The Research of Diesel Engine Performance Using Neutralized Safflower Oil as Fuel

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Abstract: Vegetable oils for use as fuel are one of the methods of use of biofuels. However, high viscosity of vegetable oils causes to some problems use long period. The problem was either solved modified vegetable oil or by modified engine. The effect of some of the physical properties of diesel fuel and safflower oil on the engine performance with kit were measured and compared in the study. In this study funded by a project of TÜBİTAK 108 O 419, fuel properties of safflower oil was investigated and transforming safflower oil to standard fuel (DIN V 51605) and its direct usage in the diesel engine with aid of a designed kit was studied. Diesel engine which is a four-stroke, single-cylinder, 15 kW was used for laboratory tests. The engine operated under 40-50% load for 1000 hours. According to the results of this research, there was 10,18% change in torque and 22,43% power engine data in comparison with diesel fuel when the safflower oil and diesel fuel were used.

Keywords: Diesel Engine, Vegetable oil, Neutralize**,** Safflower oil, Kit

Introduction

Diesel fuels play an important role in the industrial economy of a country. These fuels run major part of the transport sector and their demand is increasing steadily, requiring an alternative fuel which is technically feasible, economically competitive, environmentally acceptable, and readily available (Bouaid, et al, 2005). Vegetable oils are widely available from various sources, and the glycerides present in the oils can be considered as a viable alternative for diesel fuel. The heating value of vegetable oils is similar to that of diesel fuel.
Therefore vegetable oil which was the first fuel of diesel engines has become the focus point of all researches again. Our country, as an agricultural country, has got great biomass resources. Renewable energy sources have an importance by the point of using them as alternative engine fuels (Oğuz, 2004).

Related to vegetable oils (DIN V 51605) the direct use as a fuel without appropriate standards occurs to cause the problem to the fuel injection pumps, injectors and combustion chamber in engines. Therefore, to reduce viscosity or to make the standards oil is to done investigations (Oğuz et. al, 2009)

Vegetable oils can be used directly as fuel engine without converted for biodiesel. In this case, running the engine with diesel fuel and vegetable oil must be heated. Used as fuel directly of vegetable oil in is not notice of the new oil or waste oil fries (Öğüt & Oğuz 2006). The standardized of vegetable oils were prepared by researcher. This standard was given in Table 1.

characteristics/	**units**	**limiting values**		**test procedure**
substances		**min.**	**max.**	
characteristic properties				
Density (15ºc)	kg/m3	900	930	DIN EN ISO 3675 DIN EN ISO 12185
Flash point	° C	220		DIN EN ISO 22719
Calorific value	kJ/kg	35,000		DIN 51900-3
Kinematic viscosity (40 °C)	Mm2/s		38	DIN EN ISO 3104
Behaviour at low temperatures				rotation viscosimetry
Cetane number				process is being evaluated
Coke residues	% by mass		0.40	DIN EN ISO 10370
Iodine number	G/100g	100	120	DIN 53241-1
Sulphur content	mg/kg		20	ASTM D 5453-93
Variable characteristics				
Total contamination	mg/kg		25	DIN EN 12662
Neutralisation value	Mg KOH/g		2.0	DIN EN ISO 660
Oxidation stability	h	5.0		ISO 6886
Phosphor content	mg/kg		15	ASTM D3231-99
Ash content	% by mass		0.01	DIN EN ISO 6245
Water content	% by mass		0.075	pr EN ISO 12937

Table 1. Quality standard for rapeseed oil as a fuel (DIN V 51605)

Vegetable oils do not contain any sulphur, aromatic hydrocarbons, metals or crude oil residues. The absence of sulphur means a reduction in the formation of acid rain by sulphate emissions which generate sulphuric acid in our atmosphere. The reduced sulphur in the blend will also decrease the levels of corrosive sulphuric acid accumulating in the engine crankcase oil over time (Almeida, et al.2002).

Procedure

Safflower Oil Was Neutralized

Natural oils physical properties vary widely, even though they are composed of the some or similar faty acids. These differences result from differences in the proportion of the fatty acids and the structure of the individual triglycerides. Among the factors that effective the vegetable oil fatty acid compositions are climate conditions, soil type, growing season, plant maturity, plant health, microbiological seed location within the flower, and the genetic, variation of the plant (Brien, 1998).

The safflower oil was neutralized in this study. Therefore a pilot production plant was used. The Photo of a pilot production plant was given in figure 1. For neutralized process raw safflower oil into reactor and was heated up to 85 ^{o}C. Water was heated up to 85 ^{o}C other tank. Phosphoric acid is added to safflower oil at a rate of 0,002 were mixed for 10 minutes. Than liquids of 5% diluted caustic were mixed with safflower oil for 5 minutes. Finally, with water up to 10% safflower oil was washed with a shower method. Phase expected to occur by 60 minutes and the right bottom of the wash water and other substances that accumulated were taken. Then the safflower oil and their blending dried under vacuum at 100 ^{o}C. Neutralizing the safflower oil is heated up to 85 ^{o}C again. 0.01 percent of soil was given slowly bleaching and bleaching operations were. Soil taken from the bottom of the oil in the bleaching process has been completed.

Fig 1: Pilot Production Plant

2.2 The determination of safflower oil properties and diesel fuel.

The properties of safflower oil and diesel fuel tested in Selcuk University Faculty of Agriculture are shown in Table 2. As shown in the table, diesel fuel has the higher calorific value and the lower viscosity.

	Diesel Fuel	Raw Safflower Oil	***DIN V 51605***	
			Min -	Max
Density at 15 ºC (kg/m^3)	826,4	925,3	900	930
Kinematic viscosity (mm^2/s) at 40 ºC	2,745	31,51	-	36
pH	-	5,5	-	-
Copper Strip Corrosion (3 hours at 50 °C)	1a	1a	-	-
Flash Point (ºC)	60	158	220	-
Colour	1,7	2,0	-	-
Water Content (mg/kg)	29,168	419,17	-	750
Iodine value (g iyot/100g)	-	117,9	95	120

Acid Value (mg KOH/g)	-		-	2,0
Calorific value (kJ/kg)	46581	38997	36000	-
Cetane Number	58,38	49,31		
Cloud point, ºC	-12	-13,3		
Flow point, ºC	-28	-14		
Phosphor content, mg/kg		5,56		

Table 2: The properties of neutralized safflower oil and diesel fuel and their comparison with standard values

Kit Is Installed in Diesel Engine and Working Together

The engine must be started in the diesel fuel position. After the engine has started you can over to straight vegetable oil (SVO) immediately. The green led is on over the control panel now. After reaching the engine operation temperature (70 °C), blue led is off, the system will switch really over to SVO-run, and the yellow led is off. Until this time the engine will run on diesel fuel. Finally it needs two conditions to run on SVO: first, the switch must be in position SVO and second, the engine must be warm. The engine should run with diesel fuel before you stop it as log as it needs replace the SVO in the injection system with diesel fuel.

