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International Conference on Science and Technology 2019 Journal of Physics: Conference Series 1569 (2020) 022094 IOP Publishing doi:10.1088/1742-6596/1569/2/022094 1 The hybrid whale optimization algorithm: A new metaheuristic algorithm for energy-efficient on flow shop with dependent sequence setup Dana Marsetiya Utama1, Dian Setiya Widodo2, Muhammad Faisal Ibrahim3, Khoirul Hidayat4, Teguh Baroto1, Aminatul Yurifah1 1 Department Industrial Engineering, University of Muhammadiyah Malang, Jl. Tlogomas No. 246, 65144 Malang, East Java, Indonesia 2 Department of Manufacturing Technology, Vocational Faculty, University of 17 Agustus 1945 Surabaya Jl.

Semolowaru 60118 East Java, Indonesia 3 Logistics Department, Universitas Internasional Semen Indonesia Jl. Veteran Kabupaten Gresik, Jawa Timur 61122, Indonesia 4 Department Agroindustrial, Trunojoyo University, Jl. Raya Telang, Kabupaten Bangkalan, Jawa Timur 69162, Indonesia Abstract. Recently, The industrial sector produces about half of the worlds total energy consumption. Manufacturing companies are required to reduce energy consumption. This article aims to develop a Hybrid Whale Optimization Algorithm (HWOA). We use the objective function of minimizing energy consumption. It solves the problem with permutation flow scheduling problems (PFSSP).

Dependent sequence setup is a PFSSP problem with setups that depend on schedule sequence. We offer HWOA with local search strategies. The solution in each HWOA iteration is improved using flip and swap mutations. Furthermore, HWOA is compared with several algorithms. We use numerical experiments to show the performance of the proposed algorithm. Comparative analysis with several algorithms has previously been carried out with ten variations of PFSSP problems. Based on numerical experiments, HWOA proved to be competitive compared to other algorithms. Keywords; Efficient;

Energy; Flow shop; HWOA 1. I ??r ????ti ? Recently , ?oss ?? ?uel ? ??????t ?†t ?? ?om ??? ' s e ??r ??†s ???? [1] .

??? ??????ri ?? ??c ?or †pr ?????s †a ??? ha ?f †of †t ?? ????d's †t ??al †e ???gy ?onsum ??ion [2] . ???r ??or ?, ?a ???ac ?ur ?ng ?ompani ?s †ar ? ?he †pr ??ary s ???ce †of †gl ???l †war ??ng. ?a ???a ??uri ??†c ??panie ? ?r ? ?equir ?d ??†r ?duc ? ?nergy ?ons ??pti ? [3] . Ge ??r ??ly, ?ne ?gy ?ons ????i ??†oc ???s duri ??†t ??†produc ??on ??oce ?s ?†Howe ???, ?or †the †m ??? ???t, e ??r ?? ?s ?ons ???d whe ? ??? e ???ne ?s ???e [4] . Thi ? iss ?? ha ? c ????? t ?? at ?enti ?? ?? r ?s ??r ???rs ?n t ? f ?el ?†of †s ?he ????ng. ????dul ?ng ?s †t ?? ??loc ??i ??†of †li ??te ?†r ??our ?e ? ?o ?? ?ana ??d ??fi ??e ??l [5] .

Ge ??r ??ly, ??he ????ng ??s †t ?? ??rf ???a ??e †t ?†m ?nim ??e †c ??pl ?ti ??†ti ??. ??????r ?†at †pr ?se ???†it †uses t ?? ???f ???a ??? ?? ?inim ??i ??†ene ?gy ?onsum ???on [6] . ????gy ?ons ??pti ??†ha ? ? ???al †r ??e †i ?†t ? pr ????m of ??oba ? warm ?ng [5] . Emi ?si ??? a ?? c ?us ?d by t ?? bur ??ng of ?os ??l f ??? [3] . The †proble ?†of ?dl ?†e ???ne ?ner ??†c ???um ??i ??†ca ?†be †s ??ve ?†by ?he ? - OFF ?tr ?te ? [4] . ????ver, not †a ?? ?ndus ??ie c ?n a ????†t ?? ? - OFF ?t ?a ?egy [7] .

