Design, Manufacturing and Testing of Pipe Fittings

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Abstract - Fasteners have a very significant place in machine design, and they are the indispensable elements of many sectors such as automotive, electrical electronics, metal industry. Pipe fittings are one of the basic types of fasteners, and the most significant feature of pipe fittings is that they provide impermeability. In the first part of the study, pipe fittings were designed and manufactured. In the second part of the study, experiments were conducted to analyze the effect of the surface roughness, fluid pressure and material type on the pipe fitting's sealing performance with the help of the measured torques that prevent leakage. In the following sections, this torque is referred to as sealing torque. Experimental results are consistent with mathematically calculated results and SolidWorks Simulation results. Additionally, it is thought that the result of the performed experiments in this study can help the pipe fitting manufacturers in terms of material and surface roughness selection.

Keywords: Fastener; pipe fitting; surface roughness; sealing

1. Introduction

Fasteners are used in most machines, electronic devices and furniture. Since these products consist of more than one piece, they usually need to be connected with fasteners. Pipe fittings are one of the basic types of fasteners, and the most significant feature of pipe fittings is that it provides impermeability. Impermeability is achieved by preventing leakage from the pipe fitting. Fernando and Karabelas [1] state that the effect of sealing is found by observing the amount of liquid leaking.

Fluid leakage between statically contacting surfaces depends on various parameters that can directly affect the sealing performance. These parameters are; fluid pressure, fluid viscosity, contact pressure (CP) and surface mechanical behaviour, texture and topography [2]. In the paper written by Li et al. [3], the effect of design parameters, such as the conical angle and the conical ring's displacement, on the contact pressure was examined. Moreover, a procedure was developed by Fernando and Karabelas [1] to examine the sealing performance, and they found contact pressure distributions using this procedure.

In this study, our aim is to design and manufacture pipe fittings and determine the sealing performance of the fitting in different conditions with the help of experiments and simulations. The sealing performance was investigated in terms of fluid pressure, material type and surface roughness with the help of conducted experiments. The effect of these parameters on sealing was interpreted via measuring the bolt tightening torque which is called sealing torque for this study.

2. Design and Production

The designed connection element, which can be seen in Fig. 2.1, consists of three basic parts. These parts are the body, nut and ring. Body and ring parts were produced by using CNC machining, and the nut part was purchased.
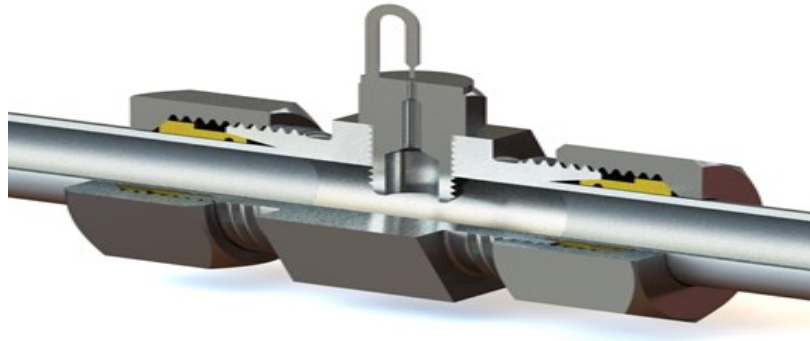
Fig. 2.1: Designed pipe fitting

In this study, our design is based on the pipe fitting standard ISO 8434-1 [4]. Basic factors such as the taper angle of the ring part, which was determined as 24^0 using ISO 8434-1 [4] were preserved. Screw and nut connection was preferred M18 x 1.5 fine thread in accordance with ISO 68-1 bolt standards [7]. An additional screw hole was drilled in the body part, suitable for the connection of standard nozzle types. Moreover, similar designs were examined during the design process [5], [6].

The main problem encountered in the designed screw fastener is the leakage problem. As long as there is a gap between the two environments, a material passage can not be prevented, and impermeability can not be achieved. Sealing is important not only for the liquid inside the pipe to leak out but also to prevent dust and dirt from mixing with the liquid inside the pipe from the environment. Dust could impair the liquid purity and block the nozzle hole.

