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- RESEARCH ARTICLE –

Investigation of Joinning Perforate and Filtrate Papers Using Different Joining Methods

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Abstract

In this study, it is aimed to investigate the joining of filter paper, which we classify as oil, fuel and air filter by four different methods. It has been determined whether it meets the post-merger requirements or not. The oil, air and fuel filter papers are pleated using pleats, ultrasonic, metal clips, polyamide-based hot melt and heat after being pleated (folded) to form media. Post-merger macro studies were performed after combination. Media was transformed into final filter product than buble test, air permeability and pore size test were applied. In terms of bonding quality, respectively it can be said that the metal clips, hot glue, ultrasonic welding and heat bonding methods should be, but in considering both quality bonding and to make saving, then metal clips, ultrasonic welding, hot glue, and heat methods should be followed.

Keywords:
Filter paper, filter, ultrasonic welding, metal clips.
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Introduction

Paper is one of the main components for filter manufacturers. These filtering elements are graded according to their ability to clean particles of a certain size from air and from different liquids (Johnson, 2017; Zhongqi et al. 2018). This rating is based on how small or large the particle holder is (Johnson, 2017). Emprical formulas related to pore size were studied in emprical formulas (Seungkoo et al., 2019).

The filter element paper (media) is making main task in the filtration area for the welding of paper, which is a cellulosic product, it can be explained, as one of the components of the paper, a

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material, such as a plastic, between the paper webs at a temperature lower than the melting temperature of the cellulosic portion of the cellulosic portion (Badawy, 2017).

For the welding of paper which is a cellulosic product, as one of the components of paper, such as a plastic materials cellulosic parts at a temperature lower than the melting temperature of the, can be explained by the interconnection of paper tissues. The ends of the filter paper must be joininged very well so that the filter is provided in the desired efficiency.

Adhesives and methods used in paper bonding must be suitable for the task and using area of the filter. When the filters working area are evaluated as liquid filtration, air and gas filtration, it is necessary to have materials sticking each other and also impermeability when filters instaleld (Evans, 2012).

Paper will be exposed to factors such as liquid, steam, temperature and air according to using area of the filters;

- It is important to choose suitable adhesive / method for this environment as it will always be in contact with liquid in oil and fuel filters. The performance of the filters working in liquid media or dry environment is different. It is known that materials such as oil mist can reduce the ability of the filtering action in filtering (Penner, 2019).
- Since the air filter will also be exposed to hot steam, air and humid environment, these must be observed in the adhesive and the applied method.
- In paper joining, both time and cost conditions should be taken into consideration for the operation to be efficient.
- It is necessary to evaluate the environmental effects of the chemicals and methods which is used in joining and the transformation of the wastes should be provided.
- The most important evaluation in the paper joining is conformity of demanded technical specifications / test with filters performing.

To provide impermeability filters medias should be stick each other or combined. There are different contents and structures according to the characteristics of the media and the using place in the vehicle. Media has different contents and structure according to their characteristics and using place in the vehicle. Oil, fuel and air media's chemical properties, structures, contents and technical datas are different from each other (Evans, 2012). Because of these differences, the joining type is important in media to be used in the merging process.

Therefore, in the merging of filtering paper; It is thought that the appropriate adhesive or method suitable for the operating temperature of the filter, suitable for mass production flow, ease of use in machines, human and environment sensitive and economical.

In this study, it is aimed to evaluate the joining of the paper of the filters (filtrate) which we classify as oil, fuel and air by four different methods and to investigate whether they meet the requirements after joining or not.

Materials and Methods

Filter papers are classified as oil (FP1), air (FP2) and fuel (FP3) (Table 1). Oil filter paper and fuel filter paper were obtained from Ahlstrom. Air filter paper was supplied by Neenah filtration. Oil filter paper is cooked in chamber oven for 5 min at 160 °C and comes to the desired drainer feature. The pore size is 70 μm. The fuel filter paper consists of two layers. Fuel filter paper, baked in the

closed system oven for 5 min at 160 °C is the desired feature (Ahlstrom TDS, 2018). Air filter paper has oil mist feature. Air permeability is 696 I / m² (Neenah filtration TDS, 2018).