???r ??or ?, ?he †r ?ght †s ?hedul ng ?a ?†mi ??mi ?e e ??r ??†c ???umpti ???†One ?? ?he †pr ???em ? ?n ?i ???iz ?ng ?ner ??†c ???um ???on ?s †t ?? ??s ? ?? ?? pe ??uta ??on ?l ??†shop ????duli ??†pr ???em †(??????. ?? ??s †n ?obs †in ?he †s ??e †or ?? [8] . ??? International Conference on Science and Technology 2019 Journal of Physics: Conference Series 1569 (2020) 022094 IOP Publishing doi:10.1088/1742-6596/1569/2/022094 2 r ?s ??rc ??rs ha ?? ?es ?ar ?he ? ?c ??duli ?? ?o m ?ni ??ze ????gy c ???um pt ?on.

Som ? ??gor ??hm ? us ?d i ??l ?? Ge ??ti ? ??gor ??hm [9] , ????i Ge ????c †Al ?????hm [10] , ?????d ?ul ? - obje ?ti ??†ba ?ktr ??ki ??†se ??c a ?gor ??hm [11] , ??rt ??l ? ???r ? ???im ??at ?on ?PSO) [12] , He ???st ??s [13] a ? Cros - Ent ????†Ge ???ic Al ????t ? [14] . ??s ??†on ??e ??ous †r e ??ar ?h, ?t †pr ?sent ?†the †m ?ta ??ur ??ti ? ?l ???it ?? ?s †i ??e ??st ?ng ? s ?udy [15] . Som ? e ????ts ?la ?? t ?? PFSSP ca ?e ?a ???? be ?es ????d i ? ???ynomi ?l ti ??. Thus ? ????? ? i ???ude ?†i ?†t ?? ? - Ha ?d ?????em [14] [16] .

????ef ??e ? ??w ?ppr ???h ?? ??e ??d ?o ?inim ??e †e ??r ? c ???um ??i ?? As †f ?r †as †we †know, ??†previ ??? ?e ??a ??h ??s †i ????ti ??t ?d ???rgy c ?????pti ??†m ?nim ?za ??on ???ng ?he Hybr ?d ?hal ? ?????i ??ti ??†Al ????t ?? ?HW ??? ??gor ??hm ?†W ???e †Opt ??iz ?ti ??†Al ????t ?? ?? ? ?? m ??a ??ur ??ti ? a ?gori ?hm ?hat ???ic ? t ?? be ??vi ?? of pre ? ???le ? hunti ? [17] . W ? ??fe ? a ? ????oa ?h to ove ?come †the †pr ???em †of ?i ???i ??ng ?ner ??†c ???umpt ?on ???ng ?he ??OA ?lgor ??hm ?†In ?hi ? ?t ??? HW ??†i ? ??e ?†f ?? ?c ??duli ??†wi ??†t ?? ?a ?hi ?? ??t †up ?im ? ??pe ?? ng ??†t ?? ?????nc ? ?? ?ob.

??†t ?? c ?s ?, we ??s ? ?ons ?de ? t ?? ?em ???? t ??e ? ???re ?or ?, t ?? pur ???? of ???s st ??? ?s ?wofol ?? ???st ? ?? ??ve ?op t ?? W ?? ??gori ??? (??OA) ?o mi ??mi ?e ?ner ?? ?onsum ??i ?? ?n PFSSP. Se ????? ?hi ? s ?udy knows ?? be ?t †pa ??me ?er ? ? t ?? ????†a ?gori ?hm ?†The †pr ?????d ?ai ?†contr ?buti ??†in ?his †f ??l ?†i ? ?o ??opos ? ne ? ??OA a ?gor ??hm ?nd pr ????? the ???t ??ra ??t ??s t ? ?ol ?? mi ????z ??? ??? e ??r ?? ?ons ??pt ?on. 2. M ?t ??? 2.1 Assumptions Problems and notations As ?um ???ons i ? ??ow s ??? ??he ???i ?? ???h de ??nde ?? se ? up t ??e a ?? ??moval ?ime ? (?? ?he s ?que ??? of j ?? (= 1 , 2 , 3 , . . . ,) c ?r ??e ? ?? on m ma ?hi ??s (= 1 , 2 , 3 , .

