2008年　1月　9日

機械・構造システム工学専攻	学籍番号	059101
申請者氏名	加藤　亨	

指導教官氏名	福本　昌宏　教授 森　謙一郎　教授 戸田　裕之　教授

論　文　要　旨（博士）

論文題目	自動車用高比強度板材の塑性接合に関する研究

（要旨　1,200字程度）

自動車における燃費向上と車両重量の軽減は重要な課題である．自動車車体の軽量化のために用いられる高比強度材にはアルミニウム合金板や高張力鋼板がある．本研究では，各種強度の高張力鋼板とアルミニウム合金板を冷間塑性加工で接合する．用いた冷間塑性接合工法は，セルフピアシングリベットとメカニカルクリンチングである．両工法の接合プロセスとメカニズムを有限要素シミュレーションと実験により検討した．

セルフピアシングリベットによるアルミニウム合金板と軟鋼板の接合性を有限要素シミュレーションと実験により検討した．セルフピアシングリベット接合における必要条件は(1)上板の貫通，(2)下板内でのリベットの広がり，(3)下板の割れ無しの3つである．接合不良を分類し，最適な接合条件を導いた．上板の未貫通と下板の割れは下板厚さが小さい場合と総板厚が小さい場合にそれぞれ生じた．上板に軟鋼板，下板にアルミニウム合金板を設定した方がその逆の板組より接合性が高い．

各種強度の高張力鋼板とアルミニウム合金板を上板を貫通し，下板内で広がるセルフピアシングリベットで塑性接合した．上板の貫通性が不十分な場合と下板の割れは，超高張力鋼板の高硬度と低延性により，それぞれ生じた．超高張力鋼板とアルミニウム合金板の板組は，ダイの最適化により接合できた．

アルミニウム合金の3枚板と各種強度の鋼板とアルミニウム合金板の3枚板の2種類の3枚板をそれぞれセルフピアシングリベットで接合した．3枚板接合では，リベットの脚部が上板と中板を貫通し，下板内で広がり，下板の破壊が生じない必要がある．上板が軟らかく，中板が硬い板組はその逆の板組と比較し，リベット先端部の変形が抑制されるため，リベットは容易に貫通でき，接合性が良い．また，上板と中板が同一材の3枚板組の接合性は，2枚板の接合性を適用できる．

自動車のリサイクル性を容易にするため，アルミニウム合金板同士の接合にアルミニウム合金製のセルフピアシングリベットで接合した．アルミニウム製リベットでアルミニウム合金板を接合するため，リベットとダイの形状を最適設計し，接合性を改善した．上板を貫通性を得るため，リベットの外径と先端部の角度について検討した．ダイの径と深さは有限要素シミュレーションにより設計した．設計されたリベットとダイの有効性を評価するため，接合実験を行った．アルミニウム合金板は最適化されたアルミニウム合金製リベットで接合できた．

各種強度の鋼板とアルミニウム合金板をメカニカルクリンチングで接合した．メカニカルクリンチング接合における必要条件は(1)上板の割れが無い，(2)上板が下板内で広がる，(3)下板の割れが無いの3つである．欠陥の発生を抑制するため，クリンチング加工中の各板の変形挙動を有限要素シミュレーションと実験によって検討した．上板の割れ，下板内での上板の広がり不足，下板の割れは，それぞれ高張力鋼板による上板の低延性，下板の高硬度，下板の低延性により発生した．高張力鋼板とアルミニウム合金板の板組は有限要素シミュレーションを用いたダイ形状の最適化により接合できた．

平成 20 年 1 月 9 日

Production Systems Engineering Department		ID	059101
Name	Toru Kato		

Advisor	Prof. Ken-Ichiro Mori

Title	Study of plastic joining of high-specific strength sheets for automobile body

(800 words)

To improve fuel consumption of automobiles, reduction in weight of automobile parts is a key issue. For the reduction, high strength steel and aluminum alloy sheets having high specific strengths are attractive as materials of automobile parts. In this study, steel sheets having different strengths were joined with an aluminum alloy sheet by cold plastic forming. The cold plastic joining methods are self-piercing rivet and mechanical clinching. Mechanism and process of both joining methods are designed by finite element simulation and experiment.

The joinability of aluminum alloy and mild steel sheets using the self-pierce riveting was evaluated by finite element simulation and experiment. In the self-pierce riveting, requisites for joining the sheets are given by (1) driving of rivet leg through upper sheet, (2) flaring of rivet leg in lower sheet and (3) no fracture of lower sheet. Optimum joining conditions were obtained by categorizing of defects. Defects of driving through of the upper sheet and the fracture of the lower sheet were due to small thickness of the lower sheet and small total thickness, respectively. The joinability of a combination of steel for upper sheet and aluminum for lower sheet was higher than that of reverse combination.

Various high tensile strength steel sheets and aluminum alloy sheet were plastically joined by the self-piercing rivet driven through upper sheets and flared in lower sheet with a die. Insufficient driving through of the upper sheet and fracture of the lower sheet were due to the high hardness and low ductility of ultra high strength steel sheet, respectively. Joining range of the ultra high tensile strength steel and aluminum alloy sheets was extended by means of dies optimized using finite element simulation.

Two types of three sheets combinations, one is all aluminum alloy sheets and the other various strength steel and aluminum alloy three sheets were joined by the self-piercing rivet, respectively. Requisites for joining the three sheets are the driving of the rivet leg through of the upper and middle sheets, the flaring of the rivet leg in the lower sheet and no fracture of the lower sheet. The joinability for the sheet combination soft upper sheet and hard middle sheet was higher than that for reverse combination because rivet tip was avoided deformation. Therefore rivet tip drove through the middle sheet easily. The joinability of the two sheets was available for a case of joining three sheets when the upper and middle sheets were same material.

Aluminum alloy sheets were joined by aluminum alloy self-piercing rivet to simplify recycling of cars. For the joining of aluminum alloy sheets by the aluminum rivet, joinability was improved by designing of optimal shape of the rivet and die. To drive through the upper sheet, diameter and edge angle of the rivet are modified. Diameter of cavity and depth of the die were also designed using finite element simulation. The effectiveness of the designed rivet and die were evaluated from experiment of riveting. The aluminum alloy sheets were joined by the optimized aluminum alloy self-piercing rivet.

Various strength steel and aluminum alloy sheets were joined by mechanical clinching. In the mechanical clinching, requisites for joining the sheets are given by (1) no fracture of upper sheet, (2) flaring of upper sheet in lower sheet and (3) no fracture of lower sheet. Deforming behavior of two sheets during the clinching were observed by finite element simulation and experiment to avoid defects. Fracture of the upper sheet, insufficient of flaring of the upper sheet in the lower sheet and fracture of the lower sheet were due to the low ductility, high hardness and low ductility of the high strength sheet, respectively. Joining range of high tensile strength steel and aluminum alloy sheets were extended by means of dies optimized by finite element simulation.