Leakage can occur from two surfaces in the screwed pipe fittings [3]. The conical ring, which is in direct contact with these two surfaces, provides sealing by applying pressure to the body element's conical surface with the help of a nut. Therefore, the ring's material type and surface roughness are significant. So, testing the effect of the conical ring's material type and surface roughness is sufficient for our experiments. In accordance with this information, the brass and the aluminium ring was produced in three different roughness classes and the copper ring in two different roughness classes for the experiments. Manufactured parts of the pipe fitting and experimental setup can be seen in Fig 2.2. Designations of the materials are Cu-ETP for copper, CuZn39Pb3 for brass and 6082 for aluminium.
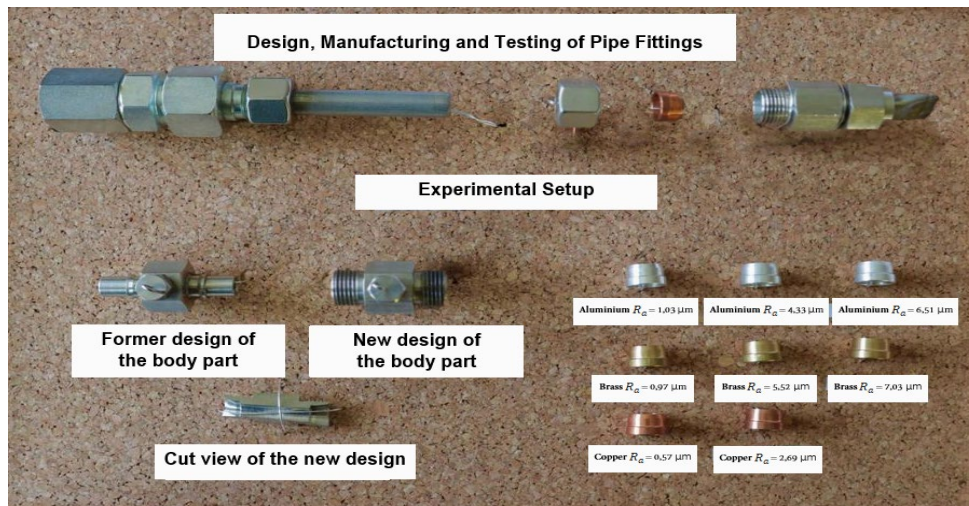

Fig. 2.2: Manufactured parts of the pipe fitting and experimental setup

The roughness classes decided for the conical ring are: N5-N7 range, N7-N9 range and N9-N10 range. The copper ring was not produced in the N9-N10 roughness class range because of the machining problems caused by the copper's high ductility nature. Moreover, surface roughness measurements were performed in Dokuz Eylul University Materials Engineering Tribology Laboratory to prove the rings' roughnesses are consistent with required roughnesses. The surface roughness measurement results were shared in Table 2.1, Table 2.2. and Table 2.3.

Table 2.1: Surface roughness measurement results of copper rings

	COPPER 1	COPPER 2
Arithmetical Mean Height (R_a)	0,57 μm	2,69 μm
Root Mean Square Deviation (R_q)	0,70 μm	3,21 μm
The Total Height of Profile (R_t)	3,26 μm	14,03 μm
Maximum Height of Profile (R_z)	3,02 μm	12,36 μm
Roughness Class	N5-N7 range	N7-N9 range

Table 2.2: Surface roughness measurement results of aluminium rings

	ALUMINIUM 1	ALUMINIUM 2	ALUMINIUM 3
Arithmetical Mean Height (R_a)	1,03 μm	4,33 μm	6,51 μm
Root Mean Square Deviation (R_q)	1,13 μm	3,91 μm	7,70 μm
The Total Height of Profile (R_t)	4,67 μm	15,05 μm	31,36 μm
Maximum Height of Profile (R_z)	4,12 μm	13,96 μm	28,44 μm
Roughness Class	N5-N7 range	N7-N9 range	N9-N10 range

Table 2.1: Surface roughness measurement results of brass rings

	BRASS 1	BRASS 2	BRASS 3
Arithmetical Mean Height (R_a)	0,97 μm	5,52 μm	7,03 μm
Root Mean Square Deviation (R_q)	1,18 μm	6,58 μm	8,37 μm
The Total Height of Profile (R_t)	6,42 μm	25,70 μm	33,62 μm
Maximum Height of Profile (R_z)	9,44 μm	24,49 μm	30,45 μm
Roughness Class	N5-N7 range	N7-N9 range	N9-N10 range

3. Method
3.1. Experimental Setup
Experiment conditions were determined in line with the needs since the regulation of the test conditions could not be found in the standards for the data desired to be obtained.

Pratissoli Plunger Pump KE28H was used to pump water to the nozzle connected to a 12 mm pipe. Jetting-Vacuum Truck was used to control water, and Pakkens MH100 Pressure Gauge was used to measıre pressure. Measurements of sealing torques were taken via Norbar 100 Torque Wrench. The schematic representation of the experimental setup can be seen in Figure 3.1. The realization of Fig 3.1.B was shown in Fig. 2.2 with the subtitle ''Experimental Setup''.

