JURNAL ILMIAH TEKNIK INDUSTRI
ISSN: 1412-6869 (Print), ISSN: 2460-4038 (Online)
Journal homepage: http://journals.ums.ac.id/index.php/jiti/index
doi:10.23917/jiti.v20i1.13765

Implementation of Additive Manufacturing in Designing A Wrist Hand Orthosis to Increase Grasping Time On The Left Hand of Cerebral Palsy Children

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Abstract. *Cerebral palsy (CP) is a physical disability in childhood with impaired development of movement and posture due to disorders of the fetal or infant's brain. The measurement results of the spastic HCP children at YPAC Surakarta show that 8 attributes have difficulty grasping the precision type and 9 attributes of the power type. To solve this problem, hand tools called wrist hand orthoses are needed to restore hand function. This study aims to design alternative designs and make prototypes of wrist hand orthoses using the 3D printing process. The research stages began by collecting activity daily living (ADL) data and anthropometric data, taking a participatory approach to produce design alternatives, selecting design alternatives with the PUGH's concept selection method. The chosen design alternative will be printed through the additive manufacturing process. Testing with the 2015 human grasping database showed an increase in grasping time in 13 types of ADL activities from 17 ADLs.*

Keywords: *cerebral palsy; wrist hand orthoses; 3D printing; PUGHS method; grasping time*

I. INTRODUCTION

The Human Activity Assistive Technology (HAAT) model is needed to design, select, implement, and evaluate assistive technology using an ordering system tailored to the user's wishes. The HAAT model is used to determine a solution in the assistive technology system, according to the needs of disabilities such as children with cerebral palsy (Cook & Polgar, 2008). Cerebral palsy (CP) is a physical disability in childhood with impaired development of movement and posture due to disorders of the fetal or infant brain (Oskoui et al., 2013). One type of CP is commonly found in Hemiplegic Cerebral Palsy (HCP), with an incidence of 20% - 30% of 1000 births of children (Pharoah, 2007). Motor disorders in CP are hypertonicity, spasticity (spastic), or stiffness in 86% of individuals (Australian Cerebral Palsy Register Group, 2016).

Observations in children with *spastic* HCP in the Yayasan Pembinaan Anak Cacat (YPAC) Surakarta as many as 2 children. Children with *spastic* HCP experience stiffness in one hand and weakness of the hand muscles (Brashear, 2010). The stiffness of the left-hand segment and the left-hand fingers makes it difficult for the HCP spastic child to grasp and hold objects for a relatively long time. The measurements using the *human grasping database* 2015 showed that the children *spastic* HCP experienced interference with *precision* and *power* grasping process. The children's *spastic* HCP measurement results showed that 8 out of 17 attributes had difficulty grasping types *precision.* The problem of accuracy in capturing and grasping small and thin objects such as medicine, keys, and paper. Other measurement results show that 9 attributes have difficulty grasping the type of *power.* Difficulty with types of *power* such as easily releasing when holding objects due to weakness of the muscles of the hands and fingers, for example, carrying shoes and sweeping the floor.

The inability of the left-hand segment and the left hand's fingers to support the right hand to carry out daily living activities makes HCP spastic children need a relatively long time to grasp and hold objects. To solve this problem,

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Submited: 24-02-2021 Revised: 20-05-2021
Accepted: 08-06-2021

hand tools called *wrist hand orthoses* are required. The purpose of *wrist hand orthoses* is to regain hand function like normal children and improve the ability to grasp and grasp objects for a relatively long time (Kang and Lee, 2013). The *wrist hand orthoses* on the market include *gripeeze and active hands*, *easy hold gripping cuff*, *saeboglove and saeboflex*, and *phoenix hand*. These products' *orthoses* still use system *customization*, have high prices, and must be imported abroad. Each product *orthoses* has different purposes and functions according to user needs.

Saeboglove and saeboflex products can be used to solve problems in HCP spastic children but are constrained by a high price of $ 599.00 or around Rp. 8,500,000.00 (Orthocanada, 2020) for 1 wrist hand orthoses product imported because it is not produced domestically. So it is necessary to conduct further studies and research to develop this product to be produced domestically at a lower cost.

The design of Wrist Hand Orthoses is produced through additive manufacturing technology because it can produce products with fast time, low cost, and the final product is accurate and precise, which is popularly known as 3D printing technology in manufacturing environments. The development of additive manufacturing has grown rapidly due to the need for individual devices that are able to adapt well to the user's anatomical shape (Gibson and Srinath, 2015). For this reason, additive manufacturing can assist in the manufacture of wrist hand orthoses. The device can adapt to complex geometric features with high accuracy and precision and be produced efficiently in cost and time (De Carvalho Filho et al., 2019).