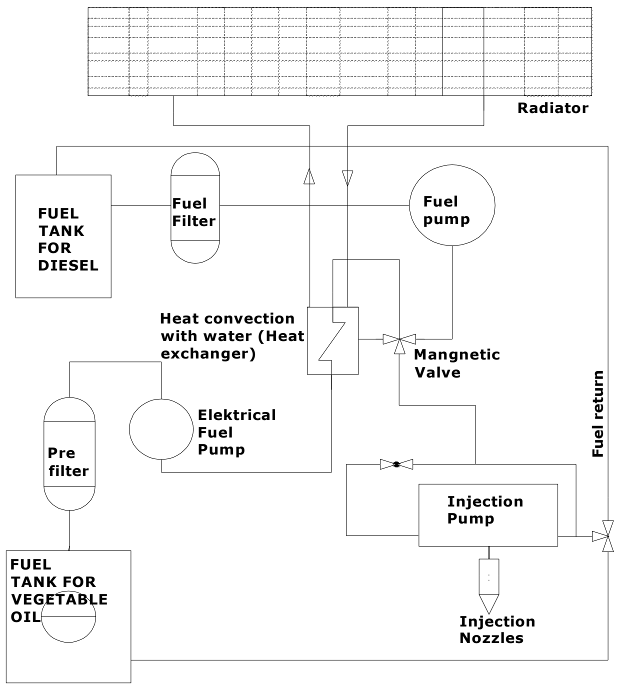

Fig. 2: Shape of kit with use of vegetable oil

Fig.3: The photos on shows the kit installed in a diesel engine.

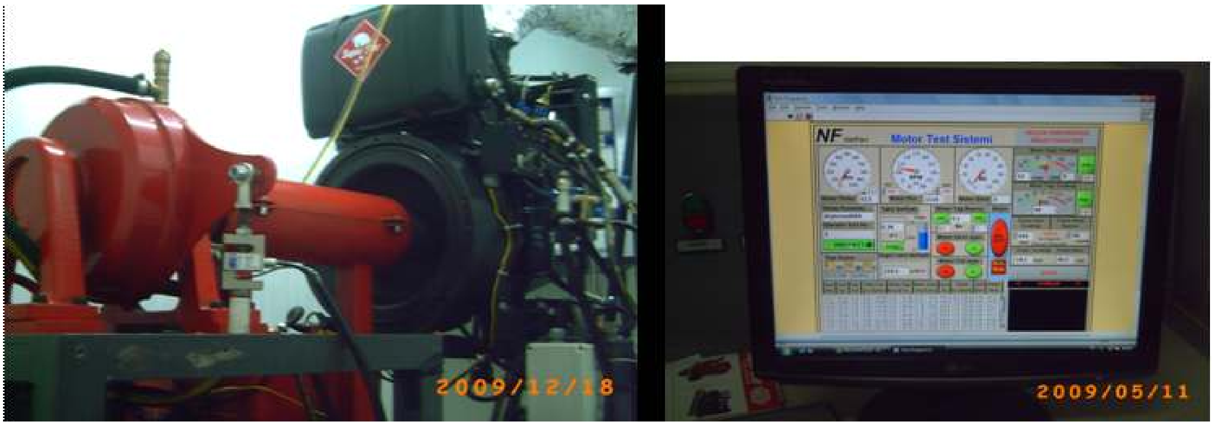

Fig. 4: The engine test rig and control unit.

Experimental Study

Facilities to monitor and control engine variables, such as engine speed, torque, power, fuel consumption, specific fuel consumption, water and lubrication oil temperatures etc., are installed on a fully automated test bed (shown in Fig. 4), single cylinder, water cooled, Super Star, experimental standard engine located at the first author's laboratory which is supported The Scientific and Technological Research Council of Turkey (TÜBİTAK). On the test bed, the engine is coupled to a hydraulic dynamometer. General properties of diesel engine are shown in Table 3.

	Unit	
Model		Super Star
Cylinder Number		1
Type		four stroke, direct injection
Fuel		Diesel
Cylinder Bore	mm	108
Piston stroke	mm	100
Volum	liter	0,92
Compression ratio		17:1
Max. Power	BG	15
Max. Torque	Nm	60
Fuel pomp		Bosch Type
Cooling		Water cooled

Table 3: General properties of diesel engine

A plan was designed for the experimental investigation. The engine was ran once diesel fuel than its ran safflower oil with kit on full loads and on different engine speed. The engine speed was controlled by the control panel. During the tests, the parameters were recorded such as engine power, torque, fuel consumption, specific fuel consumption, and emissions.

Result and Discussion

The experimental results show that the engine performance – power, torque, fuel consumption and specific fuel consumption are comparable to diesel when fueled with safflower oil. The test results are shown in the following figures 5-8. Figure 5. shows the test results of the engine power outputs for diesel fuel and safflower oil with kit as fuels.
Researchers in various countries carried out many experimental works using vegetable oils as diesel engine fuel substitutes. These results showed that thermal efficiency was comparable to that of diesel with 22,43% amounts of power loss while using safflower oils and there was 10,18% change in torque (fig. 6). Safflower oil can be used as fuel in diesel engines with kit.

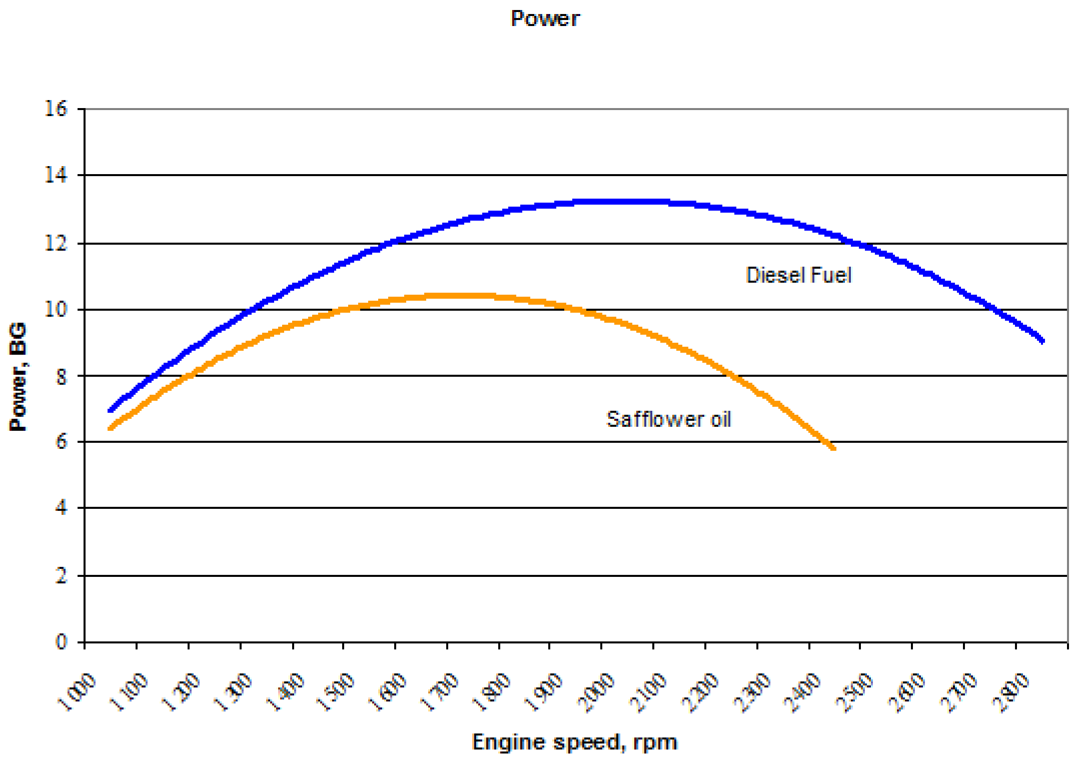

Figure 5: The comparison of engine power of diesel fuel and safflower oil as fuels with kit.