. . ,) i ? t ?? ?am . (? A ll ?ac ??nes ?? a ??il ?bl ? ??†t †= †0 . (3) †s ?? ??†t ??e †i ? ??pe ?? nt †on ?he †or ??? ?? ???k . (4) †s ?? ??†tim ? ?? ?e ???at ? ??om pr ??es ??ng ??me . (?? ?e ? ? a t ??e †f ?? ?ovi ??†f ?om †j ? t ?†j ? on t ? ma ?hi ?? ? ? (???r = , ??? ?ndi ?at ?s ??? ?et ??†ti ?? ?or †j ? i ?†the †j ??†is †t ??†fir ?t ???†i ?†s ?que ???) . (?? ?he ?em ???l ??me †is s ?par ?te †fr ?? ?he †pr ???s ????†t ??e . (?? ?a ?h ?ob ???n ?t †s ??rt ? ????es ?ing ?o ?i ??s ?†should ??? ? i ???r ?????d .

(? E a ?h ma ?hine ??a ??s a ? ???e ? ?nd f ?nis ??s ???n t ?? ?as ? ?ob on e ??h ma hi ?? ?s fi ??s ??d (?a ?? ??c ??ne ?hat ?t ??? inde ??nde ? l of ?he ??her ?ac ??nes ?. The ???pos ? of ?his ?odel ?s ?o m ?nim ?ze t ???l †e ??r ?? ?ons ??pt ?on TEC) ?†The †nota ??on ??†t ?? tot ?? ?ner ??†c ???um ???on ???d ?n ?hi ? ??ti ??e †is †as f ???ows: : index of jobs, i = 1 , 2 … , n : index of machines, j = 1 , 2 … , : total number of jobs : total number of machines , : processing time of job sequence on machines : Setup time of job in the first sequence on every machine , : set up time move sequence - 1 to on machine , : waktu removal untuk job pada mesin j : energy consumption index of machine j when removal : energy consumption index of machine j : energy consumption Setup index of machine j : energy consumption index of machine j when idle , : completion time of job sequence at on machines : completion time of machines : total busy time of machines : total idle time of machines : total setup time of machines : Removal time of machines : total energy consumption ? : the initial distance of the whale to it is prey ' ? : the distance of whales to prey (from the best solution) ? : vector position * ? : vector position of the best solution ? : vector coefficient ? : vector coefficient : number of iterations : a constant to define a spiral shape : random numbers with ranges [-1,1] Ba ?e ?†on ?he †a ???? ???at ?on, ?he †obj ??ti ?? ?????i ??†of ?he †PFSSP ??????m †i ? ?o ?i ???i ?? ?ot ?? ?ner ? c ???um ??i ?? ?TEC) [18 , 19] .

The ?oll ????? ?? t ?? PFSSP pr ???em ?or ?? a : , = + , + , (1) International Conference on Science and Technology 2019 Journal of Physics: Conference Series 1569 (2020) 022094 IOP Publishing doi:10.1088/1742-6596/1569/2/022094 3 , = ma , - , , + , + , , = 2 . . (2) , = , + , + , + , , = 2 . . (3) , = ma , - , , , + , + , + , , = 2 . . , = 2 . . (4) = ? , , ? = 1 . . (5) = ? , +

, ? = 1 . . (6) = ? , ? = 1 . . (7) = ma (,) , ? = 1 . . , = 1 . . (8) = - - - , ? = 1 . . (9) = ? (. + . + . + .) (10) The PFSSP model was modified from Li, et al. [19]. Best scheduling is defined as having the minimum TEC.

The PFSSP model for minimizing energy consumption is as follows Obj ?ct ?ve ?unc ??on = ??n (?? Subj ?ct ?o : , = + , + , , = ma , - , , + , + , , = 2 . . , = , + , + , + , , = 2 . . , = ma , - , , , + , + , + , , = 2 . . , = 2 . . = ? , , ? = 1 . . (12) = ? , + , ? = 1 . . = ? , ? = 1 . . = ma (,) , ? = 1 . . , = 1 . . = - - - , ? = 1 . . = ? (. + . + . + .) Equa ??on ?1) ?xpl ??ns ?he †com ??e ??on ??me †of †work ?????nc ?†one ??†m ??hine †1; †Equa ??on ?2) ?xpl ??ns t ??? ?ac ??ne ? ?†t ?†m ? ?????i ??†(?? ?xpl ?ins †the †c ??ple ?ion ??me †of †s ?que ??e wor ?†fr ?? ?ac ???? ? Equa ??on ?4) †s ????†t ??t ??c ??ne †j ?†Equa ??on ?5) †e ????i ? the †t ??al †m ?chi ?? ????†ti ??; ????ti ??†(? e ???ai ??†t ??†t ??al †s ?tup ?im ?. ?????ion ?7) ???ust ?at ?? ??? ?ot ?? ?em ???? ?im ?.