Research on the design of wrist hand orthoses tools began with a participatory approach involving children with spastic HCP, YPAC physiotherapists, YPAC administrators, parents, and manufacturers as stakeholder entities. A participatory approach is used to identify stakeholder needs for wrist-hand orthoses design attributes with different levels of difficulty and weakness. This study's design of wrist hand orthoses is based on product development steps (Ulrich and Eppinger, 2015). Wrist hand orthoses are designed according to concept selection through Pugh Concept Selection (Pugh, 1990). The concept selection strategy is made according to the Pugh matrix to compare design alternatives to select predetermined criteria. The concept selection in wrist hand orthoses design aims to increase the duration of holding objects. The ease of wearing wrist hand orthoses positively impacts spastic HCP children by increasing grip strength and reducing muscle tension.

This study aims to design alternative designs and make prototypes of wrist hand orthoses using a 3D printing process and test prototypes of wrist hand orthoses according to the 2015 human grasping database from Yale University.

II. RESEARCH METHOD

This research began with direct observation at the Yayasan Pembinaan Anak Cacat (YPAC) Surakarta on June 30, 2020 and July 3, 2020. The object of this research was a 12-year-old girl who had spastic HCP (Hemiplegic Cerebral Palsy) with weakness in her hand and finger segments. Left hand.

The data collected were on the ability to hold HCP spastic children's objects while doing daily living activities and left-hand anthropometric data. The techniques used to obtain the above data include observation, interviews, focus group discussion (FGD), questionnaires, and direct measurements. Data collection involved 5 stakeholder groups, namely HCP spastic children, YPAC physiotherapists, YPAC boarders, families of HCP spastic children, and manufacturers/designers.

Gripping ability data will be processed through a participatory approach and identification of the need for wrist hand orthoses design. The results of the participatory approach data processing and design requirements will produce an alternative design. Designing each alternative concept uses Autodesk Inventor 2017 software.

The next stage is the design selection process using the PUGH's concept selection method based on several design criteria. The design selection process includes two stages, namely concept screening, and concept assessment. The chosen design alternative will be printed through the 3D printing process using the Prusa i4 3D Printer. The assembly process for each design component will be carried out to produce a prototype wrist hand orthoses.

The wrist hand orthoses prototype will be tested using the 2015 human grasping database. This test will see if there are differences in the value of grasping and holding between objects before using wrist hand orthoses and after using wrist hand orthoses. The benchmarks in this assessment should show a higher value when using wrist hand orthoses than without using wrist hand orthoses.

III. Result and Discussion

Observations of Children with Spastic HCP Cases

Research observations were carried out at the Foundation for Development of Children with Disabilities (YPAC) Surakarta on a 12 years old girl with spastic HCP. Observation and measurement

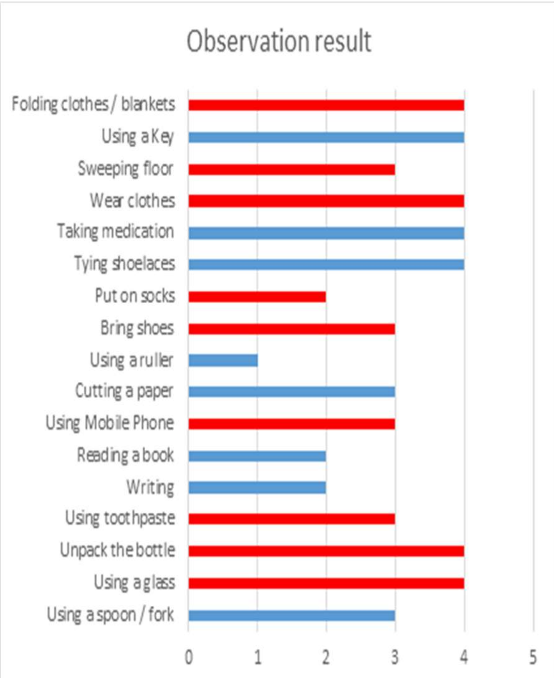


Figure 1. Graph of Early Observation Results of the Spastic HCP Child Gripping Process

using the 2015 human grasping database were then converted into 17 attributes of daily living activities, which showed disruption in the grasping process types of precision and power in HCP spastic children. The results of the initial observations are presented in Figure 1.

Figure 1 shows that 8 of the 17 attributes have difficulty grasping the precision type. The precision grip type is marked in a blue graphic. Other observations show that 9 out of 20 attributes have difficulty grasping the power type. The power type grip is marked with a red graph.