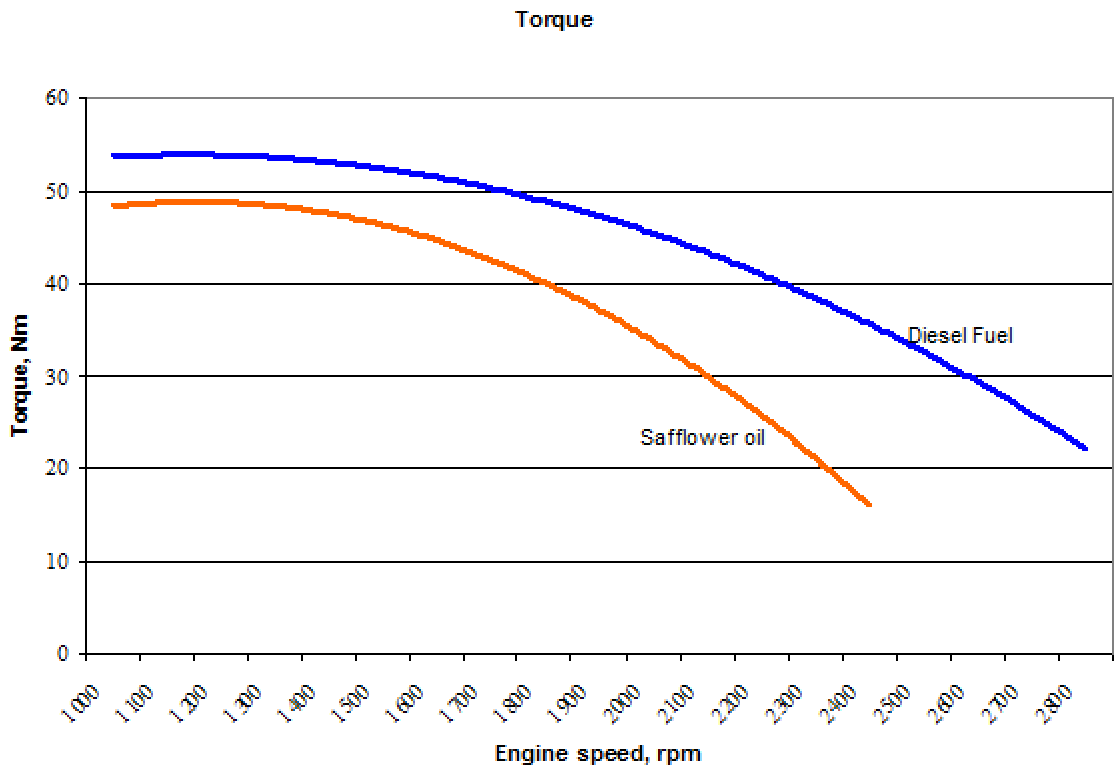

Figure 6: The comparison of engine torque of diesel fuel and safflower oil as fuels with kit.

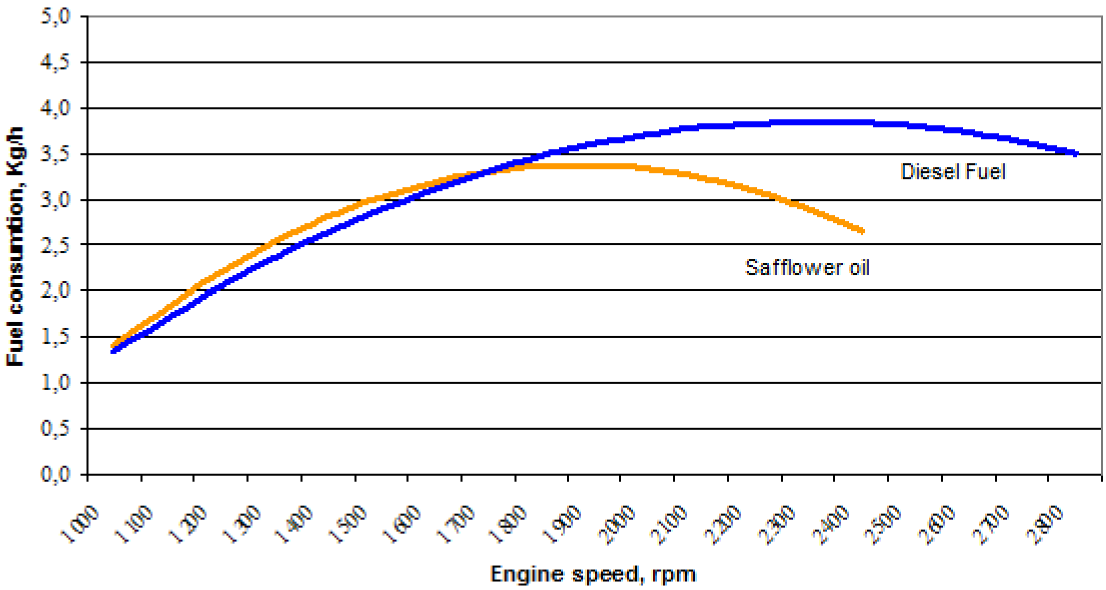

Figure 7: The comparison of engine fuel consumption of diesel fuel and safflower oil as fuels with kit.

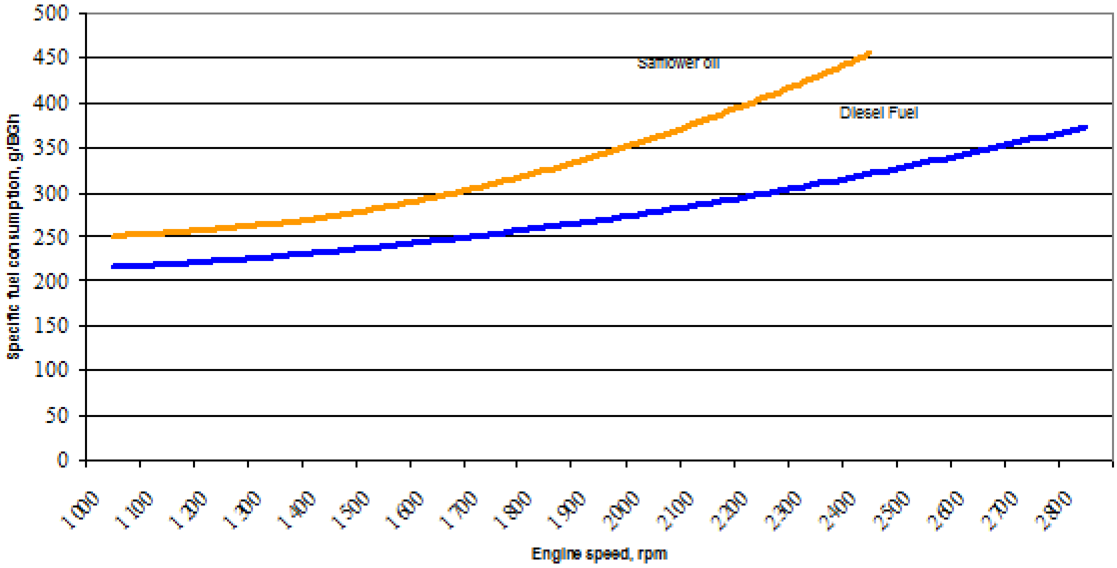

Figure 8: The comparison of engine specific fuel consumption of diesel fuel and safflower oil as fuels with kit.

Specific fuel consumption increased with increase of engine speed. Because of the low calorific value of safflower oil, specific fuel consumption is high up. The engine performance of the safflower oil was not similar to that of diesel fuel and with higher fuel consumption reflecting their lower energy content.

