software to investigate the structural performance of DIN 2633 PN16 Weld Neck Raised Flanges (WNRF). The first step involves the design of 3D flanges within the SolidWorks environment. Then, a static simulation was conducted to evaluate various aspects, including stress distribution, displacement analysis, strain evaluation, and factor of safety assessment. Based on the results obtained, this study acknowledges in respects for safety uses beyond 16 bar of pressure for flanges dimension DN200 while for DN65 and DN80 seems to shows results as expected which was safe to use beyond 16 bar of pressure.

## 1. Introduction

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Flanges are one of the components in a full piping system and flanges are commonly utilized in industrial installations to connect a pipeline to another pipeline or any equipment [1]. Flanges usage in a piping system does offer a feature that makes maintenance of a pipeline easier because it can be dismantled and installed easily [2]. Although flange does give a lot of advantages, there will also disadvantages that will be needed to face. It is very important to study the capability of flanges durability in order to have a safe, reliable and longer time span of running bolted flange joints. It may show as a small problem, but late recovery or ignorance may contribute to big problems with a variety of hazardous including pollution, environmental disaster and may lead to serious threat to human life. There are many factors that may affect the clamping durability of a flanges that lead to leakage problems such as uneven bolt tightening. Uneven bolt tightening will result in uneven pressure distribution that can shorten the lifetime of the flanges. Besides that, selection of flanges also must be accurately suitable for operating conditions. Failing to perfectly select the type flanges also will lead to corrosion and leakage. The flange material will become susceptible to corrosion due to the effluent's liquid state and the environment's pressure and temperature. Due to its sensitivity to leakage, this study was conducted to look at how far does the bolt used to clamp flange does affect the durability of the flange. From what has been observed from flange schedule of DIN standard which to be precise DIN 2633 PN16 Weld Neck Raised Flange (WNRF), the pressure nominal is 16 bar which means can be operated up to 16 bars [3]. At the same time, there were various number of bolts used. So, this study was mainly conducted to gather information on the location of where the highest stress exerted on the flanges, displacement of the flanges and the factor of safety of the flanges under certain operating conditions. Conducting this simulation study also would let us know the accuracy of the standard used which has offer maximum of 16 bar of pressure.

## 1.1 Objective

The objectives of this study are as follows:

- To compare the flange durability according to the characteristics of flanges under certain operating conditions.
- To evaluate the ability of DIN 2633 PN16 flanges to withstand pressures beyond the nominal pressure of 16 bar.

## 1.2 Problem Statement

Flanges are known as an important component in any pipeline because of their importance functionality in order to complete the piping construction. Flanges were used as a joint in piping construction to connect two pipes section to one another or to connect pipe sections to any equipment such as pumps and valves [4]. There were many designs of flanges joints with different compatibility which is suitable for low pressure and high pressure according to operating conditions. When it came to joints, of course it will have a breaking point especially when higher pressure of steam or fluid were applied to the pipeline system. Besides that, it is also hard to determine the suitable dimensions that really suit the needs of operation. This research was conducted to examine the capability of flange clamping in order to sustain a specified amount of pressure. On the other hand, failure of a flange may lead to risk of accident and productivity loss. It is important to evaluate flanges clamping effectiveness as flanges are joint and will experience high impact of pressure when fluid passes through the pipeline system. Besides, this study was also conducted to carry out the result of pressure exerted along the flanges to determine where does the weakest point on a flange. For this research, simulation is the safest method and least expensive compared to the experiment method.

## 1.3 Scope

The scopes of this study are as follows:

- Simulation testing will be done by using SolidWorks Software
- Steam as working fluid
- Flanges will be tested with 16, 18 and 20 bar of pressure
- There were three types of flanges that will be tested which are 4-point, 8-point and 12-points of bolts (DIN 2633 PN16 WNRF).
- The simulation will only be focused on coupling of weld neck raised flanges (WNRF).
- Flanges Diameter Nominal (DN) used were DN65, DN80, and DN200 according to DIN 2633 PN16 WNRF standard.
- Material used for the flanges was cast carbon steel.
- Torque applied for bolt tightening as shown in specified table.

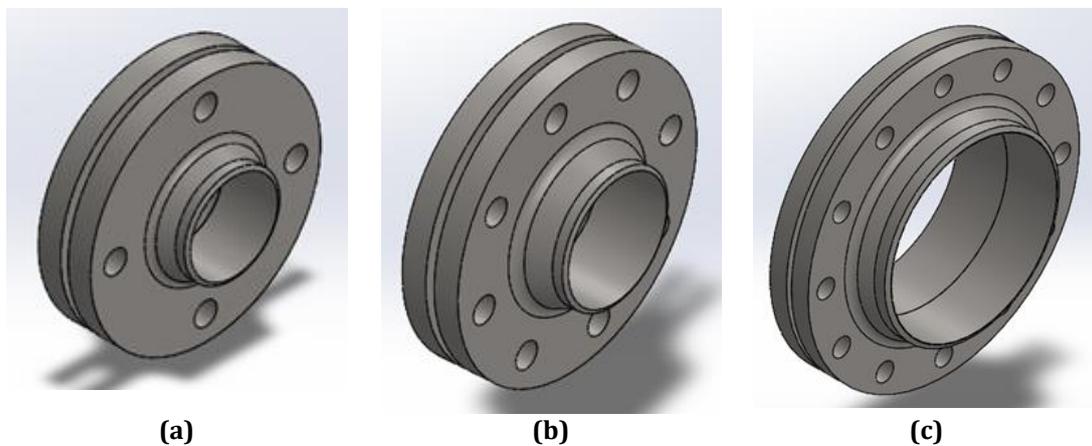
## 1.4 Significance of Study

This study's significance lies in its use of simulation software to determine the performance of a weld neck raised flange with a nominal pressure of 16 bar while operating in a variety of pressure conditions ranging from 16 bar to 20 bar. Additionally, the study aims to comprehend what happens to the flanges as the process was carried out because flanges surface is exposed to pressure when they are connected to pipelines. This study was also conducted to determine whether the number of bolts used to clamp the flanges does have any significant difference on the durability or not. By doing this simulation study, comparison of the performance of the flanges can be made by analyzing the result which where does the pressure exerted the most. The results of this simulation study may help to clarify flange features and performance under various operating circumstances. The findings also were expected to help engineers and designers choose the right flange sizes and materials for particular applications, improve system performance, and make sure that operations are dependable and secure. Besides, the result from this study can be used to develop flange designs and improve their performance in demanding industrial conditions through additional study and experimentation.