Table 1. Type of filter papers and applied joining methods

Paper Code	Paper Type	Filter Type	Materials (content)	Joining Method
FP1	Oil paper	Oil filter	Cellulosic/Synthetic	Ultrasonic welding
FP2	Air paper	Air filter	Synthetic	Metal klips
FP3	Fuel paper	Fuel filter	Cellulosic/Synthetic	Polyamide based Hot melt Joining with heat

Table 2 shows the bubble test, air permeability and pore size characteristics of the oil, air and fuel filter papers before joining. When looking at the bubble test values, the oil and air filter papers are used in factories that produce filter, almost three times the same as the fuel filter paper. The pore sizes has been also changed with this properties in direct proportion. Pore size varies according to the material to provide permeability and / or filtration pore sizes are important parameters of joining in all the methods.

Table 2. Filter paper type and pre-assembly properties (Ahlstrom TDS,2018; Neenah filtration TDS, 2018)

Paper	Bubble test (mbar)	Air permeability (I /m² s)	Pore size (µm)
FP1	min. 8	619	65 µm
FP2	min. 8	494	89.9 µm
FP3	min. 22	25	20 µm

Methods

Filter paper tests were performed using different joining methods. In the tests has been ocurred that the methods provide desired conditions, methods do not meet the requirements, methods gives negative datas.

The filter media were classified as oil, fuel and air 4 different bonding methods were applied. Filter paper, ultrasonic welding, metal joining (clip), hot glue and the combinability of the paper with heat treatment are examined. As a result of the integration, the performance and availability of the filters in working environments were analyzed (Table 3).

Table 3. Filter paper type and applied tests

Paper code	Joining method	Tests		
FP1, FP2, FP3	Ultrasonic welding	Bubble test	Air permeability	Pore size
FP1, FP2, FP3	Metal clips	Bubble test	Air permeability	Pore size
FP1, FP2, FP3	Polyamide based hot melt / hot glue	Bubble test	Air permeability	Pore size
FP1, FP2, FP3	Joining with heat	Bubble test	Air permeability	Pore size

Ultrasonic welding

In the ultrasonic welding machine, the welding takes place under the influence of rapid and variable pressure vibrations. The hardened steel wheels are rotated and driven by molecular vibrations in the media surface (Figure 1a). The ultrasonic welding parameters applied to the paper filters are given in Table 4. In the joining design, the type, geometry of the paper material and the expectations from the joint were taken into the account. Synthetic materials are hygroscopic; they absorb the moisture in the atmosphere, which seriously affects their weldability. The reason for this is porosity problem (Taş, 2008). As filter papers are porous, they have a negative effect on welding ability with hygroscopic feature. Therefore, during the welding process, the dry air environment was selected in order to prevent the diffusing air from decreasing the moisture welding ability. Ultrasonic bonder has a larger whell and higher clearance for increased access for hand-guided operations (Figure 1c) (Alleman, 2009).