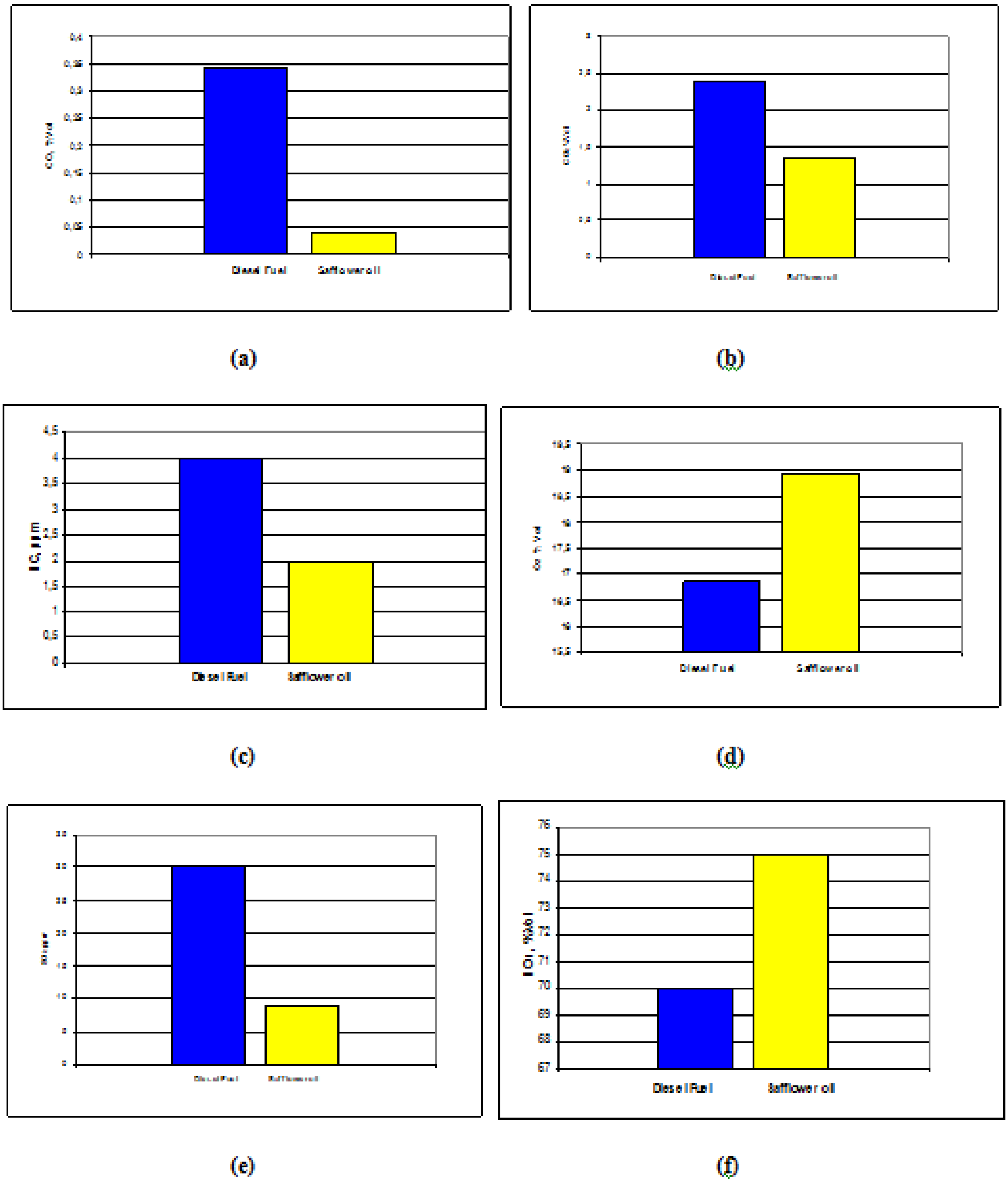

Figure 9: The comparison of CO, CO_2, HC, O_2, NO_x, and SO_2 emissions of diesel fuel and safflower oil

The fuel type on the gaseous emissions of CO, CO_2, HC, O_2, SO2 and NO_x, are shown from Figure 9 at 1500 1/min of engine speed. The CO emission from the diesel fuels is higher than that from safflower oil. This is possibly due to at the engine full load, the temperature in the cylinder of engine is higher, which makes the safflower oil easier to atomize, a better air/fuel mixture and then a better combustion can be achieved; with kit and the oxygen contents in the safflower oil makes it easier to be burnt at higher temperature in the cylinder.
HC and SO_2 emissions of safflower oil are lower than that of diesel fuel. The safflower oil produced NOx emissions that were 7 % higher than the diesel fuel.
The use of safflower oil as diesel engine fuels can play a vital role in helping the developed world to reduce the environmental impact of fossil fuels.
As a conclusion, safflower oil, in diesel engines can be used as an alternative fuel with kit. The advantages are biodegradability, their emission values are low; in addition they can be supplied by means of the energy in agriculture sector with their own facilities.

Acknowledgement

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Friction Welding And Its Applications In Today's World

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Abstract : By developing technology of today, the necessity of using different materials by joining came out. The most suitable method in joining two different alloyed steel is to weld. The fact that the properties of welding zone are naturally different from the properties of steels in different alloyed at post welding process has came up and these differences occur some important problems. Among many kinds of welding methods, using the melting welding methods has also increased the number of these problems. However, in the connecting zone, many different zones come out by depending on composition and properties of the connecting materials. Deposite remain of the melting welding methods, welding faults of porosity and inside tightens of cooling are the important disadvantages of these methods and they decreases the strength of welding. For this reason, solid state welding methods are more suitable due to these melting welding faults. The most important and applicability of these methods are friction welding. For these reasons, in this study importance and application areas of friction welding were explained.

1. Introduction

The ideas of using heat obtained by friction in welding and forming of materials are not new. Friction welding obtained by frictional heat is a commercial process, which has found several applications in different parts of the world with the advancement in technology. First, simple devices having lathe machine type and metal rods have been used in butt welding trials. However, these studies can onl be regarded as preliminary technical trials with little practical importance. The firts trial of friction welding goes back to the 15th century and the first patent was granted to J.H. Bevington, who then was a machinist. Bevington first applied friction welding in elding of metal pipes. Friction welding which was first applied to cutting tools in metal processing industry has found several applications. W. Richter patented the friction welding process in 1924 (in England) and 1929 (in Germany) and H.Klopstock patented the same proces in the USSR (1924). H. Klopstock and A.R. Neelands obtained a patent for friction welding of cylindrical parts. Studies on welding of plastic materials were carried out in the 1940s in the USA and Germany [1, 2]. A Russian machinist named A. J. Chdikov has realized scientific studies and suggested the use of this welding method as a commercial process. He has successfully done a welding process between two metal rods and patented this process in 1956. Vill and his colleagues have further investigated the process with a number of studies. Researchers of American Machine and Foundry Corporation named Holland and Cheng have worked on thermal and parametrical analysis of friction welding [3]. By the way, the first studies of fricton welding in England were carried out by the Welding Institute in 1961. By modifying the friction welding, the Caterpillar Tractor Co. in the USA developed the method of inertia welding in 1962. After this study, conventional friction welding has been regarded as the Russian type process and inertia welding as the Caterpillar type process. With these advances, applications of friction welding have found several applications throughout the world. Friction welding is one of the most widely used welding methods in the industry after electron beam welding [4].

This study addresses friction welding, its significance and types, welding capability, welding parameters and their applications.