Participatory Approach

The participatory approach involved 5 groups of respondents from stakeholders, namely Nur Rohmah as a spastic HCP child, Mr. Edy Waspada, SST.FT., as physiotherapy at YPAC Surakarta, Big Brother Wan and Brother Fauzi as the family of the HCP spastic child, Mrs. Siti Qoiriyah and Mbak Shanti as board members of the YPAC Surakarta hostel, and Mr. Kardi and Mr. Hery as manufacturers/designers. The final result of the participatory approach stage is a participatory questionnaire containing 18 lists of statements of need from 6 criteria.

Table 1 will be used as a measure of whether the 18 attributes of the 6 criteria are correct or not. To find out whether the 18 attributes are correct, the reliability and validity tests will be carried out. The aim is to find out whether each attribute that has been grouped fits the criteria. The questionnaire results are used to determine the design requirements that need to be developed in the design process of wrist hand orthoses. Design requirements are obtained through the average value of each criterion. Based on this assessment, criteria that have low to high ratings are obtained.

Based on Figure 2, the 4 criteria with the highest score will be selected as the most needed criteria to optimize the design of wrist hand orthoses. Features and strengths are not included in the criteria because they have the lowest average value. Each of the technical requirements of these criteria is already represented by other criteria. Performance criteria define the features criteria. The reliability criterion represents the

Table 1. Criteria and Needs for Design of Wrist Hand Orthoses

No	Criteria	Identification of Design Needs
1	Performance	Orthoses are capable of power grip and precision grip. Orthoses can be set up quickly. Orthoses can help users quickly grasp and hold objects. Orthoses allow the user to move the finger in an accurate position
2	Features	Orthoses have a pen holder and a spoon & fork holder. Orthoses have an interesting and less scary shape. Orthoses have a colorful appearance that kids love
3	Strength / Power	Orthoses have a tough and strong construction Orthoses can be used 1 year before maintenance. Orthoses can work in different environments (rain, summer, etc.)
4	Flexibility	Orthoses can be assembled (portable) Orthoses provide adaptability and mobility Orthoses prevent fatigue
5	Safety	Orthoses do not damage the object being held. Orthoses can be used with low physical effort.
6	Reliability	Orthoses prevent users from performing complex movements. Orthoses are easy to care for and clean with household cleaners. Orthoses can be used comfortably for at least 8 consecutive hours.

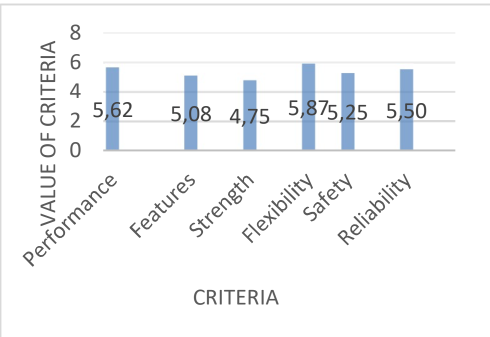


Figure 2. Graph of Mean Value of Wrist Hand Orthoses Design Criteria

strength criterion. Therefore, the next research to design wrist hand orthoses focuses on 4 selected criteria: flexibility, performance, reliability, and safety.

Anthropometric Measurements

Hand anthropometric data are taken based on standard adaptation provisions from Chandra et al. (2011) and dimensions according to Purnomo (2014). Hand anthropometric measurements were taken directly using calipers, roll metline, and 3D printed cone. The anthropometric data can be seen in Table 2.

Design Technical Requirements

The design of wrist hand orthoses for HCP spastic children uses identification data of design needs as a reference for preparing specifications and hand anthropometric data as a reference for tool size dimensions. The process of decomposing design requirements into simpler technical requirements is carried out in compiling

Table 2. Anthropometric Data of Spastic HCP Children's Hand

No	Dimensi	Kode	Ukuran (mm)
1	Thumb Width	LIJ	13,9
2	Thumb Length	PIJ	57
3	Index Finger Width	LJT	13
4	Index Finger Length	PJT	67,5
5	Middle Finger Width	LTJG	12,6
6	Middle Finger Length	jpg	74,2
7	Ring Finger Width	LJM	11,5
8	Ring Finger Length	PJM	67
9	Little Finger Width	LJK	11,4
10	Little Finger Length	PJK	48
11	Hand Length	PT	155,7
12	Palm Length	PTT	68
13	Wide Hand Metakarpal	LTM	59,8
14	Wide Hand To Thumb	LIJ	72,6
15	Thick Hand Thumb	TTIJ	28,3
16	Thick Metakarpal Hands	TTM	25,2
17	Thumb Thick	TIJ	13,6
18	Thick Fingers	TJ	18,8
19	Wide Hand Grasping	LTM	69,8
20	Length Hand Grasping	PTM	97
21	Thumb to little finger distance	DIJK	144,2
22	Maximum Grasp Diameter	DGMak	49
23	Minimum Grasp Diameter	DGMin	2,5
24	Fist Height	TgKT	62
25	Fist Width	LKT	81,7