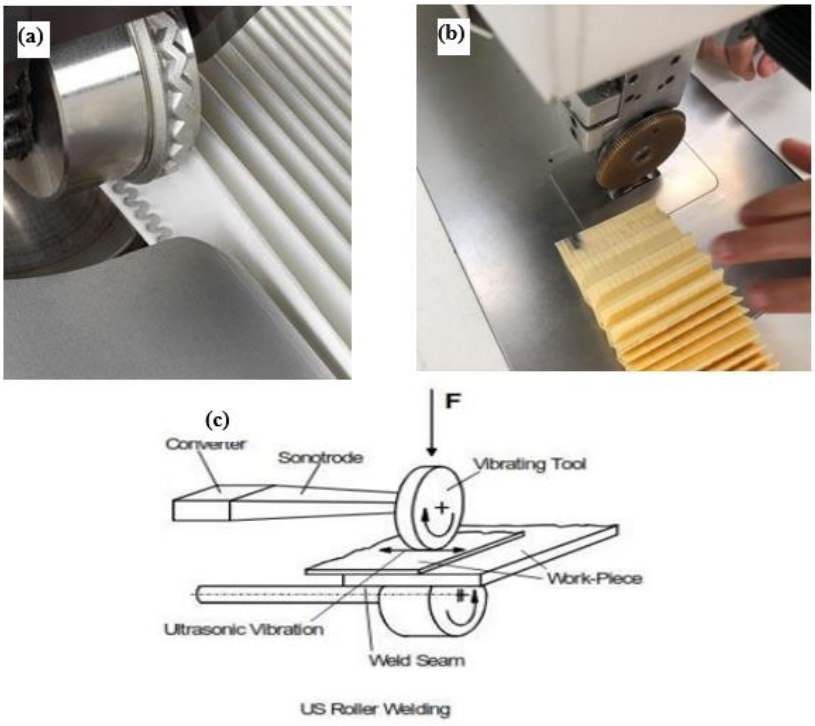

Figure 1. The method of joining with ultrasonic welding, a) Circular Horn (Lakshmikantha, 2011), b) Weld position filter paper, c) Schematic and application representation(Alleman, 2009).

Table 4. Parameters used in ultrasonic welding process.

Paper code	Cylinder pressure (N)	Cylinder rotation speed (m/dak)	Ultrasonic Amplitude (%)	Ultrasonik frekans (Khz)
FP1	500	0.6	100	35
FP2	400	1	100	35
FP3	400	1	100	35

Joining with metal clip method

The filter media were compacted with a pressure of 16 mm to 0.25 mm thick metal strip to provide sufficient compression (Figure 2). According to the size of the paper filters, oil, air and fuel filters, respectively, 75, 65, 150 mm paper lengths were cut.

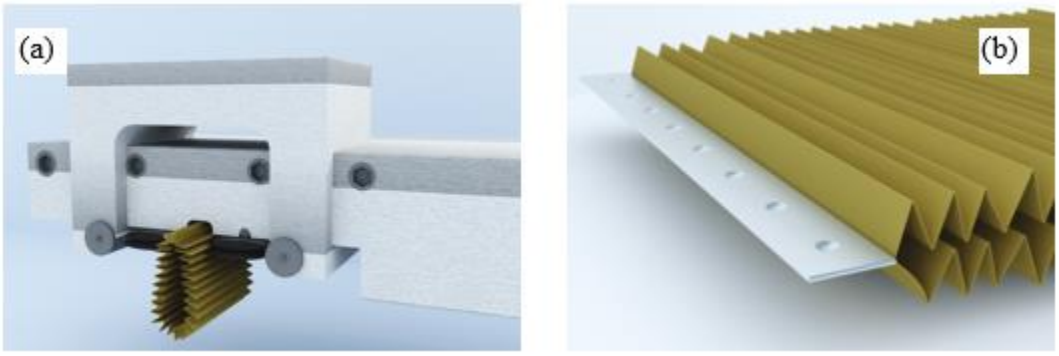

Figure 2. Schematic representation of the method of joining with metal clips, a) Clip machine, b) Paper joined with metal clip.

Polyamide based hot melt bonding

The properties of polyamide based adhesive (PAS 5030) obtained from the company are given in Table 5. It has the adhesive properties which are specified in the required values in the service area.

Table 5. Polyamide based hotmelt (PAS 5030) properties (ASTM D1963 – 85, 1996; ASTM D638-14, 2014; ASTM D3236-15, 2015; ASTM E28-18, 2018).

Density (g/cm^3)	Solid content (%)	Softening point (°C)	Viscosity (mPa.s) (at 220°C)	Application temperature (°C)	Elong. (%)	Tensile yield (N/mm^2)	Tensile break ($N/mm^{2)}$	E-Modul (N/mm^2)
0.97	100	160-175	2.000 – 3.000	200 – 230	500	8	10	130

The polyamide-based glue adhesive is placed in the granulated machine tank and heated to 200 °C, which is the formation temperature of the glue. The necessary machine settings were made according to the paper size and bonding process was done. The media are placed as shown in Figure 3 and the assembly operations are completed.