## 2. Materials and Method

### 2.1 Materials

In this study, it is crucial to determine the type of flanges and materials used before running the study to achieve reliable and accurate results [5]. The flange type that has been chosen for this study was DIN 2633 PN16 Weld Neck Raised Flanges and materials that has been chosen for the flanges was cast carbon steel. The design of the simulation consists of three different dimensions of flanges which were DN65, DN80 and DN200. Once all the measurements and data needed for the chosen flange type and piping dimension have been obtained, 3D models started to be drawn and assembled as shown in Fig. 1. Fig. 2 shows the material properties of cast carbon steel.



**Fig. 1** Flange Assembly (a) DN65; (b) DN80; (c) DN200

Property	Value	Units
Elastic Modulus	2e+11	N/m <sup>2</sup>
Poisson's Ratio	0.32	N/A
Shear Modulus	7.6e+10	N/m <sup>2</sup>
Mass Density	7800	kg/m <sup>3</sup>
Tensile Strength	482549000	N/m <sup>2</sup>
Compressive Strength		N/m <sup>2</sup>
Yield Strength	248168000	N/m <sup>2</sup>
Thermal Expansion Coefficient	1.2e-05	/K
Thermal Conductivity	30	W/(m·K)
Specific Heat	500	J/(kg·K)
Material Damping Ratio		N/A

**Fig. 2** Material Properties

### 2.2 Method

Fig. 3 shows the flowchart for the whole of the simulation methodology including all of the boundary conditions. It is crucial to determine workflow before carrying out simulation to make sure that simulation was running accordingly.

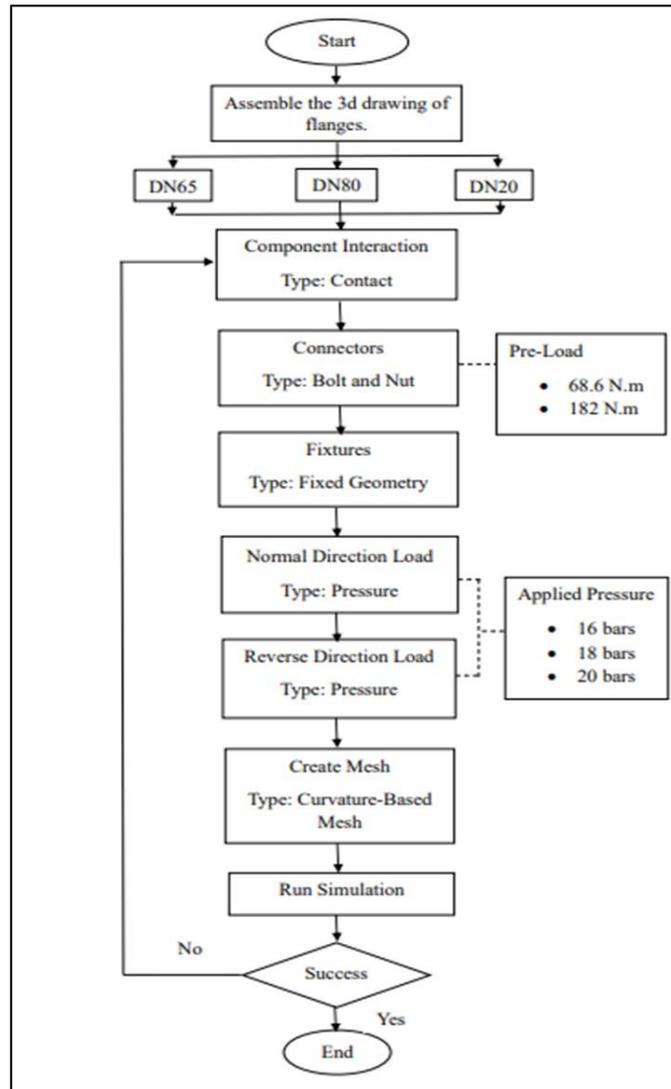


Fig. 3 Simulation Flowchart

### 2.2.1 Component Interaction

There were several types of component interaction that can be chosen according to the needs to complete the simulation. First is Bonded Component Interaction type. Bonded Component Interaction types were not suitable for this simulation study because bonded refers to component that are treated as if they are glued. Next, is Contact Component Interaction type and lastly, the Free Component Interaction type where this type assumes components can overlap without interaction [6]. Based on the three-interaction type, the most suitable and has been used for this study was contact interaction type with negligible coefficient of friction as shown in Fig. 4. Properly defining and understanding component interaction was critical for obtaining realistic simulation results.

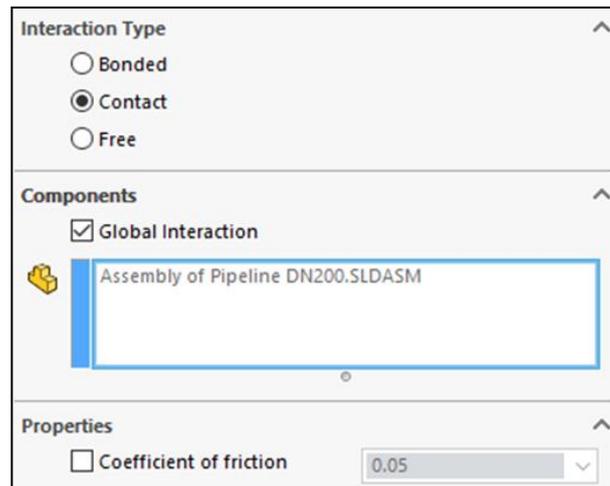


Fig. 4 Component Interaction

## 2.2.2 Connectors

SolidWorks Simulation provides various connector types, including "Bolt," "Pin," and "Rigid." For simulating flange connections, the Bolt and Nut connector type is commonly used and has been used for this study. Then, in this study, the bolt and nut parameter that has been specified which are the head diameter, nominal shank diameter of the bolt used, and bolt preload (tightening torque) were according to the Class 50: M22, M16, M14 whereas shown in Fig 6. Bolt Preload unit were shown in SI units which is Newton Meter (N.m). Connectors in SolidWorks Simulation allow to efficiently model and analyze bolted connections, providing insights into the structural behavior of flange assemblies under various loading conditions. Fig. 5(a) shows the type of connectors and where does the point of connectors apply. Meanwhile, Fig. 5(b) shows the connectors pre-load.