Table 3. Design Technical Requirements

No	Identification of Design Needs	Technical Requirements
1	Orthoses are capable of power grip and precision grip	Tools can help users complete daily living activities that require various sizes
2	Orthoses can be set-up easily	1 person can do the set-up process
3	Orthoses can help users quickly grasp and hold objects	The tool allows the finger to do the grip and grip it needs in no time
4	Orthoses allow the user to move the finger in an accurate position	The tool can make each finger have different grip movements The tool can hold objects that are grasped and held to be more stable
5	Orthoses can be assembled (portable)	The tool is not significant and easy to carry everywhere
6	Orthoses provide adaptability and mobility	Tools can be used flexibly The dimensions of the tool adjust to the user's anthropometry
7	Orthoses prevent fatigue	The tool does not require excess energy when used
8	Orthoses do not damage the object being held	The tool is made from materials that are not sharp and environmentally friendly
9	Orthoses can be used with low physical effort	Tools minimize repetitive actions and sustained physical effort
10	Orthoses prevent users from performing complex movements	The appliance can be operated in quick and simple steps
11	Orthoses are easy to care for and clean with household cleaners	The tool does not require special equipment for routine maintenance or for mounting the device
12	Orthoses can be used comfortably for at least 8 consecutive hours	The user does not experience any pain or injury after using the tool The appliance does not cause skin irritation after using the device.

specifications and design dimensions to make it easier to understand. The technical requirements for tool design can be explained in Table 3.

Determination of design specifications

Based on the observations of spastic HCP children and interviews with needs through participatory questionnaires, a concept emerged to design a wrist hand or those for HCP spastic children. The concept of wrist hand orthoses has the following functions:

a. Support the position of the hands. This function aims to support and support the hands so that the position of the hands conforms to the shape of the tool. The tool support must have strong construction and be made of the primary 3D printing material.
b. Holding Tool. This function aims to keep the tool in position and not be separated from the hand when used. The tool holder will maintain the tool from under the wrist and fingers. The tool holder has a position fixing feature to adjust the size of the user's hand.
c. Moving Tools. This function is intended as a source of power so that the tool can provide the pressure needed to hold the object's position while carrying out the process of grasping and holding things. The drive tool has easy application and has a considerable compressive strength but low power.
d. Regulating Tool Pressure. This function is intended so that the tool can help users grasp and hold objects. This function determines the size of the pressure applied. The propulsion is made of elastic material, which allows the user to adjust when it is time to open and close the fist.
e. Provider User Convenience. This function is intended to not experience pain and does not cause irritation when used. The user comfort function is made of a soft cloth and is placed under the primary material so that the tool does not directly contact the user's skin.

Generating Concept Alternatives

Based on the needs of the design functions obtained, the design of wrist hand orthoses include the primary material of 3D printing, the holding tool system, the tool moving, the tool pressure regulator, and providing comfort when used. Alternative concepts can be explained as follows:

a. 3D Printing Material. Alternative 3D printing materials provided are ABS 3D filament, PLA 3D filament, and PET filament.

b. Tool Hold System. Alternative tool holding systems used are plastic buckles, cloth and plastic molded zippers, and velcro mounting tape.
c. Tool Drive System. The alternative drive system used is SS 304 coil spring and hinge system.
d. Tool Pressure Regulating System. Alternative tool pressure regulating systems are made of rattail cord, fishing line, and nylon rope.
e. Provider of User Convenience. Alternative materials to provide comfort to users when using wrist hand orthoses are foam, flannelette, and polyester fabric.

Based on these alternative concepts, a combination of components can be arranged in accordance with the core concept of designing wrist hand orthoses. Each component is combined based on the ability of each alternative solution and whether this component can be paired with other alternative components. According to Richardson et al. (2011), concept determination using a morphological chart enlarges the design space to be explored and represents various concepts that allow unexpected component matching to be considered.