????ti ??†(?? ?hows ?he c ??pl ??i ??†tim ? ?? ?a ????? ?†fr ??†per ?ut ??ion; ????ti ??†(??†s ????†t ?? ?ota ? ?dle †tim ? ?? ?he pe ??uta ??on ?a ?hi e †j ? ????ti ??†(? ? ???c ??bes †t ?? ??r ???ati ??†TEC ?obj ?ct ???†f ????i ???; †Equa ??on (??? expla ?ns ?he ????ct ?ve ????ti ?? ?? t ?? PFSSP m ???? t ? ?i ???iz ? e ??r ?? ?ons ??pti ??? a ?? ????ti ? (??? ?????i ?? ?he †c ????ra ?nts †of †t ?? ?????†m ???l †t ?†mi ???iz ? ?ne ?gy ?ons ??p t ????†The †c ????ra ?nt ? ?n t ??? m ???l a ?? e ???ti ??? (?? ?o (? ?. 2.2 Proposed Hybrid Whale Optimization Algorithm (HWOA) W ? wa ? pr ????e ? ?? ?irj ?li ?? a ?? ??wi ? [??? t ? ?ol ?? t ?? pr ????m ?? ongoi ?? ???im ??a ??on. Howe ??r, i ? ??? ?he †c ???ac ?er ??ti ?s †t ?†s ??ve †PFSSP.

?e †pr ????e d HW ? , whi ?h ?om ??nes †W ??†wi ?h ? ?ocal s ?ra ?egy suc ? ?s f ??p a ?? ?wa ?†s ??rc ??†HW ??†ha ? t ??ee †ma ?n ?te ?? Init ??li ?e ?he ???it ?on ?? ??? ??ar ? a ??nt a ?? ?ha ??? t ?? pos ??ion t ? ??rm ??a ??on wi ?h t ?? La ?ge ??nk val ?? (???? r ??e ? ?va ?ua ?? t ?? W ?? do a ?oc ?? s ??r ?? ???h fl ?p and s ??p . The ?e ?ive ??e ?? ar ? di ?c ??s ?d i ? ?he ?ol ?owi ?? ?ubse ?ti ???: 2.2.1 Initialization of search agent positions and convert search agents to job permutations The †init ?al †posi ??on ??†t ?? ?e ?rc ?†a ??nt †i ?†ge ???at ?d ??ndoml ??†It †i ? ?ai ?ed ??om †t ?? ????? ?????†a ? l ???r bound r ?nge.

Init ??li ??t ??? ?? t ?? ?????i ?? ?? a s ???c ? ?ge ?? m ??t e ????e tha ? ???r ? ??e ?? ?e ???ti ? num ???s †i ?†t ?? ??me †s ?ar ?h ?ge ??. ???t ??rm ???, ?he †num ??? ?? ???ens ???? ?n ?he †popul ???on ??tr ?x ? s ?a ??h ?gent †posit ?ons †i ? ???e ?†on ?he †num ??r †of †j ???. ?e †pr ????e t ? c ????rs ?on ?? ?e ??c ?†a ????? ? j ??†pe ??ut ?ti ??? ??†a ???ying ??rge †Rank ???ue ?LRV) ?†In ????†t ?? ?????nuous ??lue †of †t ??†posi ??on of ?ac ? ??a ??h a ??nt ?s ?orte ? ?rom ?he l ??ges ? t ? ?he ??al ?es ?.

 2.2.2 Whale Optimization Algorithm W ??le †Opti ??z ??ion ??gor ? hm †(?OA) †is †a †ne ?†m ??ahe ???s ??c †al ???it ?? ??vel ???d ?r ?? ?he †be ????or of †hum ????k ????e ? ?????ng ?or †pr ?y [17] . ????owi ??†ar ? ??? ? e ?? ?or †t ?? ?ha ?? ????mi ??ti ? Al ????t ??. ??????ck ???l ?s †know ?he †l ??a ??on ?? ??e ?†a ??†t ??n ?ur ?ound ?he ?r †pr ?y.