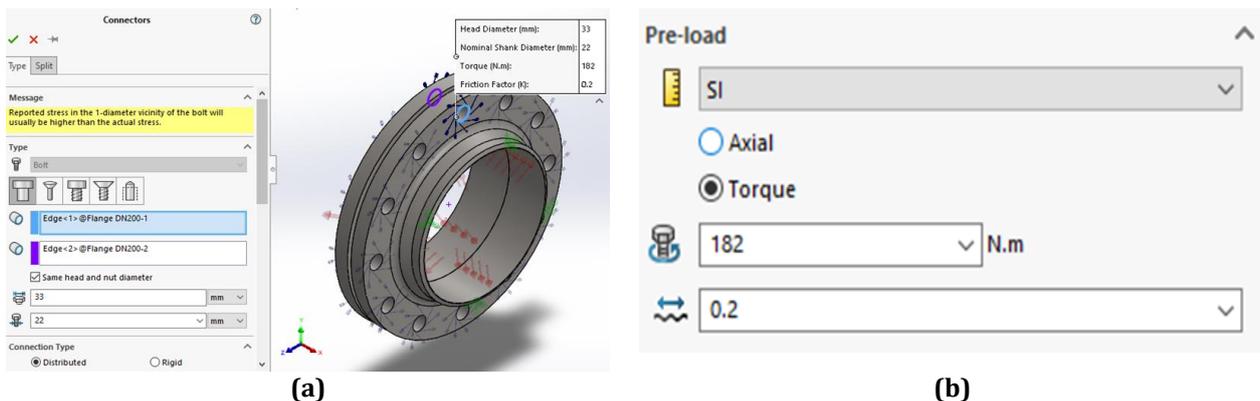


Fig. 5 Connectors Properties (a) Connectors Parameters (b) Bolt Pre-load

Hex Bolts Recommended Tightening Torque					
Nominal Size	Pitch (mm)	Stress Area (mm <sup>2</sup> )	Class		
			50	70	80
M3	0.50	5.03	0.4	0.9	1.2
M4	0.70	8.78	1.0	2.1	2.7
M5	0.8	14.20	1.9	4.2	5.5
M6	1.00	20.10	3.3	7.1	9.4
M8	1.25	36.60	8.0	17.1	22.8
M10	1.50	58.00	15.8	33.9	45.2
M12	1.75	84.30	27.6	59.2	78.9
M14	2.00	115.00	44.0	94.2	125.6
M16	2.00	157.00	68.6	147.0	195.9
M18	2.50	192.00	94.3	202.2	269.6
M20	2.50	245.00	133.8	286.7	382.2
M22	2.50	303.00	182.0	390.0	519.9
M24	3.00	353.00	231.3	495.6	660.8
M27	3.00	459.00	338.3	725.0	966.7
M30	3.50	561.00	459.5	984.6	1312.7
M33	3.50	694.00	625.2	1339.8	1786.4
M36	4.00	817.00	802.9	1720.6	2294.1
M39	4.00	976.00	1039.1	2226.7	2969.0

k Factor = 0.2      The induced load is calculated at 65% yield stress

Fig. 6 Hex Bolts Recommended Tightening Torque (Jigneshsteel, 2020)[7]

### 2.2.3 Fixture

For a static simulation study involving flanges, proper fixture application is essential to accurately model the behavior of the flange assembly under specific loading conditions. Fixtures, also known as boundary conditions, are used to simulate the way a structure is supported or constrained in the real world. In this study, there was one type of fixture applied alongside every flange which was a fixed geometry fixture type. The faces that have been chosen as the fixed geometry were at one chamfer side of the flanges which has shown in Fig 7.

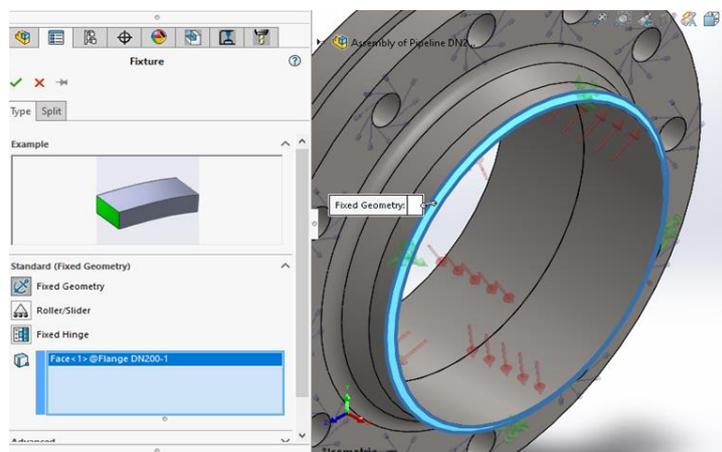
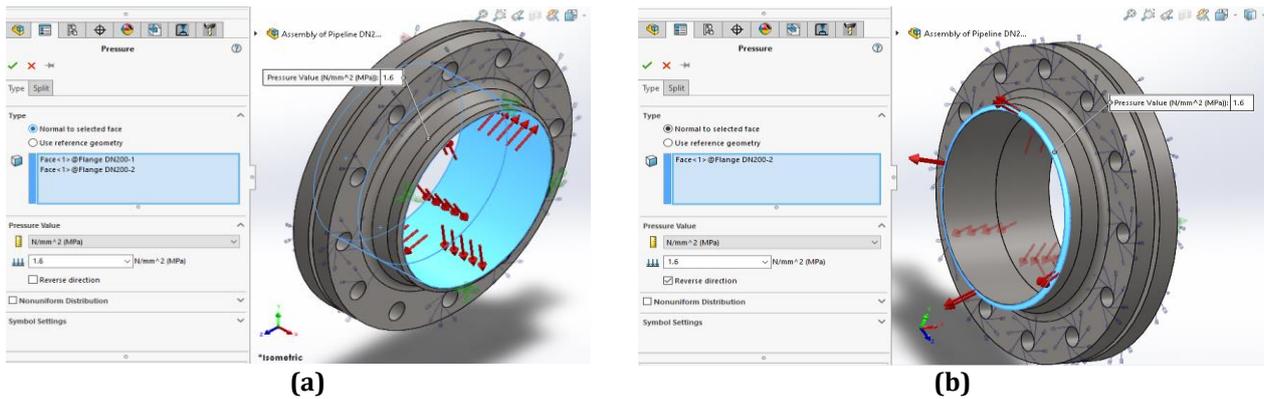