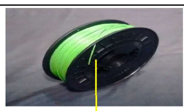
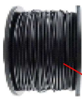
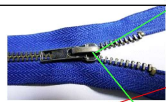
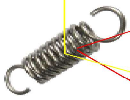
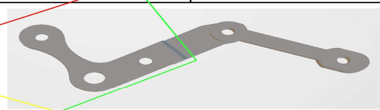
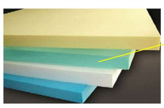
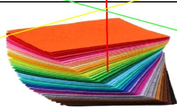
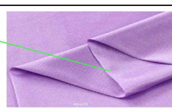
The morphological chart shows the design concept obtained based on 5 predefined design functions. The combinations obtained are 3 design concepts: green for design concept I, red color for design concept II, and yellow color for design concept III. The morphological chart can be explained in Table 4.

The three design concepts that have been described on the morphological chart are defined as follows.

a. Design Concept I

The first design concept uses PET filament as the primary material in designing wrist hand orthoses. PET filament is used because it does not bend and shrink easily. To hold the tool from under the hand so that it does not come off when used, the I design concept uses a plastic molded zipper because it is more robust and more durable. The design uses a 3D-printed arm hinges design To move the tool. The 3D-printed arm hinges design has the advantages of flexibility and broader movement. The presser will use its smooth surface rattail cord and is suitable for decorative knots. To provide comfort to the user, the I design concept uses polyester fabric because it is lightweight and durable.

Table 4. Morphological Chart Design of Wrist Hand Orthoses

Technical Requirement	Function	Component	Alternative A	Alternative B	Alternative C
1, 2, 6, 8, 10, 13, 14, 15	Support the position of the hands	3D *Printing* Material			
2, 6, 7, 8, 12	HoldingTool	Tool Hold System			
3, 4, 5, 7, 9, 11, 12	Moving Tools	Tool Drive System			
3, 4, 5, 7, 9, 11, 12	Regulating Tool Pressure	Tool Pressure regulating System			
6, 8, 9, 14, 15	Provider User Convenience	Provider of User Convenience			

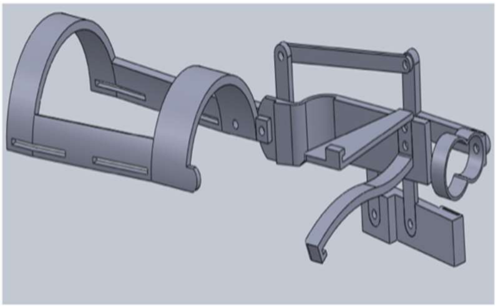


Figure 3. Draft Design Concept I

b. Design Concept II

The second design concept uses PLA 3D filament because this material is the easiest to process and can give an excellent final result. To hold the tool from under the hand, Design Concept II uses velcro mounting tape to bind and hold objects fast and straightforwardly. To move the tool, the design uses SS 304 coil spring measuring 30 mm. SS 304 coil spring has the advantage of being lightweight for the power it provides and flexibility for the user. The tool pressure regulator will use a fishing line because it can produce a strong and elastic knot. For providing comfort to users, design concept II uses flannel because it has the advantage of not wrinkling easily, and the soft fabric can retain body heat.

c. Design Concept III

Design concept III uses ABS 3D filament as the main material because this material is lightweight and has high heat resistance properties. Design concept III uses plastic buckles to hold the tool from under the hand so it does not come off when used because it can be used easily and is waterproof. To move the device, the design uses SS 304 coil spring measuring 30 mm. SS 304 coil spring has the advantage of being lightweight for the power provided and can provide comfort and flexibility to the user. The tool pressure regulator will use nylon rope because it has resistance to friction and is more elastic in making knots. Design concept III uses foam to provide comfort to users because it is light, soft, and soft, providing comfort and avoiding injury when used.

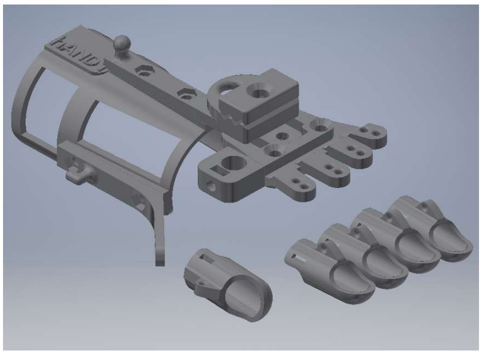


Figure 4. Draft Design Concept II

Selection of Concept Tools with the PUGH's Matrix

The choice of criteria in Pugh's selection matrix is made based on the identification of user needs. The purpose of selecting the selection criteria is to differentiate the concepts created. Concept selection with Pugh's matrix has 2 stages, namely concept screening and concept assessment.

