別紙４－２（課程博士（和文））

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機械工学専攻	学籍番号	第 179102 号
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論文内容の要旨　(博士)

博士学位論文名	超高強度鋼部材のホットスタンピングにおけるプレス成形と接合に関する研究

（要旨　1,200字程度）

近年，自動車の衝突安全性向上と軽量化のため超高強度部材の適用が増加している．冷間成形における超高強度化は成形荷重やスプリングバックの増加，工具の磨耗などの問題が生じるため，ホットスタンピングによる超高強度化が進んでいる．ホットスタンピングは加熱，成形および型内冷却の工程を持ち，熱間成形により成形荷重は小さいが，型内冷却によるマルテンサイト化により非常に硬く，スプリングバックの小さい製品が製造できる．

本論文では，車体構造部材の高強度化，軽量化およびコスト低減のため，超高強度鋼部材のホットスタンピングにおけるプレス成形と接合に関する研究を行った．第1章では本テーマにおける課題および目的を記した．

第2章では加熱炉から金型までの搬送中部分冷却を用いて成形性を向上させた．成形中に変形が集中する部位を予め工具で保持し，部分的に鋼板の温度を低下させて変形抵抗を増加させる．冷却圧力と接触幅を変更して鋼板の温度分布を制御した．W曲げ試験において，鋼板温度を250℃低下させ，変形抵抗を300 MPa増加させることによって成形性が26.1%向上した．

第3章ではテーラードブランクを用いたホットスタンピングにおいて，一般的な270 MPa級鋼板の焼入れ性が調査された．焼入れを行ってもその引張強さと延性は非焼入れ鋼板とほとんど同じであり，現在用いられている高価な非焼入れ材の代替となることを示した．

第4章では加熱した母板とパッチに対し，スポット溶接を行わずにパッチ端部にインターロックを形成することによって機械的に接合させた．炉内で重ねずに加熱を行うため，表面の合金層が均一に生成され，成形時にスポット溶接周辺に発生する亀裂を防止する．

第5章では焼入れされたホットスタンピング鋼板に対し，プロジェクション抵抗溶接を用いずに棒材やナットを機械的に接合させる穴抜き接合を開発した．ホットスタンピング材における抵抗溶接は接合性が低く問題となっている．底角部に小さな丸みや面取りを付けた棒材やナットでその直径よりも僅かに小さな穴をあけ，圧入して接合させる．穴抜き接合では事前に穴をあける必要が無いが，棒材やナットには鋼板よりも高い強度が求められる．底角部に1.0 mmの丸みをつけると最も長いしごき面が得られ，接合強度が最大になった．

第6章では超高強度鋼板に対し，側面にテーパーを付けたナットやボルトを用いた穴抜き接合を開発した．本方法ではテーパーナットやボルトで穴をあけた後に、しごきを与えながら穴を拡大して接合させる．締結時に他の部品を取り付けるために，鋼板とナットの上部はストロークを管理して面の一致を図っている．ダイクエンチされたホットスタンピング材において，JISで規定された溶接ナットの2倍の接合強度が得られた．引張強さ780 MPa，板厚1.6 mm以上でJISの溶接規格を満足する．

第7章では結論と今後の技術課題を記す．

別紙４－１（課程博士（英文））

Date of Submission (month day, year) : 2 27, 2020

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Abstract (Doctor)

Title of Thesis	Study of Press Forming and Joining in Hot Stamping Processes of Ultra-High Strength Steel Components

Approx. 800 words

In recent years, the application of ultra-high strength steel sheets to automobile components increases for the improvements of the crash safety and weight reduction. In cold stamping of ultra-high strength steel sheets, high forming load, large springback, small formability and large die wear are problematic. The high load requires the increases in press capability, and the increase in springback induces deterioration to component shapes. To solve these problems, hot stamping of quenchable steel sheets is effective. Hot stamping is a process for producing ultra-high strength steel components by heating, forming and die quenching. In forming at high temperatures, the forming force is low, whereas the strength for formed components is high and the springback is small due to martensitic transformation caused by rapid cooling with dies.

In this study, press forming and joining in hot stamping processes of ultra-high strength steel components were investigated to manufacture of high strength, weight and cost reduced components for automotive. In Chapter 1, the general introduction for overall contents of this thesis was shown.

In chapter 2, the formability in hot stamping was improved by partial cooling of a heated sheet during the transfer from a furnace to dies. By using a transfer device for reducing the temperature of portions undergoing large deformation during forming, the flow stress of these portions is increased, and thus the deformation is relieved. The cooling pressure and the contacting width for the transfer device were changed to control the temperature distribution in the sheet. By decreasing the sheet temperature by 250 °C, the flow stress is increased by 300 MPa, and the depth of the W-bent sheet is increased by 26.1%.

In Chapter 3, the quenchability for a 270 MPa mild steel sheet was examined for the use of tailor welded blanks, because the conventional non-quenchable steel sheets are expensive. The quenched mild steel sheet had almost the same ductility as the conventional non-quenchable steel sheet, and thus the material costs can be reduced by the replacement.

In Chapter 4, main and patch blanks which are separately heated were mechanically joined during hot stamping. In heating of resistance spot welded patchwork blanks, the temperature becomes non-uniform due to

thick and thin portions, and thus the intermetallic layers are incompletely formed. In forming of patchwork blanks, the thickness decreases around the edge of spot welding. The main and patch blanks were successfully joined by creating interlocks around both edges of the patch blank.

In Chapter 5, a mechanical joining process of a bar and nut to a hard hot-stamped steel sheet was developed, because the resistance projection welding generally used for joining of bolts and nuts with hot-stamped sheets has low joinability. In this process, a slightly smaller hole than a bar and nut was made in the sheet with the bar and nut having a small round or chamfer at the bottom corner, and then the bar and nut were inserted into the hole. The punched hole was ironed with the bar and nut during the insertion, and thus the joint strength became high. No pre-punching is required for the sheet, whereas higher strength than that for the sheet is necessary for the bar and nut. For the bar and nut having a radius of 1.0 mm at the bottom corner, the ironed surface was the largest, and thus the maximum joint strength was obtained.

In Chapter 6, a mechanical joining process of a taper nut and bolt to ultra-high strength steel sheet by punching was developed. In this process, the sheet is punched with the taper nut and bolt, and the nut and bolt are joined by ironing and expanding the punched hole. The upper surfaces of the nut and sheet are aligned by controlling the stroke in order to attach other parts. No pre-punching is required for the sheet, whereas higher strength than the sheets is necessary for the nut and bolt. For the die-quenched steel sheet having about 1500 MPa in tensile strength, the joint strength was about two times higher than that specified in the Japanese Industrial Standard of the weld nut. For the sheets above 780 MPa in tensile strength and above 1.6 mm in thickness, sufficient joint strength was obtained.

In Chapter 7, the conclusions and future works are given.