Fig. 7 Fixture Properties

### 2.2.4 Load Application

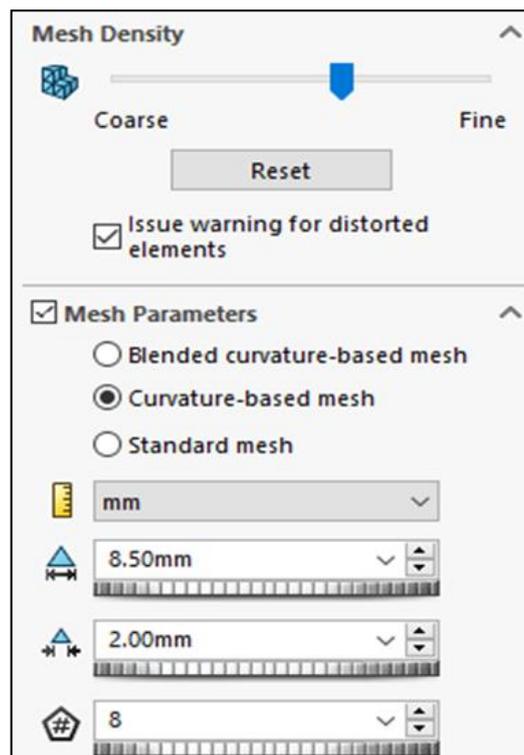
The most suitable type of load application that been used for this study was pressure load. The amount of pressure applied for each dimension of the flanges were 1.6 N/mm<sup>2</sup>, 1.8 N/mm<sup>2</sup> and 2 N/mm<sup>2</sup> which same as in the scope of study 16 bar, 18 bar and 20 bar. Next, in this study, each of the flange assemblies were subject to multiple direction of loads that been applied separately. In Fig. 8(a), the first direction of the load was in normal direction that located at the inner faces of the flanges. Next, in Fig. 8(b), load applied direction was in reverse direction because of resultant forces theory where it was located at the other side chamfer opposite to another chamfer (Fixed Geometry).



**Fig. 8** (a) Pressure Applied Inside Face of Flanges Coupling; (b) Reverse Direction Pressure at Flange's Chamfer

## 2.2.5 Mesh Structure

Meshing is a critical step in preparing a model for analysis. The mesh structure defines how the geometry is discretized into small elements, allowing the software to perform numerical calculations to simulate the behavior of the structure under various loads and constraints. In Fig. 10(a), before creating the mesh, all of the boundaries have been double checked to ensure that the end simulation result will come out reliable and accurate. However, there were many factors that affect the simulation results such as the mesh setting itself. In SolidWorks simulations, there were options for users to choose the type of mesh controls which are standard mesh and curvature-based mesh. Fig 9 shows the type of mesh chosen in this study. In this study, curvature-based mesh type has been applied to the flanges. This is because curvature-based mesh was better for curved shapes rather than standard mesh [8] since the designated flanges shapes were in curved shape. Besides that, curvature-based mesh also creates more mesh elements than the standard mesh. So, it will provide better and fine mesh quality. Fig. 10(b) shows the flanges that have been meshed. After flanges have been set up until mesh, then simulation been run.



**Fig. 9** Mesh Setting

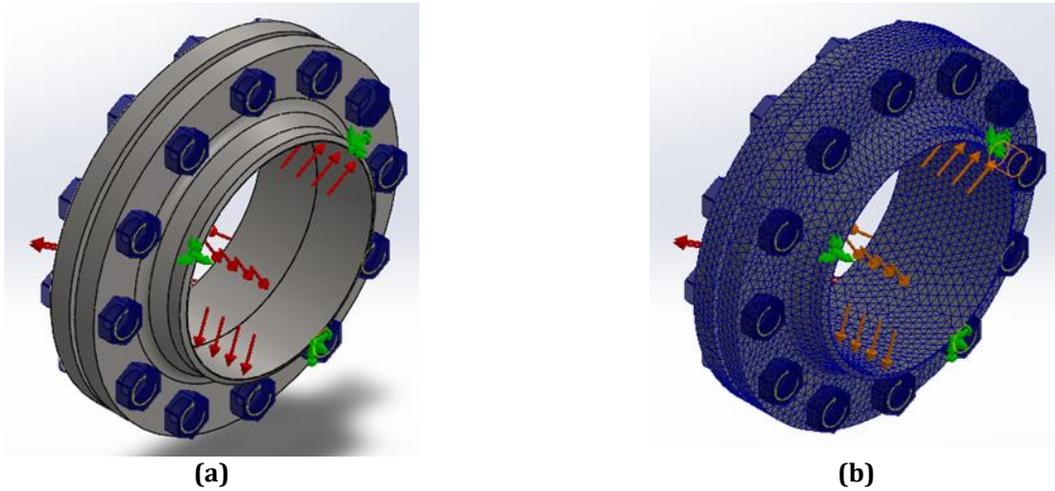


Fig. 10 (a) Full Boundary Conditions of Flange Coupling; (b) Meshed Flanges

### 3. Results and Discussion

#### 3.1 Stress Analysis

Fig. 11 shows the stress analysis of the colour contour of flanges after going through the operating pressure, which was 16, 18 and 20 bar of pressure. All three dimensions of flanges (DN65, DN80 and DN200) were tested with this operating pressure. Based on the result obtained, the red colour contour shows the maximum value where the largest stress exerted while blue colour contour shows the minimum value exerted. All the flanges tested show the same colour contour where the highest pressure exerted was located at the contact between the flanges. Besides that, from the observation the location of red colour were located alongside the bolt and nut. For the lowest pressure it was located at the rest of the flanges except middle contact.