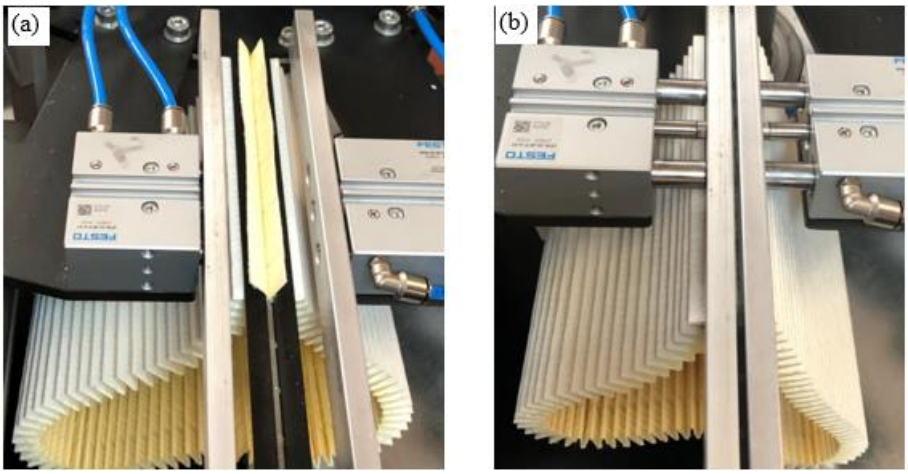

Figure 3. Application of machine assembly with hot glue. a) before compression, b) after compression.

Heat joining method

240 ˚C heat applied, 50 second pressure applied to the filters to connect to each other as shown in Figure 4 by holding the pleats of the media on top of each other and keeping it under the heat source resistance in the machine for a period of time the merge operation was performed.

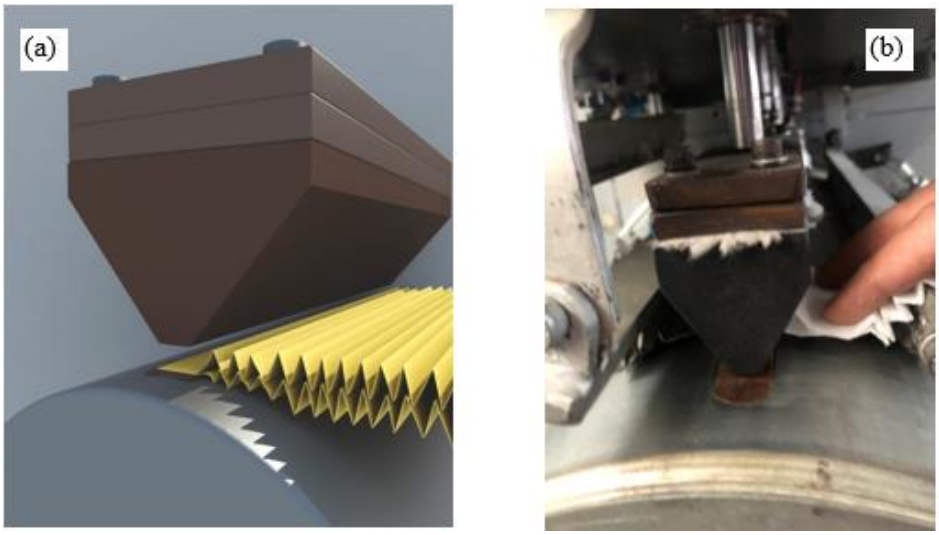

Figure 4. Heat bonding, a) Schematic and b) Application representation.

Results

The test results of the filter papers were compared with the standard test results (Table 6, Table 7 and Table 8). There are several parameters during defragmentation. Therefore, the same parametric operations are applied to each paper type. It has been determined that the conditions and conditions of joining vary depending on the paper type and the unifying person. In this study, existed small changes have been ignored.

In bubble test on oil filter paper (FP1) it was observed that the bubble formation pressure above the standard was obtained (Table 6). Ultrasonic bonding, metal clips and polyamide based hot melt glue over 8 mbar was obtained, while heat coupling could not be achieved. Air permeability and pore size test results were within acceptable limits of the standard. The results of these two tests are acceptable limits in ± 10% of the standard (ISO 5636-5: 2013, 2013). The variation of the joint type, the air permeability and the pore size do not affect the test results. Therefore, it has been observed in the oil filters whether the coupling method was successful, bubble forming pressure and economics were the most important parameters.

