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FATIGUE TEST OF PLASTICS AND MANUFACTURING COLLET NUT DRIVER FOR INTEGRATED ROTATING BENDING FATIGUE TEST MACHINE

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Abstract. The unknown fatigue life of injection molded plastic materials and the ineffectiveness of clamping both ends of the specimen in the collet of the Integrated Rotary Bending Fatigue Testing Machine with manual tightening and loosening are the obstacles faced. The purpose of testing and making a collet nut driver is to obtain a prediction of the fatigue life of injection molded plastic materials and to increase the effectiveness of clamping the end of the specimen with the help of a DC motor drive. The research method uses experiments which include injection molding of plastic materials of the type Polypropylene (PP) and Acrylonitrile Butadiene Styrene (ABS), checking the straightness and surface finishing of the specimen, fatigue testing at 1800, 2000, 2200 rpm, analysis of fatigue test results, and design-manufacturing collet nut drive with DC motor drive and transmission of a pair of spiral cone gears, manufacture of DC motor sliding movement mechanism along the reach of both ends of the specimen, installation of electric power circuits for direction and electric current switches for clockwise and counterclockwise rotation functions, and analysis of the results of the fatigue test and performance of the collet nut driver The results of fatigue testing at a bending stress (S) of 68 MPa for PP material show that at 1800 rpm, the fatigue life (N) was obtained at 2,014,605 cycles and at 2200 rpm, N was obtained at 1,506,486 cycles. Meanwhile, for ABS specimens, at 1800 rpm, N was obtained at 1,547,106 cycles and at 2200 rpm, N was obtained at 1,190,425 cycles, which means PP material has a longer fatigue life compared to ABS. The test results of the DC motor drive on the collet nut showed that the duration of tightening/loosening was 4.4 times faster than manually, which originally had a duration of 66 seconds, down to just 15 seconds for the DC motor drive.

Keywords: Acrylonitrile Butadiene Styrene (ABS), Collet Nut Driver, Fatigue Life, Injection Molding, Polypropylene (PP).

1. INTRODUCTION

The use of plastic in modern society has increased rapidly [1], because plastic has advantages such as being strong, flexible, light, cheap and stable [2][3]. Most of the plastics used in the industrial world include Polypropylene (PP) plastic including waste [4] and Acrylonitrile Butadiene Styrene (ABS). This plastic is most widely used in everyday life, because it has good mechanical properties with low density, heat resistance, moisture resistance, and good dimensional stability [5]. PP and ABS plastics, including those printed with 3D [6-7], are widely used in car spare parts and have been proven to be able to balance car functions such as reducing weight and maintaining passenger safety [8]. One of the uses of PP plastic is rear fender products, while plastic (ABS) is applied to the front crossbar of the car as a bumper [9].

One of the tests to determine the fatigue life of a material is testing using a rotary bending fatigue machine [10-11]. The test is expected to be able to estimate the fatigue life of a component, the rotary bending fatigue machine plays a very important role in fatigue testing.

Rotary Bending Fatigue is a test tool to determine the fatigue limit that occurs in materials, where fatigue occurs due to cyclical loading [12]. Fracture occurs because when the material has experienced a stress cycle which produces permanent damage as a process of permanent structural change at one point, it becomes the initiation of a crack, the spread of the crack and finally fracture which is carried out by varying loading methods [13]. The efficiency and effectiveness of these plastics is always a consideration in selecting materials according to their use.

With the widespread use of Additive Manufacturing in production, components made using Additive Manufacturing techniques can be used as components made using traditional/injection technology [14-15]. The process of making specimens was carried out using Additive manufacturing techniques using PP and ABS plastic ore. The specimens used follow the standard specimens from R.R. Moore [16].

The fatigue test method uses a rotary rod fatigue testing machine, as the specimen is gripped at both ends with a collet chuck and then the specimen is rotated at a certain speed with a load under the specimen, so that the specimen appears to receive cyclical or repeated loads. The availability of standard rotating bar fatigue testing machines whose functionality and affordability can support the ease of obtaining information about predicting the fatigue life of materials [17].

The position of installation and removal is very important in this test method, installation and removal of a fatigue test specimen that has broken after being fatigue tested, requires the operator to come to the fatigue test machine, after finding out via SMS sent by the machine when the specimen breaks. Manual installation requires certain skills so that the fatigue test can be carried out properly and does not slip during the fatigue test. In the future, it would be better if the broken specimen was replaced with a new specimen if it could be carried out automatically, the initial stage of designing the collet release and tightening was to use an automatic method, if it could be equipped with a robotic hand, however, the complete specimen replacement could be carried out automatically. Replacing a broken specimen with a new specimen semi-automatically requires a special construction design for the two collets on the existing integrated rotary bending fatigue testing machine.

2. METHODS

The research is a type of experimental research to test plastic materials that are often used in people's lives, namely PP plastic and ABS plastic. The research aims to determine the fatigue life of each material with the flow diagram is shown in Figure 1.