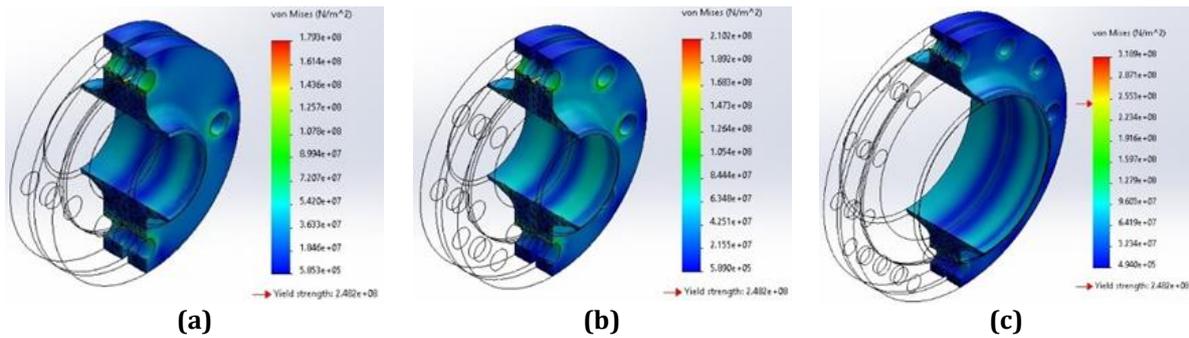
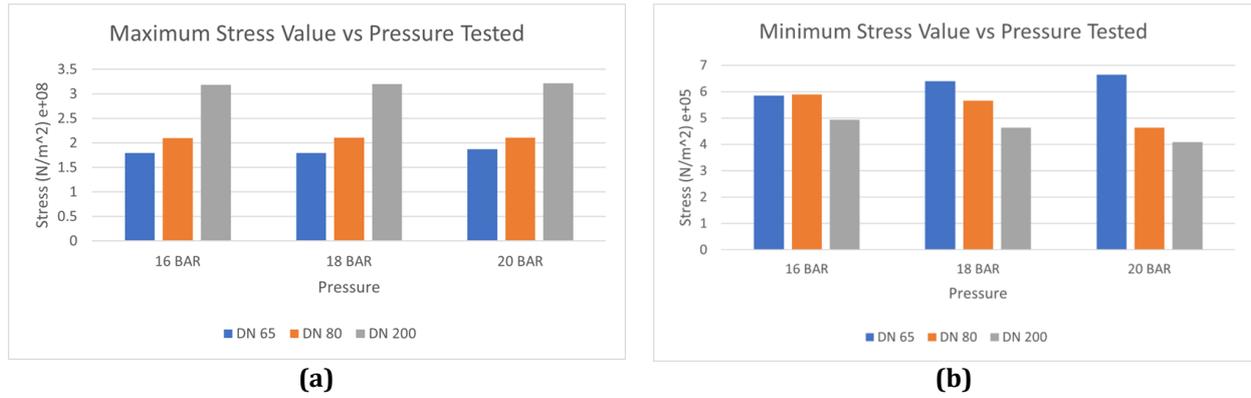


Fig. 11 Stress Analysis (a) DN65; (b) DN80; (c) DN200

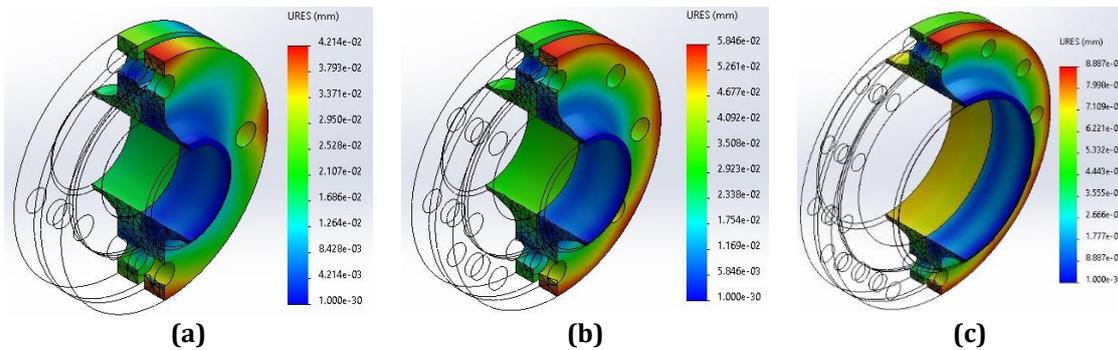
Fig. 12(a) shows the graph of Maximum Stress Value vs Pressure Tested. From this graph it shows an uptrend in term of stress value over designated flanges. Each of the flanges has their own different dimension characteristics where the major difference is the surface area and the number of connectors. This study conducted highlighting the number of connectors which were 4, 8 and 12 connectors (Bolt and Nut). As the number of connectors increased, the stress value exerted also increased. However, the size of the surface area is also applicable and plays an important role in the effect of exerted pressure value where the larger the surface area, the higher the value of pressure exerted. Besides that, based on the observation, the number of maximum stress value at flanges with DN200 dimension has over the yield strength of the material which was  $2.48 \times 10^8 \text{ N/m}^2$  while the maximum stress value exerted on DN200 flanges for 16bar, 18bar and 20bar selected pressure were  $3.189 \times 10^8 \text{ N/m}^2$ ,  $3.201 \times 10^8 \text{ N/m}^2$  and  $3.218 \times 10^8 \text{ N/m}^2$  respectively. Based on Fig. 12(b) which was minimum stress value against pressure tested, it can be observed that the minimum stress value trend decreased which also reversed from the maximum stress value.



**Fig. 12** Stress Analysis (a) Max Stress vs Pressure Tested; (b) Min Stress vs Pressure Tested

### 3.2 Displacement Analysis

Fig. 13 shows the result of displacement testing obtained after conducted the static simulation. Two of the flanges show the same minimum and maximum colour contour which were DN80 and DN200 flanges dimension. Meanwhile for DN65 flanges dimension shows different colour contour for displacement. From the observation, DN80 and DN200 flanges colour contour shows the maximum displacement which was in red colour at the outer diameter side of fixed flange while the other side stated green. Assumption made from the result; it was because of the fixtures (fixed geometry) makes it receive end pressure which also where higher pressure will exert. This will make the displacement on that side become higher than the others. Meanwhile, for DN65 flange also shows the maximum displacement colour contour (red) at the fixed side of the flange but only focused at the on top of the connectors.



**Fig. 13** Displacement Analysis (a) DN65; (b) DN80; (c) DN200

Fig. 14(a) shows the maximum value of displacement against the pressure tested. Based on the observation from the graph, it shows an increasing trend among the dimensions. This means, the higher dimensions it gets, the higher displacement it experienced. However, the highest displacement value which was  $8.861 \times 10^{-2}$  mm can be considered safe to use due to their small amount of displacement. Besides that, this simulation study has the limitation where DIN 2633 does not explicitly define acceptable displacement limits for flanges that we can comply with to determine the tolerance for the displacement. Moving to Fig. 14(b) where shows the graph for Minimum Displacement against Pressure Tested. Observation has been made and it resulted in a very low value for every minimum displacement which was  $1.000 \times 10^{-30}$  mm. From the minimum displacement value, it can be considered as no displacement on the blue colour contour.