2. Friction Welding

All welding methods can be investigated in one of the two main categories; melt and pressure welding. Friction welding is a type of pressurized welding method. Friction welding is a solid state process, where no electric or other power sources are used, mechanical energy produced by friction in the interface of parts to be welded are utilized. Using heat efficiently in the welding region is only possible by efficiently distributing heat on surfaces, to which welding will be applied. During the welding process, surfaces are under pressure and this period called the heating phase continues until plastic forming temperature is achieved. The temperature in the welding region for steels is between 900 and 1300 ^{o}C. Heated metal at the interface accumulates by incerasing pressure after heating phase. Thus, a type of thermomechanical treatment occurs in the welding region and this region has stable particle structure. Metals and alloys, which cannot be welded by other welding methods, can be welded using friction welding. In order to obtain welding connection between parts, untreated surfaces need to be contacted to one another. This contact is efficient because friction corrects contacting problems. The melting process does not normaly occur on contacted surfaces. Even though, a small amount of melting may occur, accumulation caused by post-welding process makes it invisible. Figure 1 gives the stages of friction welding. One of the parts is stationary while the other one rotates (Figure 1_1). When the roational speed rises to a certain value, axial pressure is applied and locational heating occurs in parts at the interface. Then, rotation is stopped, heated material at the interface accumulates (Figure 1_3) [5, 6]. The stages of friction welding during the welding process are given in Figure 2 [7].

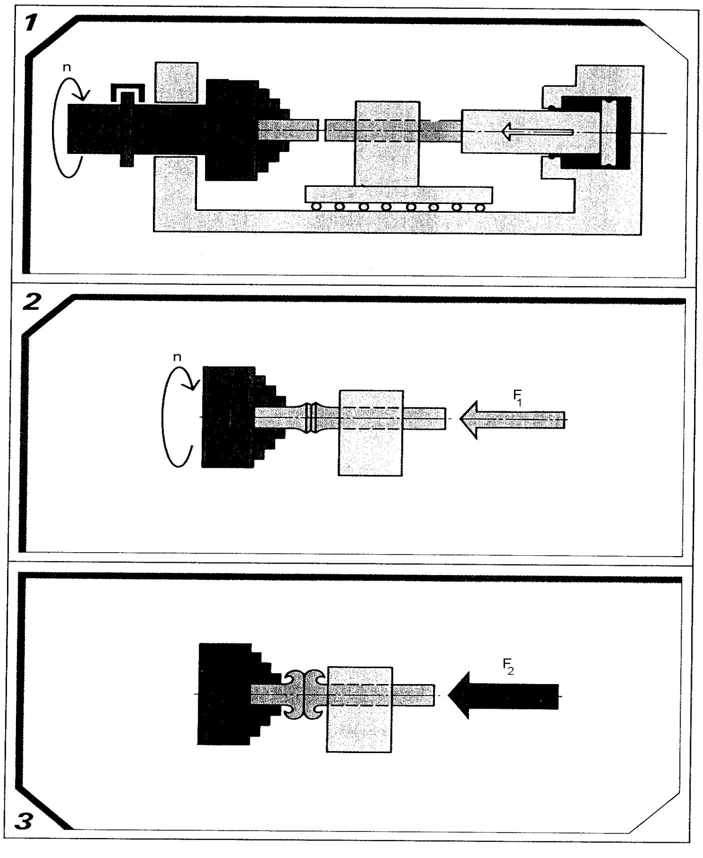

Figure 1. The schematic stages of friction welding [7].

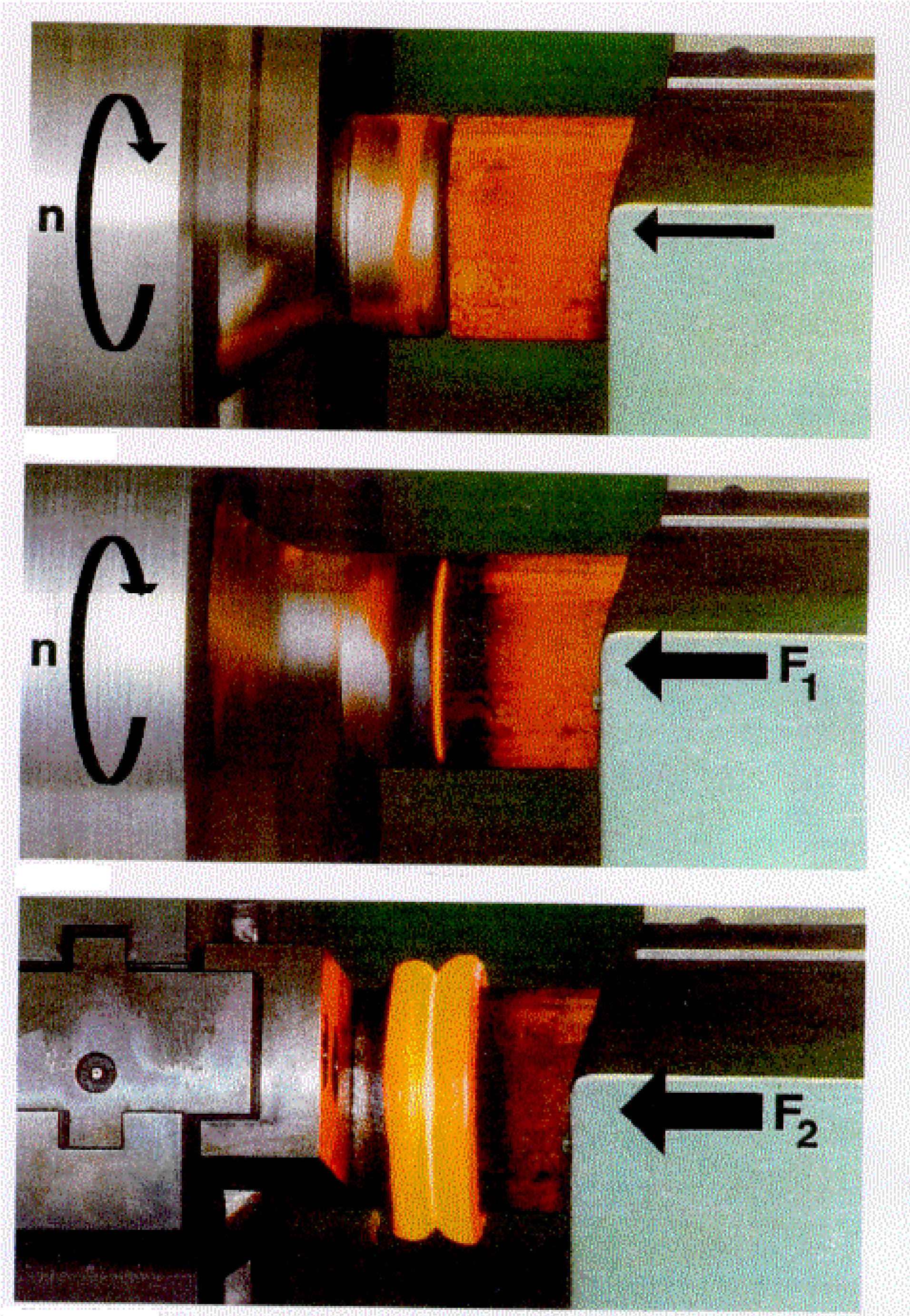

Figure 2. Actual look of friction welding process [11].

Applications of friction welding are generally used in the welding of pipes and circular rods. The basic movement in this kind of application is the rotational movement causing friction [8]. Figure 3 shows conventional friction welding methods in joining of certain size rods and pipes.

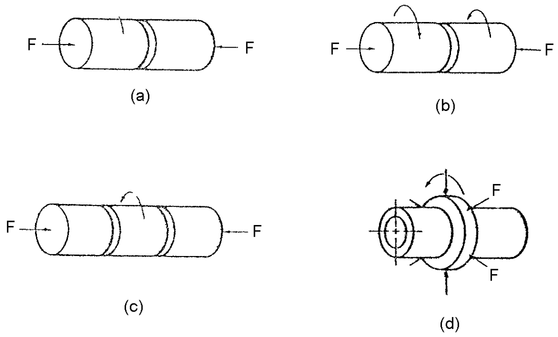

Figure 3. Applications of friction welding [9, 10].