??? ?OA a ?gor ??hm †as ?um ?? ?hat †t ??†be ?t ?ol ??i ??†i ? ? ??e ?†t ?rget †t ??? ?s ?los ?†to ????m ??. ??t ?? ????he ?†s ??rc , t ? a ??nt ?????e s t ??†posi ? on ?hat ?ppr ??che ?†t ?? ??s ?†s ??rc ?†a ??nt ?†Equat ?on ?13) †a ??†(??? ?re s ??il ?ri ??es ?n be ????or ??ound pre . ? = ? . * ? ( ) - ? ( ) (13) ? (+ 1) = * ? ( ) - ? · ? (14) ? i ???c ??es †t ?? ????ti ??†of ?he †dis ??nc ?†of ??? ???l ?†to ??? ??e . de ???e ?†it ??at on. ? a ? ? a ?e ???t ? c ??ff ??i ???s. * i ? ?he †ve ??or ???it ?on ??†t ?? ???t ?ol ???on.

? is †the †ve ?tor †pos ???on. | | is †t ?? ?bs ??ute va ?ue * a ?? ?? m ??t be updat ?? ?n e ??r ? ??er ??i ?? ?f t ??r ? ?? a bet ??r s ??uti ?? Ve ??or ? and ? f ??m ??ated i ? ?????ion (15) ??n (16) . ? = 2 ? · ? - ? (15) ? = 2 · ? (16) ? de ??e ?se ? ?ine ??l ?†fr ??†2 ??†0 ???i ??†t ?? ?xpe ???e ?? ??n ??? ??????at ???†a ??†e ?????ta ??on ???s ??. ? is a †r ?ndom †vec ??? ???h ? ??nge . Furt ???m ??e ?†t ?? ????e ?t ??c ?? s ?ng ?????e ? ?t ??†e ???oi ??ti ??†phas ??. M ?t ??ma ??c ?? ?odel ? ?? ??ha ???? ?o ??t ??k ???pba ??†wha ?es †a ?? ??si ???d ????†t ?? ?oll ???ng ?wo a ???oa ?hes ?†1).

???cl ?†s ??inka ??†me ?hani ??? ?his †be ??vi ?? ?s ?c ??e ??d ??†de ??ving ??? ??lue †of ? i e ???ti ? (5) 2) Upda t ?ng t ?? spir ?l ????ti ?? ?Equat ?on (???) ? (+ 1) = ' ? · · c os (2) + * ? ( ) (17) ' ? = * ? ( ) - ? ( ) i ???ca ??s †t ?? ??st ?nc ? ?? ??? ???l ? ?o ??ey ?t ?? ??st ?ol ???on ???ai ??d) . i ? c ???ta ?? ?or ??fi ???? ?pi ??ls . i ? a ra ???? num ??r ??t ? ra ?? [- 1,1]. Mi ??al ??i a ?? ??wi ? ?17] a ?s ?? t ??? ?he ?e ?s ? ? ? ???si ???it ?†to ?hoos ? ??t ???n he ?e ???ni ?? ??†s ??i ???ge †of †a †ci ??le †or †a †s ??ral m ???? ?o ?e ??w ??? ????ti ??†of †t ?? ????e †(?????i ??†(18) ?.

?her i ? ? ?a ???? ???ber †wi ??†a †r ?nge [?? . Fur ?he ??ore ?†t ??†Sear ?h ?or †pr ?y ????e ??he ?xplor ?ti ??†phas ?? ?s ?ode ??d ??†(????ti ??†(???†a ? (?) ? ??OA pse ?? - c ??? i ? des ??i ??d i ? ?lgori ?hm ? ? (+ 1) = * ? ( ) - ? · ? < 0 , 5 ' ? · · c os (2) + * ? ( ) = 0 , 5 (18) ? = ? · ? - ? (19) ? (+ 1) = ? - ? · ? (20) 2.2.3

The local search The ?oc ?? s ?ar ?h ??t ??? ?s a †c ??bi ???ori ?? ????mi ?at ???†me ?hod f ??†c ??nging t ??†ini ??al †se ?????e ???il a ?†opt ??al †obj ??ti ?? ?unc ????†is †gene ??t ???†The †pr ????e ?†l ??al †s ?ar ?h ?te ??†a ?? ?li ?†and ?wap. ???p ? c ?rr ?ed ?? by ?wa ????? ?wo ?andom †work ??quenc ?s. The †s ???†ope ?at ??? ?te ?at ?d ?o ?†i ?†re ??at ?d

?? ? Fl ?p i ? r ?ver ??ng t ?? or ??? in whi ?h j ??? a ?e ?el ?ct ?d. The ???p oper ??i ?? ?n i ??r ??ion t ? ? i ? a ?so r ???at ? a ? n. 2.3 Experimental procedure The ??oce ?si ?? ???e wa gene ?at ?d f ?om ? uni ?or ? r ?ndom ???tr ?????on (? ?? ?.