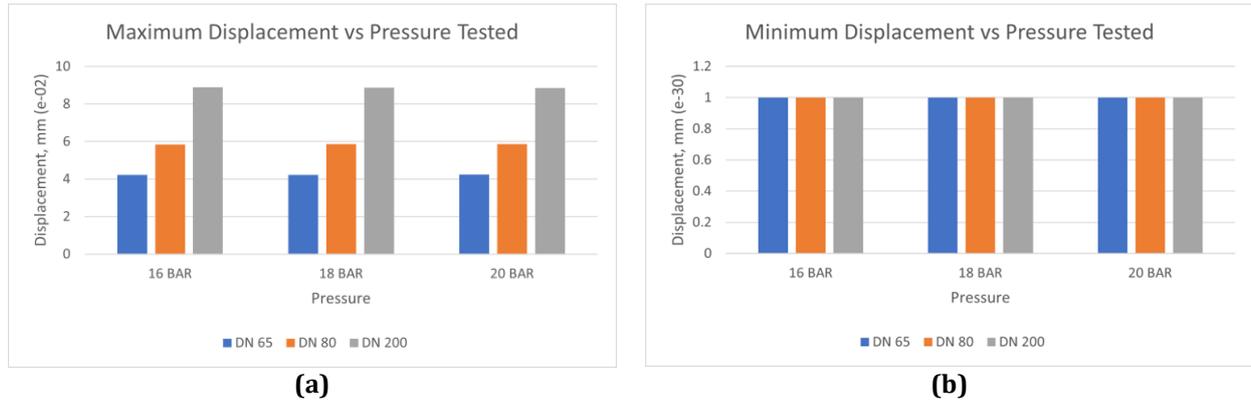


Fig. 14 Displacement Analysis (a) Max Displacement vs Pressure Tested; (b) Min Displacement vs Pressure Tested

### 3.3 Strain Analysis

Fig. 15 shows the results of colour contour of strain analysis for various dimensions of flanges (DN65, DN80 and DN200). Overall, the minimum and maximum colour contour for strain analysis was same in terms of the colour and location where the maximum value of strain was located at the contact between flanges coupling and at the same time it laid alongside the connectors same as stress analysis colour contour. But there was a slight difference which was the size of the colour contour especially for the maximum colour contour, red. From what has been observed, DN65 flanges resulted has larger size of maximum strain colour contour (red) rather than DN80 and DN200. So, as the dimension of flanges increases, there will be smaller area of strain resulted in. These results obtained can be related to the number of connectors as well. This is because, when the larger dimensions and increasing number of connectors take place, it can contribute to load distribution more even across the flanges that will make the strain area become smaller.

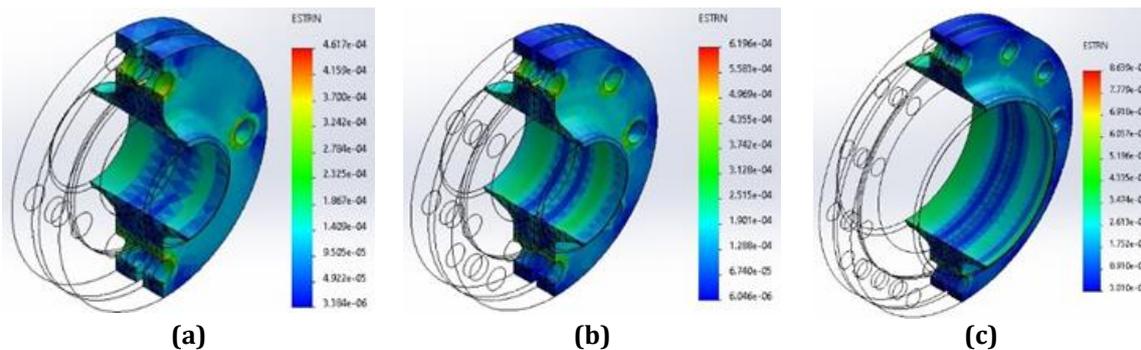
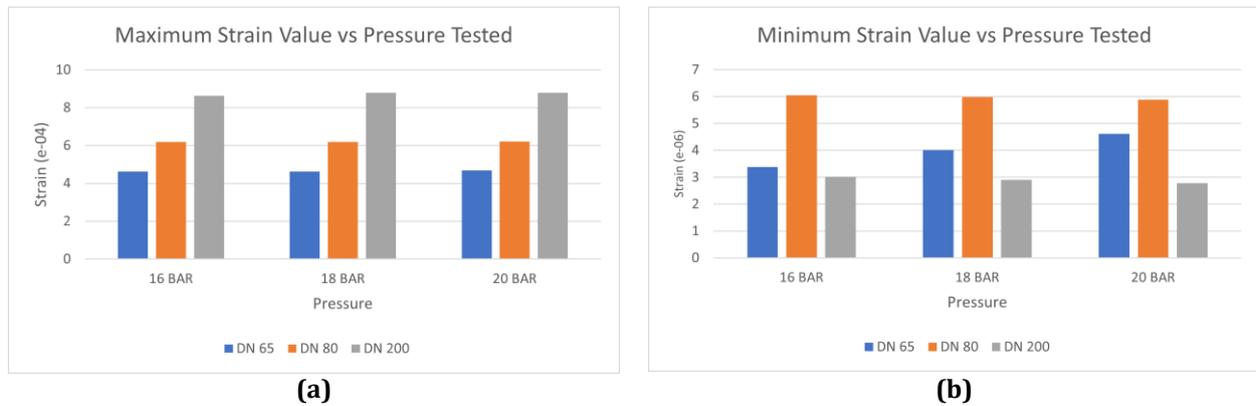