Figure 3-a shows the most simple and used application. In this application, the axes of parts to be welded are the same and rotate around other axes. Under the rotational pressure, friction forces occur on cotact surfaces. Figure 3.b suits best to the small size samples requiring higher rotational speed. It is used in applications where higher relative rotational speeds are required. Figure 3.c is for the applications where parts being very long are efficiently joined. Even though it could not find widespread applications, Figure 3.d is mainly used in welding of pipes rotating under radial forces [9, 10].

It needs to be known that a high quality welding connection can only occur in parts having claen and smooth surfaces. Several inclusions, oxides formed on the surface, films absorbed by the surface are always present and negatively affects bond formation and welding quality. These problems are removed from welding connections by wearing off surfaces during friction [8].

In friction welding, orbital movement as well as rotational movement, linear vibration movement and angular vibration movement can be applied. Orbital movement is fr the welding of non-cylindrical parts. Application shown in Figure 4 is between a stable part and a part rotating circularly [5].

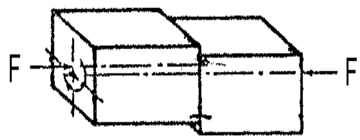

Figure 4. Friction welding including orbital movement [5].

One of the parts in figure 5 moves forward and backward in linear vibration movement. This method has firs been suggested by Vill. In angular vibration movement, one of the parts makes an orbital movement under applied pressure [3].

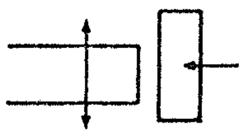

Figure 5. Friction welding including linear rotation movement [3].

2. 1. Types of Friction Welding

Friction welding can be applied by using one of the two methods depending on the source of mechanical energy. With current advances, a combined welding method including both of the methods aforementioned has been developed. These are continuous driven friction welding, flywheel driven friction welding and a combination of the two [1, 5].

2.1.1. Continuously Induced Friction Welding

A inducement driven group provides the necessary energy for rotation. Mechanical energy is converted to heat by applying pressure from rotating part to non-rotating part. This method is generally mentioned in the literature for friction welding. One of the parts is connected to the engine inducement unit and rotates at a constant velocity; a constant axial force is applied to parts. Working parts interact with each other during welding or until axial shortening occurs. Then, braking system stops the process. Pressure applied during welding is increased and stays at a certain value until weld cools down. The essential welding parameters are rpm, friction force on the surface, the length of friction period, forging force and forging time [1, 5].

A schematic of continuous inducement friction welding machine is given in Figure 6 and process parameters in Figure 7.

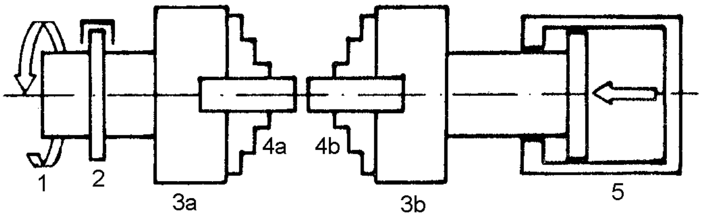

Figure 6. A schematic of continuous inducement friction welding machine [1, 5].
(1.Inducement engine, 2. Brake 3 a. Spindle of rotating working part, 3 b. Spindle of stationary working part, 4 a. Rotating working part, 4 b. Stationary working part, 5. Accumulation cylinder)

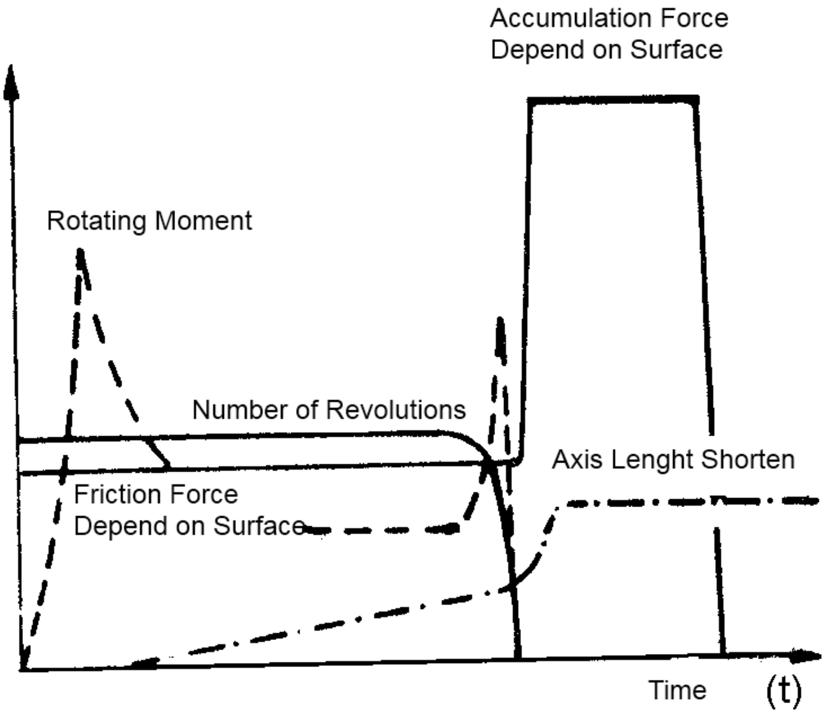

Figure 7. Process Parameters versus time in friction welding [1, 5].

2.1.1. Flywheel Induced Friction Welding

In this welding method, flywheel induced system constantly rotates and is joined to flywheel shaft system to achieve a certain speed. After reaching a certain speed, engine flywheel is separated from shaft flywheel. Shaft flywheel having a low moment of inertia stops without braking. Therefore, this welding method is known as welding of inertia in the literature. One of the parts is connected to the flywheel and accelerates at a certain speed and thus mechanical energy is stored in the flywheel. Then, the two parts are contacted and a certain welding pressure is applied. Parts under this pressure interact with each other and energy stored in the flywheel is spent for friction. The speed of flywheel decreases as welding region heats up. In some circumstances, pressure is increased before flywheel completely stop and the effect continues for some time. Flywheel induced friction welding has better seam, narrower ITAB region, better serial production, lower power need and more simple apparatus than continuous induced friction welding. The essential welding parameters are rpm, forging force on the surface, the mass of flywheel, and forging time [1, 5].

A schematic of flywheel induced friction welding machine is given in Figure 8 and process parameters in Figure 9.

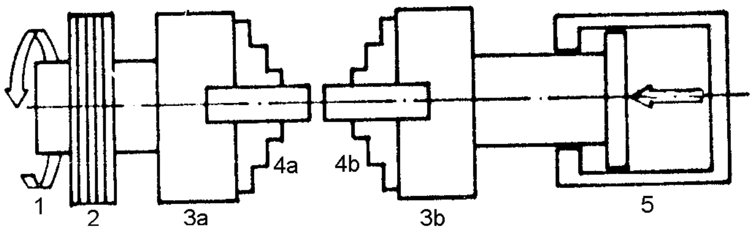

Figure 8. A schematic of flywheel induced friction welding machine [1, 5].
(1.Inducement engine, 2. Changeable Flywhell, 3 a. Spindle of rotating working part, 3 b. Spindle of stationary working part, 4 a. Rotating working part, 4 b. Stationary working part, 5. Accumulation cylinder)