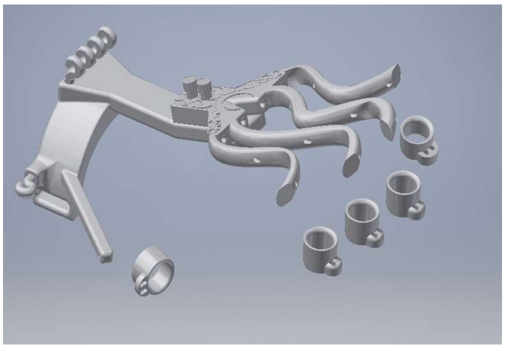


Figure 5. Draft Design Concept III

a. Concept Screening

Concept screening was carried out after the team determined one alternative concept to become a reference concept. The concept screening process will use 3 symbols as an assessment and scoring, namely the plus (+) A symbol with a relative value of "better," if the concept is better than other concepts in the same criteria, the zero sign (0) with a value "is equal to "If the concept is the same as another concept, and a negative symbol (-) with a relative value" worse "if the concept is worse than another concept in the same criteria. After that, the total weight of each criterion will be totaled for each

Table 5. Concept Screening Results

Criteria		Alternative Concept			
		I	II	III	IV
Performance	Tool ability in ADL	+	+	+	0
	Easy Set-Up	0	+	0	0
	The ability to grip quickly	0	+	+	0
	The ability to do different grips	+	0	+	0
	The power of the tool to hold objects	-	+	+	0
Flexibility	Tool size	0	0	0	0
	Tool flexibility	-	+	0	0
	Tool dimensions	+	+	+	0
Safety	Energy when using tools	+	0	+	0
	Environmentally friendly material	+	+	-	0
	Physical Effort Required	-	+	0	0
Reliability	Operation of tools	0	+	0	0
	Maintenance of tools	+	+	+	0
	Tool safety	+	-	+	0
	Use tools that don't irritate the skin	+	+	+	0
Total +		8	11	9	0
Total -		3	1	1	0
Total 0		4	3	5	15
Final Score		5	10	8	0
Ranking		3	1	2	5
Continue?		No	Yes	Yes	No

Table 6. Concept Assessment Results

Criteria		Weight	Concept			
			II		III	
			Rating	Rated Load	Rating	Rated Load
Performance	Tool ability in ADL	12	5	0,6	5	0,6
	Easy Set-Up	7	4	0,28	3	0,21
	The ability to grip quickly	10	5	0,5	5	0,5
	The ability to do different grips	11	4	0,44	5	0,55
	The power of the tool to hold objects	9	5	0,45	4	0,36
Flexibility	Tool size	7	3	0,21	3	0,21
	Tool flexibility	8	4	0,32	2	0,16
	Tool dimensions	6	5	0,3	5	0,3
Safety	Energy when using tools	10	4	0,4	5	0,5
	Environmentally friendly material	4	4	0,16	2	0,08
	Physical Effort Required	9	5	0,45	4	0,36
Reliability	Operation of tools	7	5	0,35	4	0,28
	Maintenance of tools	4	2	0,08	3	0,12
	Tool safety	7	4	0,28	5	0,35
	Use tools that don't irritate the skin	8	4	0,32	5	0,4
Total			5,14		4,98	
Ranking			1		2	
Conclusion			Yes		No	

alternative concept and will be given a ranking. Alternative concepts that will enter the concept selection stage are 2 alternative concepts with the highest value compared to other alternative concepts.

Based on the matrix above, it can be found that the alternative concept for designing wrist hand orthoses II and III is entered into the next stage, namely the concept assessment stage.

b. Concept Assessment

Concept assessment is carried out by adding the weight of importance to each criterion into the concept assessment matrix. Several different patterns can be used to weight measures, such as marking importance scores from a scale of 1-5 and allocating a value of 100%. The results of the concept assessment can be seen in Table 6.

Based on the results of the concept assessment, concept II has the highest assessment compared to concept III. So that concept II is an alternative concept chosen and will enter the 3D printing stage.