The ?e ??? ??me ?or ?obs i ?†t ?? ?ir ?? ?e ???nc was ge ??ra ?ed ?r ?? ??? ???f ??m †r ?ndom †dis ??i ????on ?1.10) ?†The †s ?t ??†a †t ??e †f ? m ???ng f ??? ?? - 1 to j ? wa gene ??t ?? ?r ?? ? unif ??? ??st ??buti ?? ?1 ,10) ? ??? ?emova ? ??me was ge ??ra ??d fr ?? a ???f ??m ??ndom ??st ??but ??? ?1,5) ? ??? e ???gy c ???um ??i ?? ??ede ? ????ng pr ???s ??ng ope ?at ??? wa ge ???a ??d ?r ?? ? ???form †ra ????†di ??ri ???i ??†(5,10) ?†Energy ?ons ?????on was ge ??ra ??d ?r ?? ???f ??m †r ????? ??s ??ibu ti ??†(????. ???r ??†c ???um ???on ??m ???l wa ge ??r ??e ?†f ?om uni ?orm †ra ???? ??s ??ibuti ??†(????.

???†e ???gy ?ons ????i ??†i ??e †m ??hine wa ge ??r ??e ?†f ?om †unif ?? International Conference on Science and Technology 2019 Journal of Physics: Conference Series 1569 (2020) 022094 IOP Publishing doi:10.1088/1742-6596/1569/2/022094 5 r ?ndom †num ???s †(????. ??†f ?nd ??? ?he †be ?t †pa ?am ??er ? ?? ??? ?lgori ???, ?? ?xpe ?im ???ed ??t ?†t ? pa am ??er ?. ???re †ar ? ?wo ??r ??et ??s †us ?d ?n ?hi ? ?xpe ?im ???, s ???†a popul ??ion ?nd ??e ??ti ???†The popul ???on c ???is ?s ?? 2 l ???l s ??h a 10, a ?? ? ? ?? ?t ??at ?on consi ??s ?? 5 l ?vels s ??h as i ??ra ??on of 10, ? ?†100, ? ?†a ??†500.

??c ?†da ?a wa t ??e ?†te t ??e ?. ?e †t ??e 8 var ??ti ???†of †j ??†a ??†ma ?hi ?? The ?ef ???, ?he ?xpe ??me ??? ?ar ??e ?†out 80 e ???ri ??nt ?. ????herm ???, ?he ???t †pa ??me ?er ?†of ?he e ???rim ?nt ?l †r ?s ???s †c ??pa ?e ?†wit ?†s ??e †pr ?vi ??? ??gori ???? ?ncl ??? ??ne ??c †Al ????t ?? ?GA) [9] , pa ?ti ??e †s ??rm †opt ???z ??i ? (??? [12] , ?nd ?OA [17] . ??gor ??hm †per ????a ?? wa me ?s ??e ?†by ?? Ef ?ic ??nc ?†Inde ?†Per e ???ge †(????. ???†i ? ??sc ??be ?†as †t ?? ??ti ?†of †e ??rgy ????um ???on ???we ?n ?he HW ?? ?l ???it ?? ?nd ot ??? a ?????t ??s a ? a ???c ?nt ?ge ?e ???ti ?? ???.

E I P =T T x100% (21) 3. Re ?ul ?? and di ?c ??si ? The re ?ul ? of ?he HW ?? ??r ??et ?r e ???ri ??nt ar ? s ???? ?n ta ??? 1. It ????? t ??? t ?? hi ???r t ?? num ?? of †it ?ra ??ons †a ??†t ?? ???ber †of t ? popula ??on ??e ??†t ?? ??OA ?e ?ult ? ??†l ???? ???r ??†c ???um ??i ?? For ?he ?as ? of ??al ? j ???? ?? be ?? par ??et ?? i ? ?o us ? a ?ma ?? popul ??ion a ?? ??e ???i ?? C onver ?el ?? ?or t ?? c ?se ?? l ?r ?? j ???, the ?????at ??? ??? ?t ??at ?on us ?d a ?e la ?ge ? ??? Eff ??ie ??y Inde ? ???c ???age ?EIP) a ?s ??sm ?nt ?? ?ner ?? ?onsum ???on i ? ?a ??e ? ?????s t ??? HW ?? ?????de ? m ? e ??gni ??c ?nt ??rf ???a ??e i ?†m ???um †a ??†la ?ge †c ?ses ?†Ove ?al ?, ???†f ?om †HWOA ?ne ?gy ?onsum ???on ???par ?d ??†Ge ??ti Al ????t ?? ?GA) [9] , par ??cl ? ?wa ?? ???im ??a ??on (??? [12] , ?nd ?OA [17] we ?e †99. 61 % ?†99.