Table 6. Oil filter papers (FP1) test results after joining with desired test results in standards (Ahlstrom TDS, 2018).

		Bubble test		**Air permeability**		**Pore size**	
Paper	**Joining Method**	**Bubble test standard (mbar)**	**Bubble test result (mbar)**	**Air Permeability standard- (I /m² s)**	**Air permeability test result (I /m² s)**	**Pore size standard (Micron)**	**Pore Size Test Result (Micron)**
FP1	Ultrasonic welding	min. 8	11.2	494	478	89.9	86.5
	Metal clips	min. 8	13.4	494	478	89.9	86.5
	Polyamid based hotmelt / hot glue	min. 8	12.4	494	478	89.9	86.5
	Joining with heat	min. 8	7.1	494	478	89.9	86.5

In the buble test of air filter paper (FP2), it was observed that hot glue based on metal clips and polyamide was low enough to be neglected by ultrasonic bonding while obtaining bubble formation pressure above the standard (Table 7). As stated earlier in the ultrasonic welding, the mechanical effects of the paper during the plating were determined by the laboratory experience, which reduced the performance. Heat bonding could not be performed on air filter paper. Air permeability and pore size test results were within acceptable limits of the standard.

Table 7. Air Filter (FP2) test results with demanded standarts (Neenah filtration TDS, 2018).

		Bubble test		**Air permeability**		**Pore size**	
Paper	**Joining Method**	**Bubble test standard (mbar)**	**Bubble test result (mbar)**	**Air permeability standard (I /m² s)**	**Air permeability Standard (I /m² s)**	**Pore size standard (Micron)**	**Pore size standard test result (Micron)**
FP2	Ultrasonic welding	min. 8	7.6	619	642	65	62.2

	Metal clips	min. 8	13.2	619	642	65	62.2
	Polyamid based hotmelt / hot glue	min. 8	15.2	619	642	65	62.2
	Joining with heat	min. 8	Paper not combined wth heat.	619	-	65	-

Ultrasonic bonding and heat coupling cannot be performed on fuel filter paper (FP3). It has been observed that the bubble formation pressure is obtained twice as much as the standard in the metal glue and polyamide based hot glue (Table 8). The air permeability and pore size test results were found to be high and equal, respectively, in the fuel filter paper assembly compared to other filter papers. In the case of fuel filters, the method of joining is different from other filter papers. In order to be resistant to fuel, it has been determined that it is already low in thermal methods because it is produced from synthetic / cellulosic chemical substances. Special methods are being developed for ultrasonic bonding.

Table 8. Air filter paper (FP3) test results after joining with desired test results in standards (Ahlstrom TDS, 2018).

		Bubble test		**Air permeability**		**Pore size**	
Paper	**Joining Method**	**Bubble test standard (mbar)**	**Bubble test result (mbar)**	**Air permeability standard (I /m² s)**	**Air permeability Standard (I /m² s)**	**Pore size standard (Micron)**	**Pore size standard test result (Micron)**
	Ultrasonic welding	min. 22	Paper did not combine with ultrasonic bonding.	25	-	20	-
	Metal clips	min. 22	37.2	25	30.2	20	19.9 ɱm
FP3	Polyamid based hotmelt / hot glue	min. 22	41.6	25	30.2	20	19.9 ɱm
	Joining with heat	min. 22	Paper not combined wth heat.	25	-	20	-

The most important step in the process of making a filter is the quality of combination and uniformity. The media are required to provide a impermeable function for the coupling locations.

Metal clips, ultrasonic welded coupling place and hot glue coupling place were observed as very smooth (Figure 5). However, it was seen that deformation occurred in the coupling place of the filter papers in the heat bonding method (Figure 6). The combination of metal clips, ultrasonic bonding and hot glue methods was found to be better with respect to the quality of image and function. This situation is clearly seen in Figure 6b in heat coupling, the area indicated by arrow in Figure 6b is heat burnt zones, which also worsens paper quality.