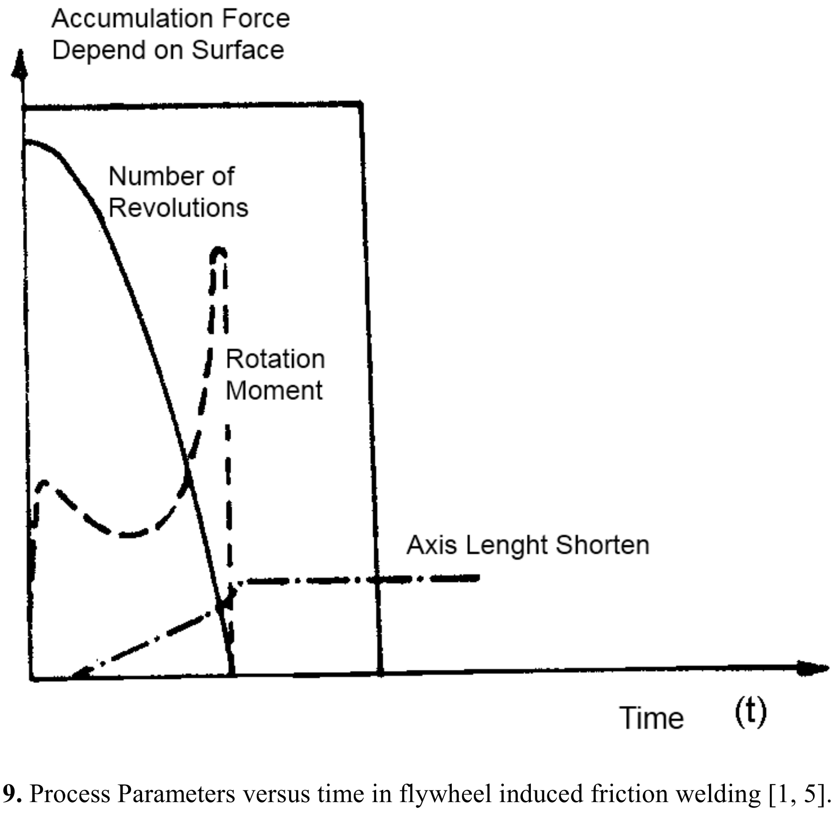

Figure 9. Process Parameters versus time in flywheel induced friction welding [1, 5].

2.1.3. Combined (Hybrid) Friction Welding

This method is a combination of aforementioned the two methods of friction welding. It has advantages in joining parts with high capacity. This method is also sometimes termed as flywheel induced friction welding. The essential welding parameters are rpm, friction force on the surface, the length of friction time, and forging time on the surface, forging time and time of brake [1, 5]. Process parameters for the combined friction welding is given in Figure 10.

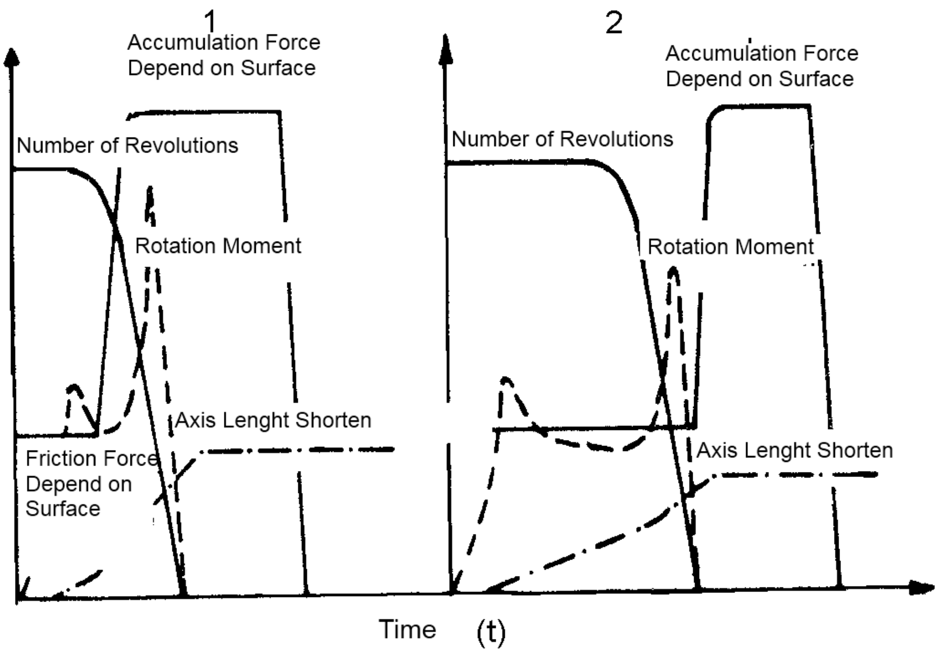

Figure 10. Process Parameters versus time in combined friction welding [1, 5].

The process of welding includes friction and accumulation stages as given in Figures 7, 9, and 10. Moment curves are essential to understanding of process parameters in all the welding methods studied. Dry friction between parts exists in the beginning of process and moment curve stabilizes after reaching the maxima.

Naked surface interactions increase due to disintegration of oxide layers among contacted surfaces and strong atomic bonding occurs as a result of these interactions. These bonds are forced to be broken due to friction. However, strong adhesion forces occur, moment increases and temperature reaches to the desired level. Velocity decreases quickly due to braking and moment becomes zero [1, 5].

2.2. Expected Properties of Friction Welding Machine

Friction welding machines are generally similar to lathe and drill. The first friction welding machines are modified forms of these machine tools. The schematic of friction welding machine is given in Figure 6 or Figure 8. As can be seen from the figures, a friction melding machine has the main body, joining parts, rotate and accumulate mechanisms, brake system, power supply, control unit and control panel. Fricton welding machines are all-mechanized machines. Joining and releasing of parts, turning of capaklar produced due to accumulation after welding are automatically accomplished. The main functions in friction welding are joining, compressing and releasing of parts, rotation and friction under pressure, braking, accumulation and meticulous adjustments of required processing times.

Sample joining apparatus needs to have a certain rigidity, must resist increased moments, must eliminate vibrations and leaks. Especially, possible vibrations during welding process need to be taken into account while designing the friction welding machine. In addition to vibrations, other radial and axial forces have to be accounted for. Therefore, joining apparatus has to have a design which will counter compressing forces. For this process, V type two chaps or special chaps are used [6].

All stopping apparatus used to hold friction equipment must be highly dependable. A slight deformation in parts to be joined may result in a low quality welding and may also damage brake system. Brake systems automatically centerd are used in most of the applications. Friction welding machines have certain particle size and material limitations. For example, a machine having 120KN compressed force and 15KW electric engine can be used in the welding of stells with cross-sectional areas of 130-800mm^2. All machines can be adjusted to meet certain specifications and can automatically be controlled. This process is sometimes done by just manually turning off the switch or protectors [11].

2.3. The Suitability of Friction Welding and Friction Welding Capability of Materials

Knowledge on material properties and applicability of metallic materials and material combinations for friction welding is not completely clear. Experimental studies and practical applications have been giben to address this problem. Preliminary trilas have been carried out in order to determine optimum parameters of welding, the applicability of welding process for every new material or material combinations. The results of these studies are not concrete since they are experimental. They can be modified or redefines as new facts come out [12, 13].

The citeria needed for other welding methods are not valid for friction welding because friction welding is applied to materials which can not be processed with other welding methods [10].

The strength of a material and its deformation capacity under heat are the two parameters needed for the test of suitability of a material to welding. The strength of material has to be high enough to resist axial pressure and torque, which may occur due to excessive deformation. Morover, the material to be joined needs to exhibit enough heat treatment deformation behavior for the quality of joining process [12].

Materials and their combinations can be categorized into two groups depending upon the characteristics of materials to be joined. The first group of materials are the ones showing the same type of heating behavior and the second group includes materials having different hor material strength and melting temperatures. The direct welding process is applied to the first group of materials. But, preliminary trials are carried out for the second group of materials before applying welding process [10].