Fig. 15 Strain Analysis (a) DN65; (b) DN80; (c) DN200

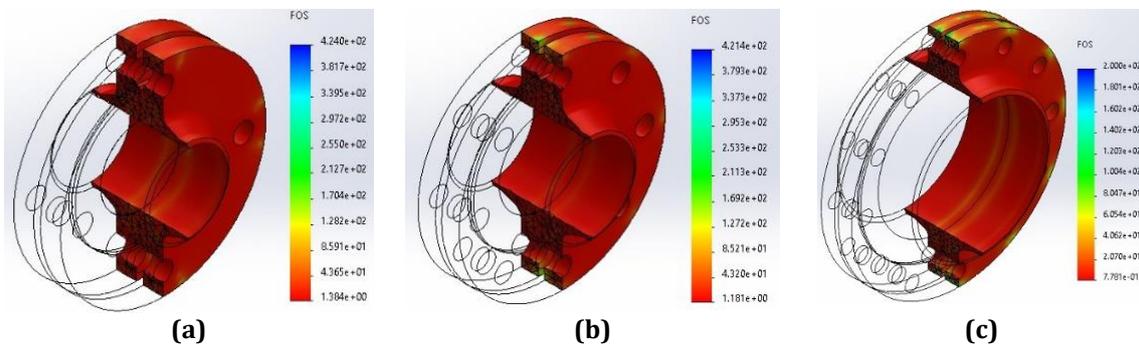
Fig. 16 shows the graph for the strain result obtained. Fig. 16(a) shows the Maximum Strain value against the pressure tested. From this graph, the maximum value between the three flanges dimension shows increased gradually trend for all of the pressure tested. So, to summarize, the larger dimensions and increasing number of connectors of the flanges, the higher maximum strains value it recorded. This is because, with larger dimensions and additional connectors may increase the overall flexibility of the flanges structure and higher flexible structure tends to experience higher strains under the same applied loads. Fig. 16(b) shows the Minimum Strain Value against Pressure Tested graph. Based on the graph, the value of minimum strain value shows non-linear trend where it increased on DN65 but slightly decreased on DN80. For DN200 it stated as the lowest value where decreased lower than minimum value of strain recorded at DN65 flange. The results obtained were not as expected where if the pressure increases, then the strain values also will increase. The results obtained for DN200 were not as expected can be potentially because of the larger stress area has been distributed over larger dimension. The concept of pressure that can be related with stress area over the study is, the smaller the area, the larger the pressure [9]. So, it can be summarized as the area of stress distributed increased, then the strain value over the flanges decreased.



**Fig. 16** Strain Analysis (a) Max Strain vs Pressure Tested; (b) Min Strain vs Pressure Tested

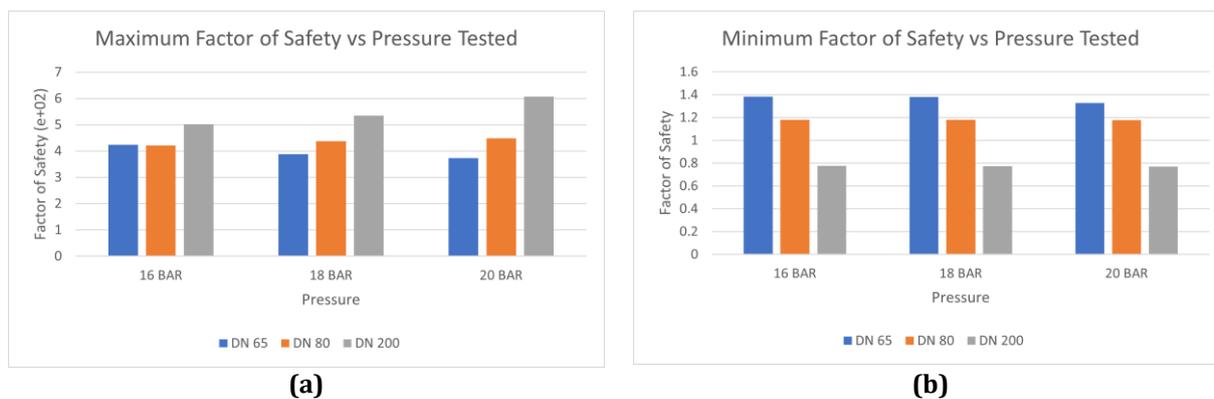
### 3.4 Factor of Safety Analysis (FoS)

Fig. 17 shows the result of Factor of Safety obtained after conducted the static simulation. Overall, the colour contour of the flanges is generally the same where the minimum value of factor of safety in red colour experienced on the major view compared to the green colour. Next, the other colour contour that can be spotted on the flanges was green where the green colour shows as the maximum factor of safety recorded and it were the minor view on the flanges. Green colour contours can be spotted alongside the outer diameter of the flanges and it aligns with the connectors.



**Fig. 17** Factor of Safety Analysis (a) DN65; (b) DN80; (c) DN200

Fig 18(b) shows the Minimum Factor of Safety against Pressure Tested where it shows linear decreased trends for the 3 flanges dimension tested against the pressure tested. In SolidWorks simulation, minimum value for the factor of safety considered safe to be operated as long as it greater than 1 and it could be hazardous to be operated when the minimum values go below 1. Based on the result obtained, flanges with dimensions of DN65 and DN80 were safe to be operated to 20bar where the minimum value were 1.327 and 1.177 respectively. Meanwhile, for DN200 flanges considered unsafe to use starting on 16bar onwards because the value was below 1 (0.7781). Fig 18(a) shows the Maximum Factor of Safety against Pressure Tested where it shows decreased value for DN65 and increased value for DN80 and DN200. The maximum value for factor of safety can be considered the safest part of the flanges.



**Fig. 17** Strain Analysis (a) Max Strain vs Pressure Tested; (b) Min Strain vs Pressure Tested

#### 4. Conclusion

In conclusion, the objective of this study conducted firstly was to compare flange durability according to flanges characteristics. To be precise, this study wanted to compare the DIN 2633 PN16 Weld Neck Raised Flanges durability to withstand the exceeding pressure but with different number of connectors and different dimension area which were DN65 with 4 connectors, DN80 with 8 connectors and DN200 with 12 connectors. Result obtained by the end of this study turns out to show that Weld Neck Raised Flanges with dimension of DN65 and DN80 can be operated beyond 16 bar which is up to 20 bar since the Factor of Safety value were more than one. Meanwhile, after simulation run for DN200 flanges it shows that flanges with dimension DN200 will be facing potential failure if operate with pressure beyond 16 bar because of the factor of safety results obtained were below than one. The first objective of this study has been achieved where it shows that as the dimension of flanges increased, the durability of the flanges decreased. Next, the second objective of this study were to evaluate the ability of DIN 2633 PN16 flanges to withstand pressures beyond the nominal pressure of 16 bar. The study has provided a comprehensive understanding of their performance limits and safety margins. By subjecting these flanges to pressures exceeding their designated limit, the investigation revealed critical insights into their structural integrity, strain responses, and potential failure modes. From the results obtained, it shows that Weld Neck Raised Flanges with dimension of DN65 and DN80 can withstand pressure beyond 16 bar while for dimension of DN200 cannot withstand pressure beyond 16 bar. However, during completing this study, there were limitations that have been failed to overcome which was firstly to determine the realistic material properties used for DIN 2633 flanges. This is because DIN standard does not explicitly define the material properties that usually been used. Besides that, the second limitation was DIN 2633 does not explicitly define acceptable displacement limits for flanges that we can comply with to determine the tolerance for the displacement. In order to achieve accuracy, reliable and applicable results of static simulation or Finite Element Analysis (FEA), every parameter and boundary condition must be taken into account [10], and it must be complied with the specification, codes and standards. Inaccuracy of boundary conditions and parameters may lead to inaccurate results.