70 % , a ?? ?? 74 % ? ???s ?xper ??ent ?hows ?ha ? HW ?? ??rf ??m ???e ?s ??tt ?? t ??n s

??e ??her ??gori ????. Tabe ? 1. The xpe ??me ?? ?? ?he ??fe ?? of ??OA pa ???et ?rs ? ene ??? ?ons ??pti ? Job Machine Population of 10 Population of 100 Iteration 10 Iteration 50 Iteration 100 Iteration 200 Iteration 500 Iteration 10 Iteration 50 Iteration 100 Iteration 200 Iteration 500 5 4 4688 4688 4688 4688 4688 4688 4688 4688 4688 4688 5 16 25558 25558 25558 25558 25558 25558 25558 25558 25558 25558 40 4 38593 38656 38577 38647 38714 38699 38638 38579 38606 38488 40 16 157645 157563 157322 157011 156907 157112 156920 156765 156522 156429 60 4 62998 62841 62693 62874 62800 62900 62797 62717 62704 62628 60 16 252238 251453 251383 251353 250995 251019 250959 250828 250697 250316 100 4 92588 92414 92324 92266 92191 92355 92256 92147 92168 92187 100 16 368938 369059 368691 368395 368278 367885 368465 367823 366869 366622 Tabe ? 2.

Com ???is ?? ?? e ??r ?? ?ons ??pt ?on a ?? ??? ?? s ???ra ? ot ??? al ???it ?? Case EIP GA PSO WOA 5 job 4 machine 100,00% 100,00% 100,00% 5 job 16 machine 100,00% 100,00% 100,00% 40 job 4 machine 99,65% 99,67% 99,68% 40 job 16 machine 99,25% 99,36% 99,53% Case EIP GA PSO WOA 60 job 4 machine 99,54% 99,78% 99,75% 60 job 16 machine 99,39% 99,56% 99,58% 100 job 4 machine 99,66% 99,80% 99,88% 100 job 16 machine 99,36% 99,39% 99,48% 4. Conc ?usi ? In ?his †ar ??cl ?, ?? ??opos ?†a †hybr ?d ???le †Opt ??iz ??ion ??gor ??hm †(??OA) ?lgor ??hm ?†Fi ???ly, ? pr ????? ?he †bes ? ??r ??et ??? ?or †s ????ng ?he †e ???gy ?ons ?????on ??s ?.

I n ??? ?ase †of †sm ??l †j ?? , it †i be ??e ?†t ?†us ?†popul ??ions †and ??al ? ?te ??ti ???. I ns ?ead, or †t ?? ?a ?? ?? ??r ?? ?obs , it †i ?†bet ?er †t ?†us popul ???on ?nd s ?gni ??ca ? it ??at ?on. F ur ?he ??ore ?†HW ??†i ?†c ??par ?d ?o ?e ???a ?†proc ?dur ??. Com ???a ??ona ? exper ??e ??s pr ??? t ??? HW ?? ??oduces ????ma ? e ???gy cons ??pt ???? ??ver ?? r ??e ??ch a ?e ?? c ?n be ??udi ?d f or ?utur ? wor ?? ?e ??opos ? t ??? HW ?? ?a ? ?? us ?d a ? a ? ?niti ?l ?ol ??i ?? ?or ??her m ??a ??ur ??ti ?†a ?????thms ?†Fi ???l ??†t ?? ??fe ?ed ??OA ?l ???it ?? ?a ?†be †a ???ie ?†to ?e ???e †e ???gy c ???um ??i ?? ?n t ?? PFSSP pr ????m.

International Conference on Science and Technology 2019 Journal of Physics: Conference Series 1569 (2020) 022094 IOP Publishing doi:10.1088/1742-6596/1569/2/022094 6 5. Re ?e ??nc ?s [1] X. Wu and A. Che, "A memetic differential evolution algorithm for energy-efficient parallel machine scheduling," Omega, vol. 82, pp. 155-165, 2019/01/01/ 2019. [2] J.-Y. Ding, S. Song, and C. Wu, "Carbon-efficient scheduling of flow shops by multi-objective optimization," European Journal of Operational Research, vol. 248, pp. 758-771, 2016/02/01/ 2016. [3] K. Fang, N. Uhan, F. Zhao, and J. W.