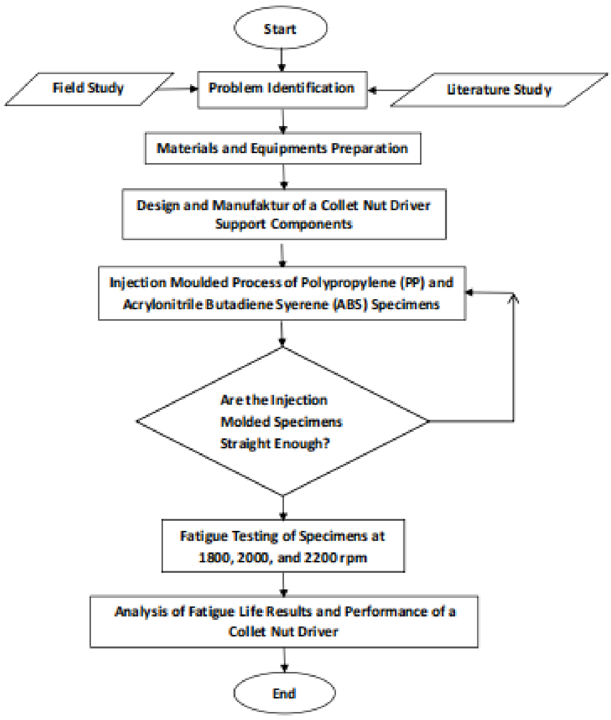

Figure 1. Research Flow Diagram

The research was carried out from March to July 2023 at the Materials Testing Laboratory on the 3rd Floor of the

Mechanical Engineering Building, Malang State Polytechnic, located at Jl. Soekarno-Hatta No. 9 Malang City, East Java. Integrated Rotary Bending Fatigue Testing Machine, FATEMACH is shown in Figure 2.

Figure 2. Fatigue Testing Machine, FATEMACH, Left Side View, Front View, and Right Side View

Fatigue life data in units of cycles obtained from testing for PP and ABS materials is directly recorded by the computer in the Integrated Rotary Bending Fatigue Testing Machine for the number of revolutions until the specimen breaks, while the load in units of kg given is recorded in the data entry to on the computer before the test includes the name of the material, the contact number of the operator who will send a short message (SMS) to the mobile phone, and the date. The bending stress is directly calculated by the computer and plotted directly in the form of an S-N curve. The shape of the collet nut and its installation on the spindle is shown in Figure 3.

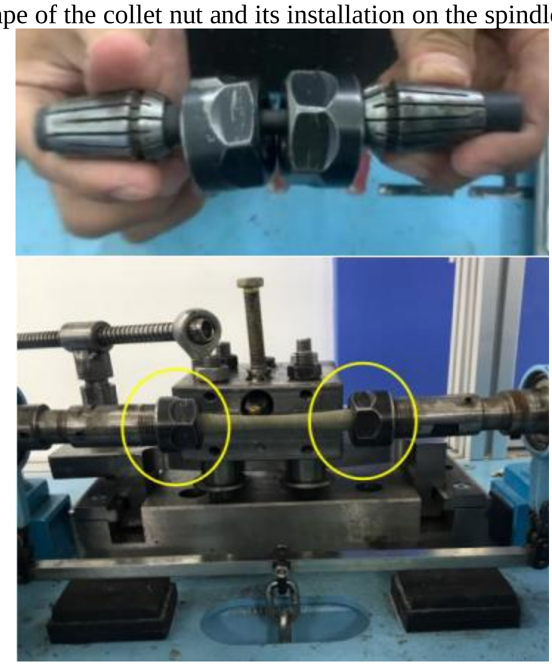

Figure 3. The shape of the collet nut and its installation on the spindle

3. RESULTS AND DISCUSSION

In fatigue testing, installing specimens with manual collets requires skill and time in installing specimens using a 22 mm spanner and a 30 mm wrench with limited space, so it becomes less effective. By changing from a manual collet to a collet nut driver with the support of a DC motor and a pair of spiral cone gears, it can make it easier to install fatigue test specimens and save the time. The collet nut driver mounted on the integrated rotary bar fatigue testing machine table is shown in Figure 4.

Figure 4. Collet nut driver mounted on an integrated rotary bending fatigue testing machine table

The trial results of installing a specimen with 2 ends clamped manually using a 22 mm spanner and a 30 mm wrench took 66 seconds, while installing a specimen with 2 ends clamped with a collet nut driver assisted by a DC motor with a torque of 6 Nm requires a duration of only 15 seconds, which means its effectiveness is 4.4 times faster or only takes 22.7% of the time compared to manually installing specimens. The fatigue life of PP plastic is shown in Table 1 and Figure 5.