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#### Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

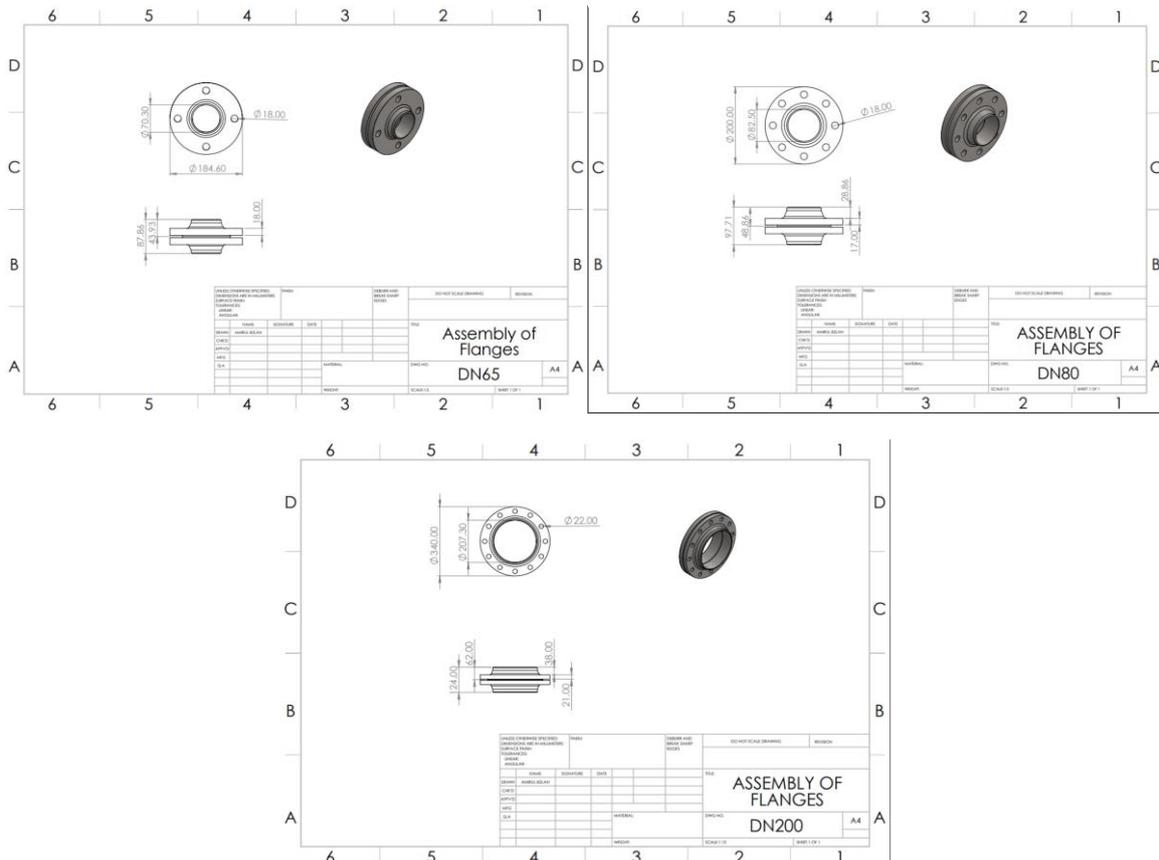
#### Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Amirul Iezlan Ismail; **data collection:** Amirul Iezlan Ismail; **analysis and interpretation of results:** Amirul Iezlan Ismail; **draft manuscript preparation:** Amirul Iezlan Ismail. All authors reviewed the results and approved the final version of the manuscript.

## Appendix A: DIN 2633 PN16 WNRF Chart

DIN 2633 PN 16 WNRF																		
Size		Pipe		Flange					Neck				Raised Face		Drilling		Weight	
mm	inch	d1	D	A	T	T-F	K	h1	h2	d3	s	r	F	G	Bolt No.	H	Kg / Pc	
DN 15	½"	21.3	95	17.3	14	12	65	35	6	32	2.0	4	2	45	4	14	0.66	
DN 20	¾"	26.9	105	22.3	16	14	75	38	6	40	2.3	4	2	58	4	14	0.96	
DN 25	1"	33.7	115	28.5	16	14	85	38	6	45	2.6	4	2	68	4	14	1.15	
DN 32	1¼"	42.4	140	37.2	16	14	100	40	6	56	2.6	6	2	78	4	18	1.67	
DN 40	1½"	48.3	150	43.1	16	13	110	42	7	64	2.6	6	3	88	4	18	1.85	
DN 50	2"	60.3	165	54.5	18	15	125	45	8	75	2.9	6	3	102	4	18	2.51	
DN 65	2½"	76.1	185	70.3	18	15	145	45	10	90	2.9	6	3	122	4	18	3.06	
DN 80	3"	88.9	200	82.5	20	17	160	50	10	105	3.2	8	3	138	8	18	3.86	
DN 100	4"	114.3	220	107.1	20	17	180	52	12	131	3.6	8	3	158	8	18	4.45	
DN 125	5"	139.7	250	131.7	22	19	210	55	12	156	4.0	8	3	188	8	18	6.12	
DN 150	6"	168.3	285	159.3	22	19	240	55	12	184	4.5	10	3	212	8	22	7.47	
DN 200	8"	219.1	340	207.3	24	21	295	62	16	235	5.9	10	3	268	12	22	10.95	
DN 250	10"	273.0	405	260.4	26	23	355	70	16	292	6.3	12	3	320	12	26	16.02	
DN 300	12"	323.9	460	309.7	28	24	410	78	16	344	7.1	12	4	378	12	26	21.44	
DN 350	14"	355.6	520	339.6	30	26	470	82	16	390	8.0	12	4	438	16	26	31.67	
DN 400	16"	406.4	580	390.4	32	28	525	85	16	445	8.0	12	4	490	16	30	39.66	
DN 450	18"	457.0	640	441.0	34	30	585	85	16	490	8.0	12	4	550	20	30	47.41	
DN 500	20"	508.0	715	492.0	34	30	650	90	16	548	8.0	12	4	610	20	33	60.18	
DN 600	24"	610.0	840	592.0	36	31	770	95	18	652	8.8	12	5	725	20	36	83.30	

## Appendix B: Detail Drawing



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