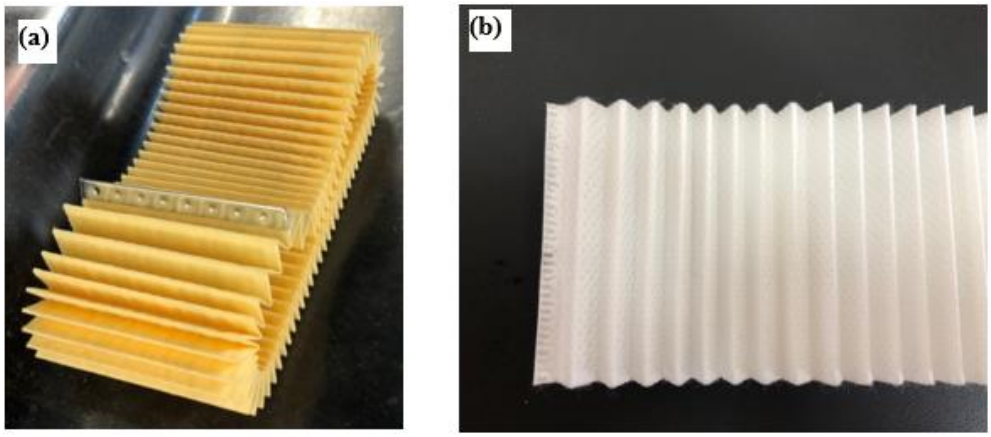

Figure 5. Joints of filter papers. a) Metal clips, b) Ultrasonic welding.

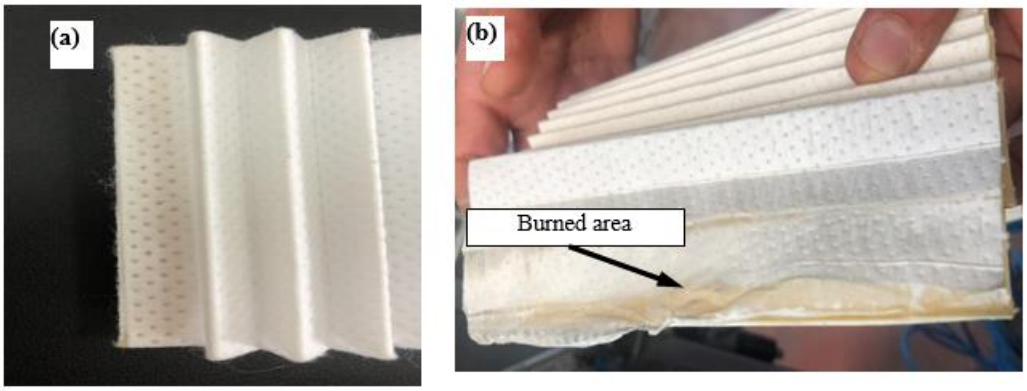

Figure 6. Joints of filter papers. a) Polyamid based hotmelt, b) Joining with heat.

The main purpose of the operations using additional adhesive material is the effect of surface free energy, adhesion studies and the formation of the interface free energy between the phases. The quality of adhesive connections is often a very complex issue (PETKOVIC and others, 2017). For this reason, the results obtained with polyamide based bonding were not consistent. High adhesion quality was achieved by combining FP3 filter papers with polyamide-based adhesives, while FP1 and FP2 were less than one-third.

Conclusions

The results obtained by using ultrasonic, metal clips, hot melt and heat bonding methods which are used for joining filtration and porous paper are given below.

- In the test results of the filter papers, pore size and air permeability were determined to be in the desired technical data (standard) range. It was determined that the properties of the papers did not change after the joining process.
- In oil filter paper, it is concluded that ultrasonic, metal clips and polyamide based hot melt glue provides the desired standard over efficiency while the other is the opposite.
- Air filter paper, metal clips and polyamide based hot melt glue is provided on the desired standard.
- A high quality combination is provided with metal clips and hot glue based on polyamide in fuel filter papers.
- When the quality of bonding is considered, it can be said that metal clips, hot glue, ultrasonic welding and heat bonding, respectively, but in combination with metal clips, ultrasonic welding, hot melt, and heat, respectively, both in terms of quality bonding and economics.
- It has been observed that the surface properties, thickness and content of filter papers are the most important parameters in the joining methods.
- In all assemblies, it was determined that the filter papers were cut from the main material part and not from the joint

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