Sutherland, "A new approach to scheduling in manufacturing for power consumption

and carbon footprint reduction," Journal of Manufacturing Systems, vol. 30, pp. 234-240, 2011/10/01/ 2011. [4] G. Mouzon, M. B. Yildirim, and J. Twomey, "Operational methods for minimization of energy consumption of manufacturing equipment," International Journal of Production Research, vol. 45, pp. 4247-4271, 2007/09/15 2007. [5] D. M. Utama, T. Baroto, D. Maharani, F. R. Jannah, and R. A. Octaria, "Algoritma ant-lion optimizer untuk meminimasi emisi karbon pada penjadwalan flow shop dependent sequence set-up," 2019, vol. 9, p. 10, 2019-06-28 2019. [6] S. Rubaiee and M. B.

Yildirim, "An energy-aware multiobjective ant colony algorithm to minimize total completion time and energy cost on a single-machine preemptive scheduling," Computers & Industrial Engineering, vol. 127, pp. 240-252, 2019/01/01/ 2019. [7] H. Luo, B. Du, G. Q. Huang, H. Chen, and X. Li, "Hybrid flow shop scheduling considering machine electricity consumption cost," International Journal of Production Economics, vol. 146, pp. 423-439, 2013. [8] A. K. Garside, D. M. Utama, and M. R. Arifin, "Penjadwalan produksi flowshop menggunakan algoritma branch and bound untuk meminimasi mean tardiness," 2018, 2018-08-11 2018. [9] Y. Liu, H. Dong, N. Lohse, and S.

Petrovic, "A multi-objective genetic algorithm for optimisation of energy consumption and shop floor production performance," International Journal of Production Economics, vol. 179, pp. 259-272, 2016/09/01/ 2016. [10] X. Liu, L. Wang, L. Kong, F. Li, and J. Li, "A Hybrid Genetic Algorithm for Minimizing Energy Consumption in Flow Shops Considering Ultra-low Idle State," Procedia CIRP, vol. 80, pp. 192-196, 2019/01/01/ 2019. [11] C. Lu, L. Gao, X. Li, Q. Pan, and Q. Wang, "Energy-efficient permutation flow shop scheduling problem using a hybrid multi-objective backtracking search algorithm," Journal of Cleaner Production, vol. 144, pp. 228-238, 2017/02/15/ 2017. [12] D. Tang, M. Dai, M. A. Salido, and A.

Giret, "Energy-efficient dynamic scheduling for a flexible flow shop using an improved particle swarm optimization," Computers in Industry, vol. 81, pp. 82-95, 2016/09/01/ 2016. [13] D. M. Utama, "Pengembangan algoritma neh dan cds untuk meminimasi consumption energy pada penjadwalan flow shop," 2019, p. 8, 2019-01-10 2019. [14] D. M. Utama, D. S. Widodo, W. Wicaksono, and L. R. Ardiansyah, "A New Hybrid Metaheuristics Algorithm for Minimizing Energy Consumption in the Flow Shop Scheduling Problem," International Journal of Technology, vol. 10, pp. 320-331, 2019. [15] D. M.

Utama, "An Effective Hybrid Sine Cosine Algorithm to Minimize Carbon Emission on Flow-shop Scheduling Sequence Dependent Setup," 2019, vol. 20, p. 10, 2019-02-26 2019. [16] M. R. Garey, D. S. Johnson, and R. Sethi, "The complexity of flowshop and jobshop scheduling," Mathematics of operations research, vol. 1, pp. 117-129, 1976. [17]

S. Mirjalili and A. Lewis, "The Whale Optimization Algorithm," Advances in Engineering Software, vol. 95, pp. 51-67, 2016/05/01/ 2016. [18] J.-q. Li, H.-y. Sang, Y.-y. Han, C.-g. Wang, and K.-z. Gao, "Efficient multi-objective optimization algorithm for hybrid flow shop scheduling problems with setup energy consumptions," Journal of Cleaner Production, vol.

181, pp. 584-598, 2018/04/20/ 2018. [19] S. Li, F. Liu, and X. Zhou, "Multi-objective energy-saving scheduling for a permutation flow line," Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, vol. 232, pp. 879-888, 2018.