3D Printing Stage

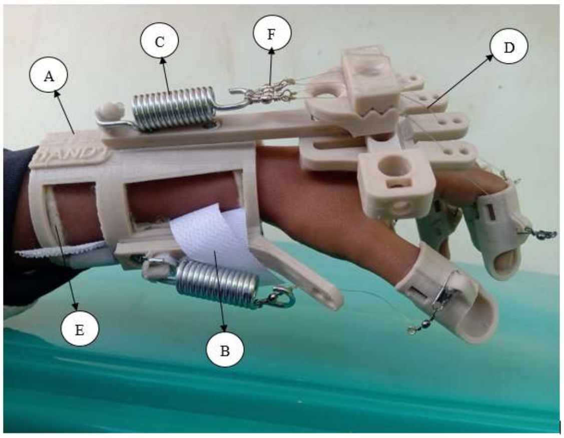
Making prototypes in this study using additive manufacturing (AM) or in the world of manufacturing is known as 3D printing. The 3D printing process uses the Prusa i4 printer with the PLA 3D filament type material. Before starting the 3D printing process, there are a number of things that must be done, namely making settings on the Ultimaker Cura software.

Ultimaker Cura software is used to adjust the layout of the 3D design objects printed on a 3D printer machine and to adjust the things that affect the final printing result. Designs that have been designed in the Autodesk Inventor 2017 application must first be converted to STL so that they can be entered into the Ultimaker Cura software. The settings made are material, temperature, layer height, infill, speed, support, and print mat. The printing process is carried out using PLA material with an extruder temperature of 210°C - 215°C and a bed temperature of 60°C. The layer height used is 0.2 mm with a grid-shaped infill. The extruder speed used is 40mm/s. The printing process uses support and a printing base in the form of a raft. The use of support in the printing process is carried out because there are hanging parts of the object, so that it requires a base in the form of support.

Settings for the printing process are also made on the hardware, namely the 3D Printer machine. The 3D printer machine used is the Prusa i4 3D printer. The settings on the 3D printer are done manually, namely entering the material, namely PLA 3d filament, into the extruder, adjusting the bed height according to the extruder height so that the printing results match the settings in the software and adjust the temperature and try the initial extruder position. The material that has been put into the extruder is sure to come out properly from the extruder. If the extruder position is in accordance with the bed position, the printing process can begin. The printing process lasts for 8 hours 25 minutes.

The overall design yields a weight of 100 grams. The recommended weight in designing wrist hand orthoses is 200 grams (Nycz, 2016). Figure 6 shows the results of the assembly and the use of wrist hand orthoses designs used on the left arm of a spastic HCP child. From the picture, it can be seen that the tool can be appropriately attached to the user's left arm. The following is the location of the parts and components used in wrist hand orthoses, which can be seen in Figure 6.

There are 5 main components in the design and 1 additional material. The additional material used is a swivel used to make a knot that connects the coil spring and fishing line. Velcro mounting tape is used as tool support. The tool supports help maintain the stability of the tool position on the user's arm (Safonov, 2017).



Information:
A = Main design of PLA 3D Filament, B = Velcro Mounting Tape, C = Coil Spring, D = fishing line, E = Flannelette, F = Additional Material (Swivel)

Figure 6. Examples of Using Wrist Hand Orthoses on User's Arm

Testing Stage of Wrist Hand Orthoses

The test was carried out using the 2015 Human Grasping Database. This test will see if there are differences in the value of time in the process of grasping and holding objects between before using wrist hand orthoses and after using wrist hand orthoses. The test is carried out on 17 daily living activities and takes about 30-60 minutes. Testing is done with the exact mechanism for every daily living activity. The benchmarks in this assessment should show a higher value when using wrist hand orthoses compared to not using tools. The results of wrist hand orthoses testing can be seen in Table 7.

The results of time testing in grasping and holding objects before using wrist hand orthoses using 17 types of movements. Of the 17 types, 8 are precision grip types, and 9 are power grip types. Object types are determined based on the provisions of the 2015 human grasping database.

The activity of using a spoon/fork experienced a more prolonged time decrease of 0.66 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 10.3 seconds.

The activity of using glasses decreased longer by 3.76 seconds so that the time needed to complete the exercise after using wrist hand orthoses is 23.51 seconds.

The activity of opening the bottle packaging has increased by 1.45 seconds so that the time it takes to complete the activity after using wrist hand orthoses is 8.76 seconds.

The activity of using toothpaste had an increase in time by 2.64 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 33.7 seconds.

Writing activity increased the time faster by 1.68 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 17.84 seconds.

The activity of reading books experienced an increase in time faster by 1.77 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 41.83 seconds.

Using cellphones decreased in a longer time by 3.51 seconds, so the time needed to complete the activity after using wrist hand orthoses is 78.9 seconds.

Papercutting activities have increased the time faster by 2.79 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 17.64 seconds.

Activities using the ruler have increased time is faster by 2.35 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 13.05 seconds.

The activity of carrying shoes has an increase in time faster by 2.46 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 34.41 seconds.