Several iron based and non-iron materials can be joined using the friction welding. In addition, friction welding can be used in joining of metals exhibiting different thermal and mechanical properties. Most of the time, these materials can not be processed using conventional welding methods. Friction welding method is more preferred than any other conventional welding method because metals can be joined at temperatures lower than their melting point and welding time is a lot shorter. Friction welding of metals having different thermal amd mechanical properties causes asymmetrical deformations. A higher welding strength is generally achieved for the materials giving symmetrical deformations. To achive this, Vill suggested a 15 to 25% increase in ductile parts during the welding process [11].

Any material not having good friction properties but forgable with friction welding can easily be welded. Alloy elements supplying dry oiling prevent the joining section from reaching welding temperature.

Ferrous based material from soft steel to high alloyed steels can be processed using friction welding. Steels with lower strength can be more easily joined with a large parameter range. High alloyed steels, on the other hand, requires critical processing parameter range and higer axial forces. Heat-treated stainless steels can be welded in a more sensitive parameter range just as in high alloyed steels. For high alloyed steels, higher forces on the surface and long friction time are needed due to their lower deformation capability. Especially for “air watered steels”, a suitable ITAB region is required to minimize cooling rate of welding region. Since crack formation is very fast in high strength materials, joined surfaces have to be rid of crack effects [11].

Sintered materials, Al, Cu, Ti, tr, Mg alloys, heat resistant Ni and Co alloys and refractory materials such as Ta and Mo alloys can successfully be joined by friction welding [13].

- Austentistics steels due to their higher ductility and heat deformation capability need lower friction time and pressure,

- Higher stregh alloys due to their lower heat conductivity and higher heat strength capability need higher friction time and lower friction pressure,

- Cu, Al, Ti and their alloys are subjected to friction welding at higher rpm and lower friction pressures.

A successful friction welding can not be achived in some metals and alloys due to their inherent metallurgical properties.

These are as follows:
- All pig iron due to its friction temperature limitation caused by free graphite,
- bronze and grass having Pb concentration of more than 0.3% and automat steels having S or Pb concentrations more than 0.13%,
-highly anisotropic materials due to their high fractureability in the transtition region
-materials having graphite, Mn, S and free Pb in their structure [10, 13].

2.4. Preparation of Materials for Friction Welding and the Design

Parts to be processed using griction welding method have different design considerations from those processed with conventional welding methods. Paint, oil and other impurities do not pose a problem in friction welding. Though not preferred, surfaces cut by oxygen can be welded. Moreover, additional layer on the surface such as corrosion layer does not affect welding process. However, thick oxide layers, pin sand needles on the surfaces, deep cuts and holes habe to be avoided. A poor heat distribution may occur if too many indent and bulge are present. Bulges behave as bracket beam when surface roughness is very high. Inner layers occur and addition layers occur even with deformation because root (base) structure is cold. Deformation in welding region must remove these structures. In addition, surface pre-teratment of different metals and alloys is significant. A special form of a material on surfaces to be weld is not needed as in the case of traditional welding processes. However, spherical or conical mouth may be necessary in high diameter parts to assit in friction. Mininum axial loss is required in parts to be welded. The tolerance of welding depens on not only defects in working parts but also the welding machine itself [12, 14]. The tolerance value for lenth is given as 0.203 mm. Begg and Humpreys have reported 0.2mm axial KACIKLIK tolerance and 0.001 rad angular tolerance [15].

Basic design of friction welding includes rod-rod, pipe-pipe, pipe-sheet, rod-sheet and pipe-disc combinations. Based on friction welding theory, at least one of the parts has to be able to rotate. Mixed type parts and difficult to be forged parts can be joined using more than one friction welding machine. The angular range in friction welding is given to be between 30 and 45 or 45 anf $60^{0.}$ D. L. Kuruzar suggested an angle more than 30°. In some of the designs, welding joints are specifically designed to account for problems in removing metal parts after welding [14].

2.5. Parameters of Friction Welding

Apart from traditional welding methods, several welding parameters can be controlled in friction welding. These parameters include diameter of experimental rod, rpm of the part, rpm of parts in to lathe, friction contact time, forging delay time, forging time, time of increased friction pressure, friction pressure. Moreover, other parameters such as geometry of parts and material properties are also significant. The rpm of rotating parts, friction time, friction pressure, forging pressure and time are the parameters needed to be take into account while optimizing the welding process. A successful welding process can occur if parameters are optimized [8].

The lower rpm of roating parts causes enormous moments and nonuniform heating results in. On the other hand, lower rpm values minimize formation of intermetallic compounds. With higher rpm of rotating parts, ITAB widens, and power supply is not affected. To prevent overheating in the welding region, friction pressure and friction time have to be carefully controlled.

Pressure values applied in welding is very significant bcause it controls temperature gradient and affects rotoational torque as well as power.

Friction and forging pressure are directly related to geometry and material properties of parts to be welded and have a wide range.

Over applied pressure values increase power needs accordingly. Due to increased energy input, higher pressures decrease the width of ITAB, accelerate metal displacement ratio and reduces welding time resulting in heat band on the boundary. The variable of pressure can be controlled by the temperature in welding region and decrease in axial length. Optimum pressure must be applied to materials in order to get uniform deformations throughout [13].

Friction pressure has to be high enough to allow the removal of oxides, to get uniform heating throughout and to interrupt the affinity between surfaces and the air. The application of forging pressure especially during friction process improves welding properties.

Forging pressure depends on the heat yield stress of the material. It should neither be high enough to cause welding accumulation nor is it low enough to cause under welding. Forging pressure in some materials are determined depending on the lower strength material. The diffusion of macro particles from surfaces to surfaces occur during forging. Bonds continuously form and break down during friction at interface locations. In the beginning of forging maximum bonding have to occur on the surface because permanent bonds are these lastly formed bonds. Parts need to interact with each other under pressure and this pressure should not be reduced until welding heat cools down. [11].

Friction and forging times are directly related to material properties. The friction time should allow plastic deformation to occur or remove possible residuals and particles. For a high quality welding joint, minimum friction time needs to be exceeded. Lower friction times as well as nonuniform heating result in nonjoined areas at the interface and inadequate plastic deformation. This brings the problem of low quality weld. Higher friction times, on the other hand, causes rough structure and wide ITAB region formation. This is especially important to the welding of different materials because poor mechanical properties may be obtained due to formation of undesirable substances. Moreover, overheating and material loss are also possible [13].

2.6. Applications of Friction Welding

This method is especially useful for the serial production. Relatively high overhead cost is balanced with higher production rate and lower labor requirement. Process has several dimensions and hardware could easily be adjusted. Thus, the method also becomes useful for the production of relatively smaller parts. With these advantages, friction welding has found widespread application in the industry. Friction welding can generally be applied in the following industries with listed applications:

-Machine production and spare part industry: cogwheels, piston rods, hydraulic cylinders, radial pomp pistons, shaft with worm screw , crankshafts, drill bits, valves.

-Automative industry : valves, clack valve, drive shafts, gear levers, axle fasteners, break spindles, transmission mechanisms, preheat rooms, pipe spindles, banjo axles.

- Aviation and space industry: repulsion jets, combustion chambers, spindles, turbines, rotors, pipes, fittings, flanges.

- Work set industry: Spiral drills, milling cutters , borers, reamers, cutting tools.

- Electrical, electronics, and chemical industry: receiver camera for gas analysis, segregation columns forchromatograph, Electrical connectors, continuous solder top, swing contacts, pipe fittings [16].