A. Pakkens MH100 Pressure Gauge
B. Pipe Fitting
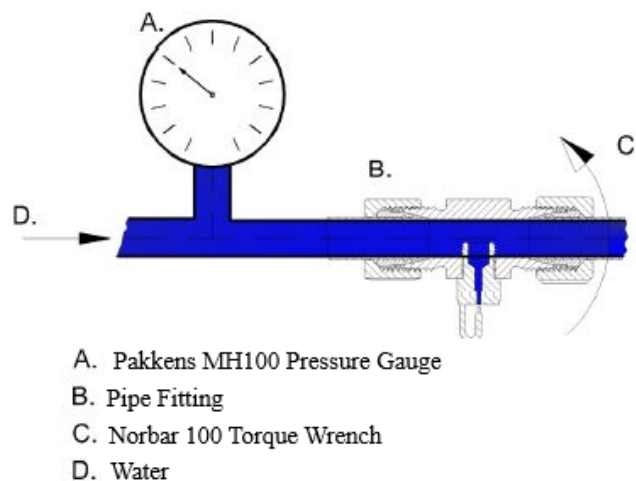C. Norbar 100 Torque Wrench
D. Water

Fig. 3.1: Schematic representation of the experimental setup

3.2. Procedure

Experiments were performed to determine the sealing performance of the fastener. Experimental variables are material, surface roughness and fluid pressure, and the effect of these variables on the sealing performance was examined by comparing the sealing torques in static and dynamic conditions separately. In the experiments, the nut was tightened with a torque wrench, starting from 20 Nm and increasing 1 Nm until the sealing was achieved and the sealing torques in different conditions was examined.

During the experiments, it was observed that, in the case of dynamic load(such as turning the nut by hand, hitting the connection element), the body disconnected from the ring and further disconnected from the pipe.

Table 3.1: Experimental Conditions

Experiments	Material	Arithmetical Mean Height (R_a) of Conical Part of The Ring	The Diameter of The Pipe
Experiment 1	Aluminium	1,03 μm	11,8 mm
Experiment 2	Aluminium	1,03 μm	12 mm
Experiment 3	Aluminium	4,33 μm	12 mm
Experiment 4	Aluminium	6,51 μm	12 mm
Experiment 5	Brass	0,97 μm	12 mm
Experiment 6	Brass	5,52 μm	12 mm
Experiment 7	Brass	7,03 μm	12 mm
Experiment 8	Copper	0,57 μm	12 mm
Experiment 9	Copper	2,69 μm	12 mm

Ring materials, surface roughnesses and pipe diameters used for the experiments can be seen in Table 3.1, and the leakage, drip and sealing torques measured in the experiments conducted under these conditions at different water pressures are indicated in Table 4.1.

4. Analysis and Results

The results of the experiments can be seen in Table 4.1. These results were measured in static conditions. It has noticed that under any dynamic load (such as hitting the fastener, rotation of the fastener, etc.), the connection element perform its function for these experiments. The reason is that the sealing torques specified in Table 4.1 are not sufficient the pipe and ring to be squeezed until plastic deformation occurs.

Table 4.1: Experiment Results

EXPERIMENTS	10 BAR			30 BAR		50 BAR		70 BAR	
	TORQUE (Leakage) (Nm)	TORQUE (Drip) (Nm)	SEALING TORQUE (Nm)	TORQUE (Drip) (Nm)	SEALING TORQUE (Nm)	TORQUE (Drip) (Nm)	SEALING TORQUE (Nm)	TORQUE (Drip) (Nm)	SEALING TORQUE (Nm)
Experiment 1	34	44	50	50	53	53	54	-	54
Experiment 2	35	44	46	46	53	53	55	55	57
Experiment 3	30	40	42	-	42	42	48	48	50
Experiment 4	30	34	35	-	35	-	35	-	35
Experiment 5	30	42	43	43	44	-	44	-	44
Experiment 6	30	37	41	-	41	-	41	-	41
Experiment 7	30	34	35	-	35	-	35	-	35
Experiment 8	30	40	41	41	48	48	49	-	49
Experiment 9	30	40	41	-	41	41	43	-	45

Further experiments were performed to examine the dynamic characteristic of the pipe fitting. For dynamic conditions at 70 bar, the sealing torques are 75 Nm, 60 Nm and 80 Nm for the copper, brass and aluminium ring, respectively.

5. Conclusion

The effects of material, surface roughness, and pressure are examined with experiments in this research.

Firstly, there is an absolute relationship between surface roughness and sealing performance. As the surface roughness increases, the sealing torque decreases because the decrease in the contact area provides the same surface pressure with the less applied force. Therefore, the surface roughness of the conical ring is suggested to be high.

Secondly, the systems' sealing torques, in which the brass rings were used, most of the time have the lowest values than other systems. Thus, the brass material is the most suitable material for the conical ring since it would be appropriate to choose the material which provides the lowest sealing torque.

Additionally, it has been observed that the increase in liquid pressure generally increases the sealing torque as expected. The system in which the aluminium ring was used was more affected by the increase in liquid pressure than the other experimental systems. The system with the brass ring is the least affected.

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