The activity of wearing socks has increased

Table 7. The results of holding time before and after using the wrist hand orthoses

No	Activity	Movement name	Grasp Type	Test Object Variable		
				Time of Gripping Before	Time of Gripping After	Δt
1	Using a spoon/fork	*Writing Tripod*	*Precision*	9,64	10,3	-0,66
2	Using a glass	*Medium Wrap*	*Power*	19,75	23,51	-3,76
3	Unpack the bottle	*Large Diameter*	*Power*	10,21	8,76	1,45
4	Using toothpaste	*Light Tool*	*Power*	36,34	33,7	2,64
5	Writing	*Lateral*	*Precision*	19,52	17,84	1,68
6	Reading a book	*Parallel Extension*	*Precision*	43,6	41,83	1,77
7	Using Mobile Phone	*Adducted Thumb*	*Power*	75,39	78,9	-3,51
8	Cutting a paper	*Parallel Extension*	*Precision*	20,43	17,64	2,79
9	Using a ruler	*Lateral*	*Precision*	15,43	13,05	2,35
10	Bring shoes	*Fixed Hook*	*Power*	36,87	34,41	2,46
11	Put on socks	*Sphere 4 Finger*	*Power*	46,08	45,84	0,24
12	Tying shoelaces	*Tip Pinch*	*Precision*	22,1	20,37	1,73
13	Taking medication	*Palmar Pinch*	*Precision*	6,21	8,38	-2,17
14	Wear clothes	*Power Sphere*	*Power*	74,78	72,56	2,22
15	Sweeping floor	*Small Diameter*	*Power*	58,32	53,89	4,43
16	Using a Key	*Lateral Tripod*	*Precision*	14,65	13,19	1,46
17	Folding clothes/blankets	*Power Sphere*	*Power*	34,4	32,23	2,17

time by 0.24 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 45.84 seconds.

The activity of tying shoelaces has increased in time by 1.73 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 20.37 seconds.

The activity of taking medicine decreased over a longer time of 2.17 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 8.38 seconds.

The activity of taking medicine decreased over a longer time of 2.17 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 8.38 seconds.

The activity of using clothes has increased in time by 2.22 seconds. So the time it takes to complete the activity after using wrist hand orthoses is 72.56 seconds.

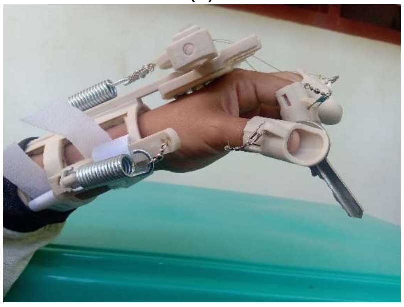
The activity of sweeping the floor experienced an increase in time by 4.43 seconds, so that the time needed to complete the activity after using wrist hand orthoses is 53.89 seconds.

Activities using keys have increased time faster by 1.46 seconds. So the time needed to complete the activity after using wrist hand orthoses is 13.19 seconds.

The activity of folding clothes has increased by 2.17 seconds, so that the time needed to complete the activity after using wrist hand orthoses is 32.23 seconds.

Based on the handheld time testing results after using wrist hand orthoses, there was an increase in grip time in 13 types of movements. Documentation of handheld time measurement before and after using wrist hand orthoses can be seen in Figure 7.

(a)



(b)

Figure 7. Grasping Time Measurement Documentation, (a) Before Using; (b) After Using the Wrist Hand Orthoses

IV. CONCLUSION

The conclusions resulting from this study are described as follows:

a. This research resulted in wrist hand orthoses design alternatives that can help improve a child's spastic handheld HCP daily living activity*.*

b. Prototype wrist hand orthoses were printed using an additive manufacturing process. The time needed to create a prototype is 8 hours 25 minutes.

c. The test results showed increased activity when handheld at 14 for daily living while using hand-wrist orthoses. Daily living activities that experience an increase in handheld time are: opening bottles, using toothpaste, writing, reading books, cutting paper, using a ruler, carrying shoes, wearing socks, tying shoelaces, using clothes, sweeping floors, using, and folding clothes. -blanket. Daily living activities that reduce handheld time are using a spoon/fork, using a glass, a cellphone, and taking medicine*.*

Some suggestions given in research to optimize the functionality of wrist hand orthoses in spastic HCP children are that it is necessary to consider the development of overhand and fingertip designs to accommodate the stability and comfort of the user's fingers. Can grip objects more firmly, and the grip reach of the object is more excellent. Another suggestion that can be given is that further research is needed to find a better material when making prototypes of wrist hand orthoses compared to PLA 3D filament without reducing flexibility in the gripping process.

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