Table 1. Fatigue Life of PP Specimens

Specimen	Test Speed (rpm)	Load (kg)	S (MPa)	N (Cycles)	Duration (Minutes)
PP	1800	10	228	42327	21
		9	205	82255	45
		8	182	128739	73
		7	159	182553	104
		6	136	282164	160
		5	114	418613	239
		4	91	1305358	746
		3	68	2024567	1043
	2000	10	228	29439	15
		9	205	67482	34
		8	182	101469	62
		7	159	152547	90
		6	136	232912	148
		5	114	338455	221
		4	91	1233525	702
		3	68	1702591	1011
	2200	10	228	22371	10
		9	205	43034	30
		8	182	73784	56
		7	159	113045	85
		6	136	178515	136
		5	114	278258	180
		4	91	1056839	672
		3	68	1506486	936

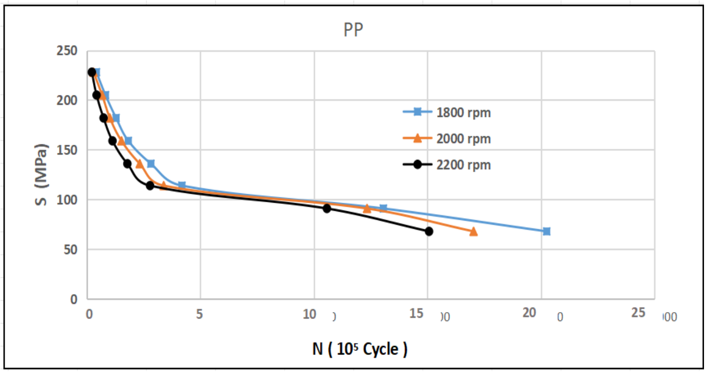

Figure 5. S-N Curve of PP

From fatigue testing on PP with test speeds of 1800 rpm, 2000 rpm, 2200 rpm, the data in Table 1 shows that PP material with a speed of 1800 with a load of 3 kg and a bending stress of 68 MPa has a longer fatigue life of 2014605 cycles with a duration of 1043 minutes, while for speeds of 2000 rpm and 2200 with a load of 3 kg with the same bending stress the fatigue life values are 1684536 cycles with a duration of 1011 and 1506486 cycles with a time of 936 minutes respectively. The fatigue life of PP plastic is shown in Table 2 and Figure 6.

Table 2. ABS Specimen Fatigue Life Table

Specimen	Test Speed (rpm)	Load (kg)	S (MPa)	N (Cycles)	Duration (Minutes)
ABS	1800	10	228	5459	4
		9	205	8336	6
		8	182	12562	9
		7	159	16324	12
		6	136	33840	16
		5	114	73258	37
		4	91	340979	205
		3	68	1547583	852
	2000	10	228	4868	3
		9	205	7456	4
		8	182	9651	6
		7	159	11751	9
		6	136	26676	13
		5	114	68558	44
		4	91	294643	178
		3	68	1317534	757
	2200	10	228	4037	2
		9	205	5905	2
		8	182	8384	4
		7	159	9991	5
		6	136	23851	12
		5	114	63880	51
		4	91	289660	185
		3	68	1190457	766

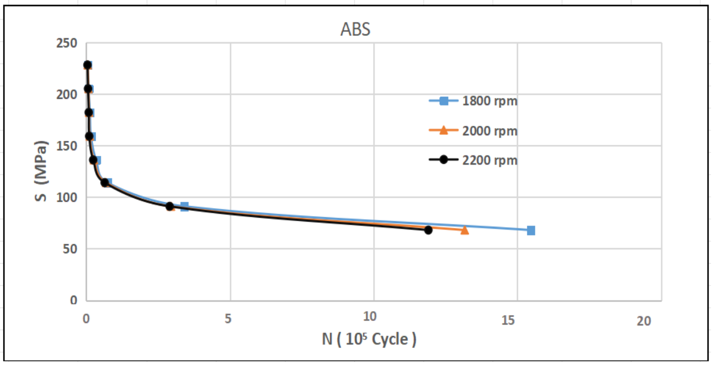

Figure 6. S-N Curve of ABS

From fatigue testing on ABS with test speeds of 1800 rpm, 2000 rpm, 2200 rpm, the data in Table 2 shows that ABS material with a test speed of 1800 rpm with a load of 3 kg and a bending stress of 68 MPa has a longer fatigue life of 1547106 cycles with duration of 852 minutes, while at speeds of 2000 rpm and 2200 with a load of 3 kg at the same bending stress the fatigue life values are 1317029 cycles with a time of 757 minutes and 1190452 cycles with a time of 766 minutes respectively.

4. CONCLUSION

Conclusions from the research results of fatigue tests on PP and ABS plastic materials as well as collet nut driver performance tests are:

1. The fatigue testing results at a bending stress (S) of 68 MPa for PP material indicate that at 1800 rpm, the fatigue life (N) was 2,014,605 cycles, while at 2200 rpm, N was 1,506,486 cycles.
2. The fatigue testing results at a bending stress (S) of 68 MPa for ABS material show that at 1800 rpm, the fatigue life (N) was 1,547,106 cycles, and at 2200 rpm, N was 1,190,425 cycles, demonstrating that PP material has a longer fatigue life (N) compared to ABS.
3. The performance test results of the collet nut driver with a DC motor drive show that the tightening/loosening duration is 4.4 times faster than manual operation, reducing the duration from 66 seconds to just 15 seconds when driven by a DC motor.

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